Distribution grid planning and operational principles for EV mass roll-out while enabling DER integration

PlanGrid EV

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Technical Requirements for tools/methods for smart grid integration of EVs

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Further information	**www.PlanGridEV.eu**

Executive Summary

The PlanGridEV Deliverable 2.2 presents the outcomes of Task 2.2, where the requirements for technical tools and methods for the integration of EVs into the LV/MV electricity grid have been defined. The above mentioned tools and methods have been designed according to the specific purposes of each of the 4 PlanGridEV testbeds (Italy, Portugal, Ireland and Germany). Therefore the requirements are derived through testbed overviews (Chapter 3 to Chapter 6) and a selection of products/services for the advanced integration of EVs into the LV/MV electricity grid (Chapter 2). The technical tools and methods hereby designed lead to the validation, within WP5, of different operational scenario for EVs integration, as classified against the outcomes of PlanGridEV Deliverable 2.1 (see figure below).

	Conventional	Safe	Proactive	Smart grid
Charge management	No	Soft, fleet-focused	Massive	Massive, local
Type of charge management	None	On/off	On/off	Charge modulation
Expected grid reinforcements Non EV-related EV-related	 Yes Yes	 Yes Minimal	 Minimal No	 No No
Energy flow in EVs that are used to provide services	None	Grid → EV	Grid → EV	Grid (←)→ EV
Provider of the service	None	EVSE Operator (fleet manager)	EVSE Operator/EVSP	EVSP
Remuneration scheme	None	ToU	Regulated contract	Competitive market
Type of power flow control for[1]: Emergency constraint mgt. Forecasted constraint mgt. Real-time constraint mgt. Ancillary services for the TSO Energy trade DER integration	 Centralised None None None None None	 Centralised Centralised None None None None	 Centralised Decentralised None None None None	 Centralised Decentralised Decentralised Decentralised Decentralised Decentralised

Figure 0.1 PlanGridEV demonstration scenarios

[1] Centralized control means that the DSO is controlling the charge, while decentralized means that either the Electric Vehicle Supply Equipment (EVSE) Operator or the Electric Vehicle Service Provider (EVSP) are taking control of the EV charging process, based on a set of constraints including DSO's ones.

Within D2.2 the high level requirements are defined for the tools and methods to be implemented in the four PlanGridEV's testbeds that will be validated in PlanGridEV WP5. For each of them this document identifies who are the different actors, how they should interact and what is the technology enhancement needed to implement the testbed. The outcomes of testbed will be eventually fueling improvements of planning rules and operational methods in day-by-day business for Distribution System Operators within Europe, for which PlanGridEV WP 7 will give a perspective outlook regarding their economic, regulatory and technological feasibility.

Furthermore, some of the smart charging services drawn within this document will be further investigated at use case level in D3.2. Some of the use cases selected for demonstration will be scoped in at test cases level within PlanGridEV WP5 (D5.1), in order to properly execute the PlanGridEV's demonstration activities and monitor the quality of the results. Hereby the reader will find some details regarding the mapping between PlanGridEV's testbeds and high level scenarios drawn in D2.1 and which product/service will be demonstrated.

The Portugal's testbed (run by EDP) will mainly match the Conventional Scenario. Some minor adjustments were made against the Conventional Scenario, especially in order to predict the possibility of electricity grid investments where the EDP's proof of concept provided through this project cannot be applied. The other adjustment made is to describe the necessity to have some ICT technology to get real-time values from the electricity grid.

- No Charge Management. EV customers will be able to charge their EVs as soon as they arrive to the charging spot and without any limitation on the power to be demanded.
- Expected grid reinforcements: it's assumed that in some cases/grids the solution could be a mix of placing some remote switch devices along with minor conventional "copper-based" investments.
- Energy flow in EVs that are used to provide services: it's necessary to have some ICT technology only to get on line load (EV) and generation (DER) values in order to apply the decision criteria developed in the test bed (new Operational Methods). Therefore, EVs, EVSE Operators and EVSPs will not provide any other services to the DSO or other actors (TSO, electricity retailers…).
- Type of power flow control: in emergency situations, the DSO will be able to cut off the charging EVs by remotely disconnecting the portion of the grid where the relevant loads are located. The communication between EVSE Operators and the DSO is not in place in this scenario, as this is a Conventional approach.

The Ireland's testbed (run by ESB) will match a scenario which is actually overlapping the conventional and safe scenarios, because the trial will be run according to 3 different configurations:

- No EVs connected.
- EVs connected with charging only allowed at night between 11 pm and 7 am.
- EVs connected with unlimited 24hrs charging permission.

These scenarios will give a good representation of the effects of EV charging and the possible benefits of future Smart Grid technologies applied to EVs. It is planned that this trial will lead to a recommendation for future smart grid implementation, especially related to the planning of electricity grid in order to sustain an increasing EV penetration, thus moving ESB to the adoption of more advanced scenario such as Proactive or Smart Grid scenario coming out of PlanGrid EV Deliverable D2.1.

The Germany's testbed (run by RWE) and Italy's testbed (run by Enel) will partially match the Smart Grid Scenario, but without a competitive market interaction (that would be unfeasible to be represented within a Demo project) and with unidirectional energy flow (hence, G2V only).

The services described in Chapter 2 builds up a catalogue of products that could be traded within e-mobility framework in case of a Proactive or Smart Grid scenario. For the Enel testbed, by taking account the status of the LV/MV electricity grid and the forecast of availability of renewable production, the EV recharging process will be modulated in order to create value for all actors involved during the process (customer, DSO, EVSE Operator, DER Operator). This is matching the services described as "Planned Demand Response: Enhancement of RENs integration". For the Germany's testbed, same use case is being applied but at local level, triggering enhancement of local RENs integration. In this case the Germany's testbed could be understood as a proof of concept for the implementation of a "Quasi-Real Time Demand Response: Enhancement of RENs integration service". In fact, within the Germany's testbed, the deployment of controllable equipment and appliances at household level, including EVs, will allow an optimum integration of local RENs. The control information is generated on a local substation level taking into account forecasts for weather as well as for the local network load for the next hours and derives control information for all the equipment in the grid including EVs. The control schemes are implemented by the DSO to avoid local overload voltage problems while increasing the hosting capacity for local renewable generation and EVs at the same time.

Table of contents

List of figures

List of tables

Abbreviations and Acronyms

Table 0-1 Acronyms

BAU	Business as Usual
B2B	Business to business
B2C	Business to customer
BMS	Battery Management System
CBA	Cost Benefit Analysis
DER	Distributed Energy Resources
DMS	Distribution Management System
D/R	Demand Response
DSM	Dynamic Strategy Management
DSO	Distribution System Operator
E2P-ratio	Energy to Power ratio
EMM	Electric Mobility Management system
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EVSP	Electric Vehicle Service Provider
GIS	Geographic information system
HEC	Home Energy Controller
HEM	Home Energy Manager
HMI	Human-Machine Interface
ICT	Information and communications technology
KPI	Key performance indicator
LV	Low Voltage
MV	Medium Voltage
MB	Management Board
OLTC	On-Load Tap Changer

PC	Project Coordinator
QM	Quality Manager
QA	Quality Assurance
QAS	Quality Assurance System
QAP	Quality Assurance Plan
QO	Quality Objective
POD	Point of delivery
REP	Renewable Energy producer
SM	Smart Meter
SOC	State Of Charge
SSS	Stationary Storage System
TSO	Transmission System Operator
TTM	Time To Market
VCDT	Controlled Distribution Transformer
WP	Work Package

1. Introduction

1.1. Scope of the document

Deliverable 2.2 is the outcome coming from PlanGridEV Task 2.2, where description and requirements of different technical tools and methods for the integration of EVs into the LV/MV electricity grid are defined. Those requirements have been derived according to the purpose of PlanGridEV 4 testbeds (German, Ireland, Italy, Portugal). The tools and methods hereby outlined fit in the purpose of project's testbeds. Their validation in PlanGridEV WP5 (Demo) will allow the usage of innovative Demo results in order to draw out new guidelines on how DSO could react in the future EVs uptake (PlanGridEV WP7).

The requirements of the above mentioned tools and methods have been derived by jointly taking into account, wherever possible (Italy and Germany testbeds only), the purpose declared by each testbed alongside a possible "smart charging product" to be demonstrated, amongst the one presented within this document (see Chapter 2).

As a framework of reference for the "smart charging product" meaning, it is hereby declared that it is understood as a product which could be traded between parties belonging the general electric mobility business framework (see Figure 3.1), having as a consequence a Power Modulation being applied to an EV charging process, usually with a financial benefit for the final product buyer. In this sense, the aim of this document could be also viewed as a description and high-level technological requirement of possible marketable products in nearby future to reverse EVs electricity load uptake as an opportunity for DSOs. This is classified and put in context of the PlanGridEV testbeds as follows.

For the Italy's test bed, a demonstration of a "Planned Demand Response: Enhancement of RENs integration" service will take place. Basically, it will be demonstrated that a cluster of EVSEs could be properly managed by an EVSE Operator simultaneously taking into account the EV Customer preferences and the DSO power flow constraints elaborated with regards to the RENs availability and the current status of the LV/MV electricity grid where the EVSEs are being installed. Such a service is relaying on an IT infrastructure partially developed within other FP7 initiatives by Enel, including ADDRESS (http://www.addressfp7.org), Green eMotion (http://www.greemotion-project.eu) and MOBINcity (http://www.mobincity.eu) projects, that will be improved for the purpose of this demonstration. Furthermore, two key advancements will be made in this project:

• Updating of a typical MV Distribution Management System (software) to be used in LV operation through short-term planning. The DMS will evaluate against the current LV status the feasibility of a DSO Target Load Curve to be applied, trough the EVSE Operator, to a cluster of EVSEs in order better allocate local DER (usually RENs) availability. Such interaction at IT infrastructure level will leverage and improve the B2B services between DSO and EVSE Operator as defined in Green eMotion project and the relevant BOs defined in that sense (see D3.6 of Green Motion project). Such B2B services infrastructure developed by Enel will be the basis for the deployment of an Open The algorithm for tradeoff optimization (hosted in the EVSE Operator back-end) between DSO Target Load Curve and EV Customer Preferences (the two most significant Business Objects) will be executed according to the ongoing development of MOBINcity project. The requirements hereby defined are hence focused on the DMS installation and will lead the implementation phase run by Enel in WP5. The requirements will enable scalability of the solution and its replication in other pilot tests, even beyond the project, allowing for taking this service into account when planning a future approach of DSOs to EVs uptake.

• IT and asset infrastructure is not enough for the deployment and marketability of “Planned Demand Response: Enhancement of RENs integration” service as part of “Smart Grid” scenario defined in D2.1. An operational methodology to track DER usage during EV charging process is needed, as a key business process innovation to allow a local balancing of DER fed-in in real-time with the aim of enabling possibility to ‘certify’ the amount of RENs used in an EV charging process.

For the testbed of Portugal the key items are the following ones:

- ICT and Data Management that allow data access on real-time to DER generation data, EVs charging data and Consumers data, enabling better understanding/characterization the LV network.
- Remote Controlled Switch in LV network and ICT to enable tilting between LV feeders.

There is no specific smart charging products to be demonstrated, but a better understanding of EVs impact will be available, possibly moving to the adoption of advanced Proactive or Smart Grid scenario in the future.

For the Ireland testbed the focus area described is the following one

- LV Network trials monitoring power quality, volt drop and load on rural single phase networks. The trial will identify whether the introduction of EV’s to a rural LV network will cause the network to operate outside of our distribution standards and what benefit smart charging or smart grid technologies will have on the system.

Alongside Portugal testbed, also this one does not provide a demonstration of product belonging to the Smart Charging catalogue of Chapter 2.

Germany’s testbed focus areas described are the following ones:

• Evaluation of the LV grid load curves, which are expected to meet quality requirements far better, when the Smart Operator (see chapter 6 for definition of Smart Operator) based forecast of DER production will be mapped to load forecasts and the available load management capacity is exploited. In this test bed, the Smart Operator is a newly developed component, which derives information about local forecasts for renewable generation and load on a local substation level. It follows the idea, that it is easier to stabilize a system on a local level than to carry all information to a centralized DMS and then transmit the control information back to the local level. The Idea behind the Smart Operator is the extension of the hosting capacity of the grid for renewable generation as well as for EVs. An increased usage of DER for EV charging is expected as a result and this effect will be documented and evaluated.

Additionally further controllable loads are integrated into the Smart Operator test bed, to give a more complete view on future grids:

• Usage of energy storage assets (Pb or Li-Ion batteries) in the LV grid will be complemented by those car battery storages available for reducing grid load when high DER productions is encountered. The effects of the management by the Smart Operator will be monitored.

• Ad hoc derivations from forecasted energy usage in customer's homes might impact the expected charging of EV with DER energy. These effects are to be monitored.

In the case of Germany's test bed, a proof of concept of "Quasi-Real Time: Enhanced RENs integration" service will be given, validating a Power Modulation applied to EV charging process according to the availability of local DER (RENs) installation.

1.2. Structure of the document

The document is structured as follows:

- Chapter 2: Smart Charging Catalogue
- Chapter 3: Requirements for ENEL field test: DMS improvement to control local EV charging based on local DER availability
- Chapter 4: Requirements for EDP field test: Managing EV charging and DER peaks by dynamic network reconfiguration
- Chapter 5: Requirements for ESB field test: Intelligent charging and smart meshing of the LV system
- Chapter 6: Requirements for RWE field test: Load management in the LV network through autonomous agents

2. Smart Charging: a catalogue of products

2.1. Overview

At the backbone of Smart Grids integration of EVs (Italy's and Germany's testbed involved in PlanGridEV) there are a set of services that might be traded across a future Smart Charging market, in order to distribute value across stakeholders. In this Chapter a set of possible Smart Charging services will be anticipated. They build up a Catalogue that might be used by DSOs in future to change their perspective against BaU for the uptake of EVs.

The use cases, including overview of behavioral requirements for EVs, will be derived in WP3 and some of them will produce test cases to monitor and control the execution of demonstration activities.

This process at project management level is depicted in Figure 2.1.

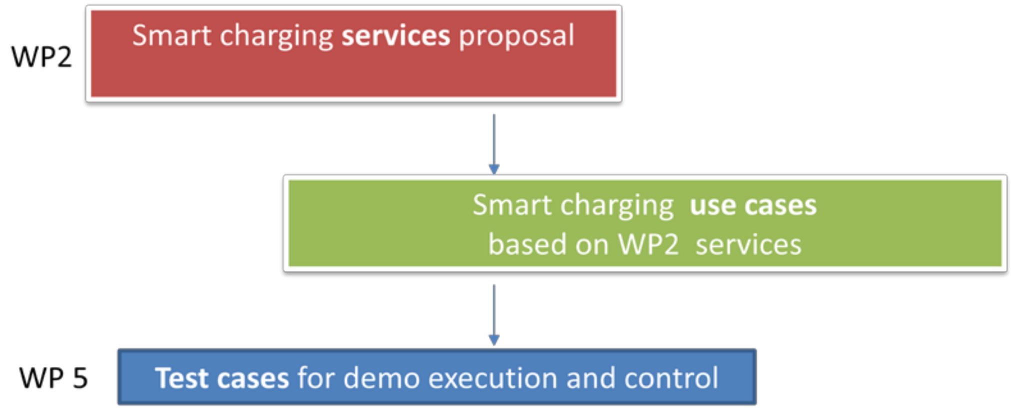

Figure 2.1: Project Management process for the delivery of smart charging products in PlanGridEV

For the purpose of this project, smart charging is equivalent to load management, in the case of the EV being the electricity load. The definition of Chapter 1 for smart charging product services as a basis for the context of this catalogue.

The principle of smart charging is to allocate EV charging processes according to external constraints, as depicted in Figure 3.2.

The final impact on EV customer experience is the same, regardless the purpose of smart charging service for the DSO domain. In all of smart charging services anticipated below, the customer will be trading time flexibility with service cost savings.

A typical today's smart charging use case at customer experience level is the following one: the EV driver gets his EV parked, with expected parking time of 6 hours, 50% initial SOC, 100% desired final SOC, and 22 kW battery charger on board of the EV. The EVSE, properly managed by a smart charging algorithm, would be able to spread the EV customer request over the 6 hours, modulating the charging process (which would only last 30 minutes to cover the remaining 50%) driven by specific customer, DSO or energy produces needs. The smart charging services below are derived according to the driving force of the optimization between customer preference and service buyer stakeholder needs. In some cases (like Real time D/R at Home), the stakeholder needs is an expression of customer constraint, e.g. minimization of service cost, integration of household renewable plant. In some other, it is the DSO who is fixing constraints as service buyer stakeholder (e.g. Planned D/R Load Management).

Hence EV customer preferences are made up of: Initial SOC, Final SOC, Time Of Departure (from the charging station). This concept will be further developed within Chapter 3.

The following list serves as a possible product catalogue for a smart charging market. Whilst the short description of the services could be valid throughout the next years, the relationship between stakeholders might vary across the development of EV industry. Some of these products will be demonstrated in this project, as the main legacy of the operational domain of PlanGridEV. Particularly, “Planned Demand Response: Enhancement of RENs integration” will be demonstrated as proof of concept in Italy's testbed, whereas “Quasi-Real Time Demand Response: Enhancement of RENs integration” will go live through the Smart Operator concept within Germany's testbed.

None of these services should be implemented in order to modify the expected number of cycles of charging as planned by the customers. There is always a customer participating in a smart charging product either issued by his EVSP (e.g. in case of D/R) or automatically planned by household IT systems, whilst guaranteeing the customer preferences in terms of Final SOC and Time Of Departure.

Whilst some OEMs are expected to play EVSP role within such services, they are hereby considered as technological enablers, thus not directly involved in the stakeholders relationship, although they can be seen of course as EVSP in the long run for the reason mentioned above.

For what regards the charging domain of application for these services, they are all considered viable in public, private and semi-public charging, with different nuances of TTM and profitability.

The PlanGridEV Catalogue of Products / Services could also be viewed means by which DSO could capitalize in short to long term the technology and equipment deployed in order to properly support EVs market uptake without performing low-level conventional asset investments, fitting in the “Smart Grid” scenario of PlanGridEV 2.1. This is also giving an interesting market-perspective which has been missing until today in the whole literature related to smart charging, although international efforts are increasing towards the delivery of such market vision.

2.2. Catalogue of Products (Services)

This paragraph describes what kind of new services could be introduced in a Smart Grid scenario and how they could be supported by EVs. It explains how the services could work, what the relevant stakeholders would be and what the expected Time To Market is. The services will be further explained at use case level during the project and related test cases level will be drawn for the test-bed that are delivering proofs of concepts of these products (Italy's and Germany's testbeds).

2.2.1. Frequency Regulation

In typical EU electricity markets, frequency regulation services are requested by TSOs to guarantee frequency stability at system scale. The prerequisites for power plants to provide this ancillary service varies across EU. Nevertheless, a reasonable expectation of minimum power rate would be 100-200 MW for each power plant (Italy's case, with an average peak consumption of 50 GW in working days). Response times varies depending on whether a primary level, secondary level or third level frequency regulation is executed. Smart charging would be applicable to secondary level / third level frequency regulation, by aggregating enough EVs to sum up at least 200 MW within a geographically constrained group of primary HV/MV substations, controlling their charging process though a controlling load curve designed in order to have an impact on frequency regulation, with a range of 10 secs – 5 minutes response time and an estimated maximum depth of process of 2 hours.

Involved Stakeholders

Customer, DSO, TSO, EVSP, EVSE Operators. Expected relationship: DSO/TSO are buyers.

Time To Market

It requires in some countries 25,000+ EVs within a cluster of 3-4 primary HV/MV substations in order to have an accountable impact on frequency regulation. Expected market exploitation to be set beyond 2025.

2.2.2. Voltage Regulation

Within the domain of a LV and MV electricity grid, voltage regulation might be implemented by either controlling reactive power devices within primary and secondary substations or modulating the active and reactive power of appliances and distributed energy resources located within LV/MV domain.

Voltage regulation at DSO level through EVs would have a threshold number of appliances (EVs) depending on the design of LV/MV grid, the depth of regulation and the typical CosPhi (ratio between active and reactive power), which in turn has high sensitivity on the charging technology and EV model. A reasonable expectation below a primary substation serving 10,000+ customers would be to have 10% penetration rate of EVs in order to have a significant impact. The mechanism by which EVs might have an accountable impact on voltage regulation is to have them working at low power rate, where the sensitivity against bias of the ratio between active and reactive power allows for using the EVs as a controllable passive load for voltage regulation.

Involved Stakeholders

Customer, DSO, EVSP, EVSE Operators. Expected relationship: DSO/TSO are buyers.

Time To Market

1,000+EVs within a single area served by a HV/MV substation are expected, leading even to 10/20 EVs at LV feeder level. Although with current market predictions this is unlikely to be happening before 2020, some areas with higher EV early adopters rate might experienced this kind of opportunity.

2.2.3. Planned Demand Response: Load Management according to long term minimization of electricity grid investment

Within the family of Planned D/R services, the load management for minimization of grid investments is amongst the expected core services of PlanGridEV demonstration. With this service, DSO aims at lowering EVs penetration impact by postponing, or avoiding, power assets and wires investments in order to sustain EVs adoption. The final purpose of this product is to enable electric mobility without burdening the national system with additional technological adoption cost for the electricity grid. Customer preferences (Initial SOC, Final SOC and Time of Departure) are traded with power availability at LV level, demanding target load curve to be followed possibly by all charging process within a pre-defined Load Area, as a cluster of EVSEs installed within the same LV (or MV) domain. Such a service could be planned a few hours in advance, especially for low-variation charging behaviors (e.g. home charging, fleet charging), like in the Smart Operator business actor demonstrated within PlanGridEV Germany's test bed.

The proper allocation of controllable charging process within day allows DSO to keep the LV and MV grid with today's design, without changing overloaded transformers due to simultaneous charging.

In order to understand for such a load management service the possibility of having a significant savings impact at system cost level, a CBA analysis is going to be run within Eurelectric association in late 2014 and its results are going to be leveraged later on in PlanGridEV within WP 7 activities (business case evaluation of smart charging). A reasonable expectation would be that turnover happens when 30% overload has to be avoided on transformers, which would lead to 30 EVs out of 90 grid customers simultaneously charging at 3.3 kW for a typical MV/LV substation (Italy's and Germany's case) or more than 5 EVs charging at 22 kW rated power under the same hypothesis, without improving electricity grid against today's situation. The mechanism by which EVs participates to such a service is by simply applying the desired load curve to each EV. This will be usually leading to a widening of charging process duration and a lower EV bias point, in order to relax power stress for the electricity grid.

In order for such a service to be properly marketed, customer preferences and DSO constraints spread over a selection of EVSEs are not enough. The trade-off optimization algorithm usually working at EVSE Operator back-end level should also take into account the typical parameters of EV battery. This holds true for very single service belonging to this catalogue. A worldwide repository of EV models as IT Business Objects, whose property and liability belongs to each OEM, is highly recommended to be established within the duration of PlanGridEV, in order to speed up Time To Market of such a service and timely exploit a significant innovation effort held within this project. Such a repository would include fundamental parameters of each EV that must be taken into account when allocating a charging process against Customer Preferences (Initial SOC, Final SOC, Time Of Departure) and DSO constraints. In order to deliver the necessary EV batter parameters to properly run smart charging processes, a Business Object including these parameters might be specified and shared amongst the stakeholders.

Such a Business Object would be based on the following parameters list:

EV Model Name

EV Battery Capacity

EV Battery Capacity maximum degradation range whilst in operation

EV maximum incoming power rate

This Business Object might be delivered either through a worldwide repository as previously mentioned or implemented, whenever feasible, through power line communication by exploiting free payload available over standards such as ISO/IEC 15118. A release of this Business Object specification could be implemented in future by “eMI3”, an established international initiative of the biggest international players in electric mobility, that could be the proper driver of such a harmonization (www.emi3group.com)

Finally, as timing constraint related to this service, the expectation is that as minimization of grid investments is a long-term goal, the execution of this service could properly be scheduled on a day-ahead basis, leading to a well reasonable response time for the EVs, as part of a planned initiative without needs of quasi-real-time adjustments.

Involved stakeholders

Customer, EVSE, EVSE Operator, EVSP, DSO. Expected relationship: DSO/TSO are buyers.

Time To Market

30+EVs within a single area served by a MV/LV substation are expected for positive CBA. Although with current market predictions this is unlikely to be happening before 2020, some areas with higher EV early adopters rate might experienced this kind of opportunity.

2.2.4. Planned Demand Response: Load Management for fleets

This service is a variation of the above. Although the same principle of trading off customer preferences and time availability against target power load curve holds true, this time the target power load curve generation could be driven by purposes different than DSO requirements.

For example, such a smart charging service could be run in order to minimize electricity bill (target load curve compiled against the contracted energy price schedule), enhance the usage of local distributed energy resources that might be installed at the premises of the fleet owner (target load curve matching medium-term DERs forecast), or both at the same time (maximization of local DERs plants whilst minimizing the power requested to the electricity grid, lowering the global service bill).

The mechanism by which EVs are used in this services is the same of Load Management for minimization of grid investments, although the purpose generating the target load curve is a different one.

As EV fleets are expected to be great contributors to global EV shares within the next few years, due to supporting policy in terms of CO2 certificates and corporate taxes discount, such a service looks the one with most realistically short Time To Market. The number of EVs participating in the service does not depend on the EVs penetration rate as the previously described services, but on the capability to gather enough EVs to locally counter-peak the production of household/building DER or the pricing time schedule that the fleet owner (customer) has contracted with its Energy Vendor.

Typically, fleet owner could simultaneously be final customer and driver of this service. The service could either be provided third party, acting as a Virtual Utility in the combination of minimization of electricity consumption from the grid and maximization of DERs production, the same entity possibly holding the DERs installed at the local premise, the EVSEs and the EVSE Operator back-end.

Involved stakeholders

Fleet Owners, EVSE Operator, Virtual Utility. Expected Relationship: Fleet Owners are buyers.

Time To Market

As fleets appear to be the biggest market share for EV business in the near future, a combination of white certificates for CO2 savings and energy efficiency incentives could trigger a marketability of this service, where the Customer is the Service Buyer, to a timeframe below 5 years.

2.2.5. Planned Demand Response: Load Management due to electricity market price

This is a variation of the service described in paragraph 6.3, where the target load curve is in this case generated due to pricing signal at either the wholesale or local electricity market. This load curve could even collapse into a simple digital signal, in the case of most EU countries where ToU tariffs based on 2 timeslots are available.

The mechanism by which EVs participate at such service is the same of the 6.3 and 6.4, with long term response rate (few minutes are enough as this action is a planned one) and expected maximum time depth of service execution a few hours (maximum 6).

The feasibility of implementation for this service highly relies on the discount rates/incentives that might be applied by EVSP through a ToU based service tariff. In case of a clear return on the investment, every EV driver will ensure that his home charging equipment would be capable of performing such hard-level binary power modulation, once his EV has been plugged in.

As the algorithm at the core of such a services is quite simple and straightforward, there is even no need of a harmonized approach of EV modeling at Business Object level, like it would be necessary when trading off different parameters, including stakeholders constraints and customer preferences.

Involved stakeholders

Customer, Fleet Owners, EVSE Operators, Energy Vendors, EVSP. Customers are buyers.

Time to market

Due to complexity of wholesale market, the pricing model driving the execution of this service could be simplified in ToU tariffs, leading to digital Power Modulation control to be applied to EVs (either switched ON or switched OFF). As some EVSPs are already experimenting in Europe pay-per-kWh tariffs, the might easily expand the set of services provided to their customer with a ToU control.

2.2.6. Planned Demand Response: Enhanced RENs integration

This service, alongside Load Management for minimization of grid investments, is also one of the core services of PlanGridEV project and at key root of electric mobility success in the long term future. The purpose of this service is to plan EV charging processes within MV and LV domain in accordance with the planned (forecasted) availability of RENs/DERs. DSO or DER Operator is supposed to behaving as buyer of this service, as DSO would have interest in enhancing DERs hosting capacity without necessarily designing the electricity grid for the worst case (Business As Usual approach) but maximizing the controllability of active appliances like EVs. DER Operator on the other side might invest in such service in order to access proper remuneration schemas. Regardless who is buying such a service, the customers might participate as long as their preferences are satisfied.

Home charging and low to medium speed public and semi-public charging is home turf for such a service, which needs a minimum amount of 10% penetration rate to properly allocate enough EVs charging processes below a HV/MV transformer to match a significant production coming from cluster of some PV or Wind DER plants. This would mean, with 10,000+ customers served by HV/MV substation, 1000 EVs to be properly programmed.

The mechanism by which EVs participate at such service is the same of the 2.2.3, 2.2.4, 2.2.5. Response time and time depth of service execution are equal too.

As RENs integration is mainly relying on DSO assets, this service is always involving DSO (different from Load Management for fleets, where the value distribution might even not involve DSOs).

Reliability of DERs forecast should be mandated, whenever possible, to DER Operators.

Involved stakeholders

Customers, Fleet Owners, EVSE Operators, EVSP, DSO, DER Operator. DSO/DER Operators are buyers.

Time To Market

1000+EVs within a single area served by a HV/MV substation are expected for positive CBA against a cluster of 5 to 10 typical DER plants. Although with current market predictions this is unlikely to be happening before 2025, some areas with higher EV early adopters rate might experienced this kind of opportunity, especially where there is a simultaneous increase of DER penetration.

2.2.7. Quasi Real Time Demand Response: Enhanced RENs integration

This is a service belonging to the quasi real time demand response domain, usually aiming at implementing control at household level, with a Service Provider leveraging a Smart Operator, like in the case of Germany's test bed. Actions are planned with a few minutes / seconds notice in this domain. The typical use case does not necessarily involve the DSO and could be applicable to the EV driver with a household DER (e.g. solar panel). The customer preferences includes necessarily a setting that triggers EV charging ON whenever the DER flags an output active power. The mechanism of EV participation to such a service is the same of previous ones, although more tight constraints are applied for the timings.

In case of unavailability of buffer solutions (e.g. household storage), the DER signaling is basically a Heavyside function with milliseconds response time. The time depth of service execution could be very long, for example as long as there is sunshine in case of integration of household photovoltaic installation.

This service might be executed in a granular way, where the buyer could even be the customer himself, asking a Virtual utility to minimize the charging service fees while maximizing the usage of household RENs installation, or in a centralized approach, where the DSO is the buyer and DER Operator must comply with technological requirements (traceability requirements) to participate alongside DSOs with remuneration schemas leading to a positive feedback loop between EVs penetration and DERs hosting capacity, whilst reducing and possible avoiding conventional power assets and wires investments. This latter is the general approach to be partially covered and demonstrated within Italy's testbed.

Involved stakeholders

Customers, Fleet Owners, EVSE Operators, EVSP, DSO, DER Operator. DSO/DER Operators are buyers in the centralized approach, customer himself is a buyer in the granular approach.

Time To Market

General approach needs established regulatory framework to allow DSO and DER Operator to invest into the necessary technology to cope with such a demand response program. The same hypothesis for EVs market penetration (10%) holds true, which could be realistic beyond 2020. Developing and testing the enabling technology for such scenario is the ultimate goal of the operational domain of PlanGridEV project.

Granular approach might be viable in a shorter term, depending on the business model adopted by the Service Provider, who might be aggregating several appliances and even possibly reversing the flow of energy from the EV upon request, leading to V2H service.

2.2.8. Quasi Real Time Demand Response: Load Balancing

This service is the short-term version with tight timing constraints of 2.2.3, 2.2.4 and 2.2.5 depending on the driving force generating the load curve (DSO, Electricity Price, or both of them). This means that the purposes of 2.2.3, 2.2.4 and 2.2.5 holds true, but response time is fairly shorter (few seconds) due to congestion issues (DSO as driver), wholesale pricing adjustments (Electricity Price as driver).

Involved stakeholders

Customers, Fleet Owners, EVSE Operators, EVSP, DSO, DER Operator. No expected buyers, it depends on the specific scenario.

Time To Market

In order to request a short term change in the behavior of EV as a controllable appliance, the cases of DSO and Electricity Price as driving force are fairly far away in time, reasonably beyond 2020 with current market predictions, as a massive amount of EVs should be available to justify their short-term modulation in order to produce a significant impact over load balancing within few seconds (same rational of frequency regulation).

2.2.9. V2H

V2H is a complex service belonging to the quasi-real time demand response domain, with the additional feature of possibly including the reverse flow of energy from the EV.

The purpose of this service is a composition of most of the above, depending on the amount of assets installed at household/building location: minimization of power back-up from the electricity grid, maximization of production coming from household/building RENs installation, exploitation of ToU tariffs if available to perform off-peak charging of EV and on-peak discharging of EV, using the EV as hydro pump storage plant. All of these appliances/parameters might be managed by a Virtual Utility, played by conventional utility, OEM, EVSP, depending on how the value chain will be evolving in the next years.

The mechanism by which the EV participate to such a service is the same of 2.2.4 to 2.2.8, with response time depending on the availability of energy buffers (e.g. storage) within the appliances domain.

Involved stakeholders

Customers, Fleet Owners, EVSE Operators, EVSP, DSO, DER Operator. Customer is the buyer.

Time To Market

Depending on the price evolution of the involved appliances/assets (EV, Storage, V2G features on board of EVs, compliant charger), this service could be executed at household level without necessarily general EV penetration rate preconditions, upon a solid ROI is presented to the final customer. Within a favourable regulatory framework (e.g. simultaneous incentives for storage and EV, like in California, US) this is a realistic service even at low EV market share (TTM < 5 years).

3. Requirements for ENEL field test: DMS improvement to control local EV charging based on local DER availability

3.1. Description of the process and of the different actors involved

The field test of Italy, run by Enel, will be demonstrating a sub-set of use the cases derived from "Smart Grid" scenario as described in D2.1. In particular, the use cases will be designed around the "Planned Demand Response: Enhanced RENs integration" service as outlined in Chapter 2.

	Conventional	Safe	Proactive	Smart grid
Charge management	No	Soft, fleet-focused	Massive	Massive, local
Type of charge management	None	On/off	On/off	Charge modulation
Expected grid reinforcements				
Non EV-related	Yes	Yes	Minimal	No
EV-related	Yes	Minimal	No	No
Energy flow in EVs that are used to provide services	None	Grid → EV	Grid → EV	Grid (←)→ EV
Provider of the service	None	EVSE Operator (fleet manager)	EVSE Operator/EVSP	EVSP
Remuneration scheme	None	ToU	Regulated contract	Competitive market
Type of power flow control for[2]:				
Emergency constraint mgt.	Centralised	Centralised	Centralised	Centralised
Forecasted constraint mgt.	None	Centralised	Decentralised	Decentralised
Real-time constraint mgt.	None	None	None	Decentralised
Ancillary services for the TSO	None	None	None	Decentralised
Energy trade	None	None	None	Decentralised
DER integration	None	None	None	Decentralised

Table 3-1 Summary of main characteristics of PlanGridEV scenarios

[2] Centralized control means that the DSO is controlling the charge, while decentralized means that either the Electric Vehicle Supply Equipment (EVSE) Operator or the Electric Vehicle Service Provider (EVSP) are taking control of the EV charging process, based on a set of constraints including DSO's ones.

The framework architecture of the demonstration will be setup according to Figure 3.1 , where a general e-mobility architecture is depicted. The roles hereby described are needed regardless the kind of service / product that will be traded in the market. This model architecture is applicable to a set of interaction and products ranging from basic charging, to roaming with different EVSE Operators, to smart charging and route planning. IT is build on the previous work performed in Green eMotion project (see Green eMotion, Deliverable D4.2) and Eurelectric (2013 Paper: “Deploying publicly accessible EV charging stations: how to organize the market?).

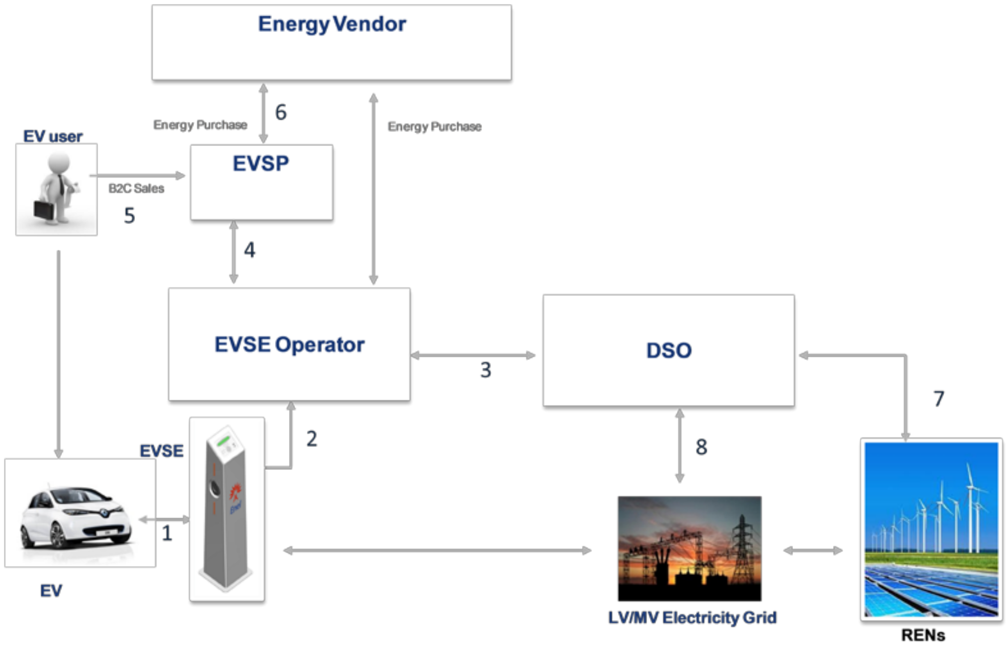

Figure 3.1 Framework architecture of electric mobility and embedded IT interfaces (IF 1… 8)

The framework architecture describes the whole processes and market actors interaction needed to deliver the services of “smart charging services” catalogue of D2.2 (from now on D2.2 Catalogue). Again, this architecture holds valid regardless the kind of service delivered to the EV user or other interested Party (Service Buyer).

For basic charging service (simple charging: not included in D2.2 Catalogue) EV and EVSE need to be physically connected in conductive charging according to ISO/IEC 61851 (IF 1, arrow between EV and EVSE) as a consequence of the charging process authorization, which happens by validating the B2C relationship between the EV user and his preferred EVSP (IF 5, arrow between EV user and EVSP). Each EVSP has to guarantee access of his EV users in a set of charging stations (EVSEs) to which the EVSP has established a B2B relationship, either by bilateral contracts (IF 4) or by a Marketplace-based model, according to the demonstrations run within Green eMotion FP7 project (See Green eMotion, Deliverable D3.6).

The EVSE Operator has the purpose of performing O&M of charging assets and needs information from the DSO, at least for Point Of Delivery setup and grid connection contract. Energy purchase happens at the level of relationship between EVSP and Energy vendors. This framework describes an unbundled approach, where each actor is independent: EVSE Operator is different than EVSP. In principle, some of them might collide in one actor. For example, in the hypothesis of having a regulated deployment of EVSEs, the DSO might be in charge of installation and O&M of the assets. In this case, multiple EVSPs access the charging stations in a multi-vendor approach and each of them could be backed up by its own Energy Vendor of choice.

The pilot test in Italy run by Enel will be focused on the deployment and demonstration of a specific value added service written in D2.2 Catalogue: " Planned Demand Response: Enhanced RENs integration". Such a service is run similarly to basic charging for what regards the stakeholders interaction. The only significant change is that the charging process setup according to a set of constraints: Initial SOC, Final SOC and Time Of Departure for the EV User perspective and a power target Load Curve given by a third party, which in "Planned Demand Response: Enhanced RENs integration" is the DSO, because the integration happens at the whole LV and MV system level. The interaction described above is depicted in Figure 3.2. The EV user sets through his end user application (e.g. mobile app) his charging preferences and the EVSE Operator system finds the tradeoff between customer constraints and load curve constraints, which are going taking into account the availability and reliability of DERs production nearby a set of EVSEs (IF 7).

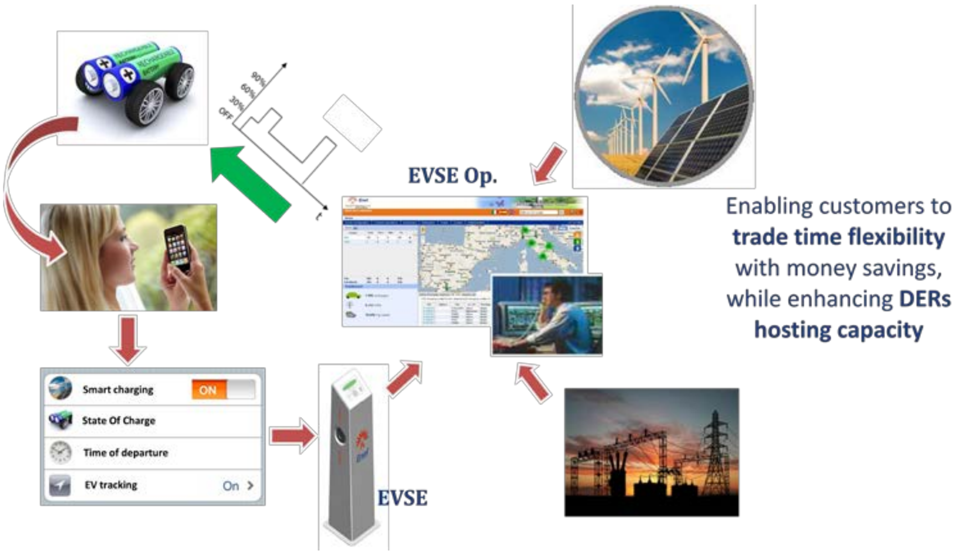

Figure 3.2 Deployment of smart charging service in Italy test bed

"Planned Demand Response: Enhanced RENs integration" is delivered hence when a basic charging process is executed properly allocating the process as a controllable load reacting to DERs availability below MV/LV transformer, enhancing the DERs hosting capacity of the local electrical grid.

The EVSE Operation system is in charge of running the optimization algorithm between customer constraints and DSO load curve target. Nevertheless, there is the need of physical validation of such load curve target sent by the DSO, which is implemented through a Distribution Management System (DMS). DMS system is in charge of simulating power flow at LV level, taking into account availability of

EVSEs to be modulated in order to host DERs production uptake in a specific timeframe of the day. This simulation validates such a flow against the description of the physical electrical grid where the EVSEs and DERs are connected. Upon its validation, the target load curve is then sent to the EVSE Operator through a set of services. This means that the interface between EVSE Operator and DSO (IF 4) is not the simple one of basic charging (Figure 3.1) but a wider one, which includes a set of real time services to let EVSE Operator and DSO exchange information.

Further technical details regarding the interfaces of Italy's testbed will be delivered within Task 5.1 for an extended presentation of Italy's testbed and its test cases.

3.2. DMS Requirements

DMS is a system which will be monitoring the LV area where the EVSEs are installed and perform simulation (for high EV penetration) and real time operation requests to the EVSE Operator, during which a set of EVSEs will be controlled by assuming they are part of larger deployment of EVSEs and a much broader scenario of Planned Demand Response against the current situation and availability of EV Customers during the project timeframe.

The EVs are a source of intermittency, because a big load (3kW ÷ 43kW for AC charging, spanning to 50kW and more for DC charging) can be connected/disconnected at each moment. This new load will be added to the traditional one in the LV grid state estimation as well as renewable energy sources, that are also intermittent and random resources, in order to validate a DSO Target Load Curve that will be applied to the cluster of EVSEs.

The challenge is to properly plan the connections in order to avoid not manageable situations, but also to properly operate the assets in order to take advantage as much as possible of controllable load, whilst respecting the physical description of the LV grid. In particular, the recharge processes have to be controlled in order to avoid contingency but also to respect the customers need will be necessary. For this reason the DSO Target Load Curve produced by the DMS will be feeding the EVSE Operator tradeoff optimization algorithm between the above mentioned Load Curve and the EV Customer Preferences.

3.2.1. Architecture of DMS LV

The approach will be the same as the DMS MV, which is already a marketable product available to the DSOs in order to perform MV state estimation.

The systems connected to the DMS LV will be (Figure 3.3): DMS MV, Sigraf (Enel GIS platform for the description of the grid) and EMM (Enel's EVSE Operator back-end system to manage the EV recharging infrastructure); all the other main information will be available thanks to the DMS MV. The data exchanges will be static or dynamic.

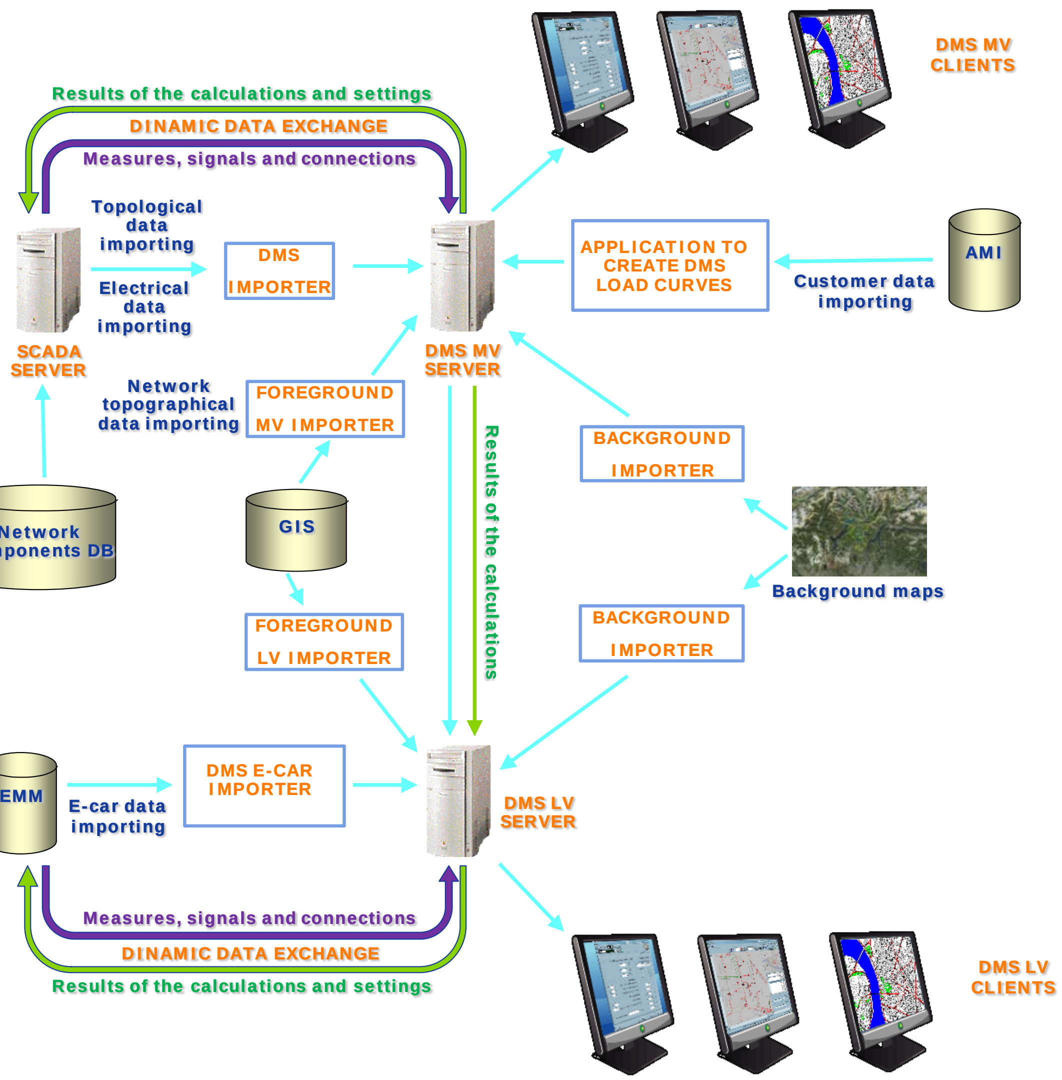

Figure 3.3 – DMS LV Architecture

3.2.2. The necessary functions for the test bed

<u>Traditional functions</u>

a. To complete performance indices of considered network including calculation of losses for different network states (peak load, light load);

b. To monitor overloaded substations and sections in network or in other way violated technical constraints (voltage limits), with reports and graphical presentation;

c. To monitor substations and feeders where operation reliability is violated, according to some operation security criterion.

DMS power applications are used for such analysis, for example: Load Flow, State estimation, Performance indices, Operation and Energy Losses, Security Assessment and Reliability Analysis.

Load forecasting and generation forecasting

The Load Forecasting Tool will be used for short, medium and long-term load forecasting for considered network. It uses adequate mathematical model for estimation of future consumption and demand development. The model is based on actual (basic year) and historic (previous period) consumption data and includes empirical conditions and projections (urban plans, heating conditions, granted consumer's demand requests and future development). The forecast is divided into small consumer's areas to enable generation of different scenarios.

The generation forecasting will be used to take into account the effect of actual and expected dispersed generation (renewable sources in particular) in LV grid.

DMS power applications are used for such analysis as Renewable generation forecast, Long-Term Load Forecast, Medium-Term Load Forecast. and Short-Term Load Forecast.

Verification of customer connection

- Simple verification

In the actual network must be possible to test the connections of new customers (active, passive, recharging infrastructure, etc.).

All the customer characteristics must be configurable for each of them.

This test requires just manual load flows with different scenario imposed by operator.

- Smart verification

According to analysis of the actual network state, forecast and simulation of future network conditions, it is possible to establish the list of problems to be solved in future. Using mathematical optimization methods and user's empirical experience, different (alternative) scenarios are generated for every problem to be solved.

Every scenario comprises one or more actions to be completed in specified time.

A long term action could be construction of supply substations or feeders, building new sections or consumer's substations in MV network, putting out of operation and dismantling of some installations.

A short term action could be the modulation of the recharge power in some recharging process.

Thanks to the connection with EMM, DMS can immediately implement the short term actions, so the DMS can suggest the correct setting to the EMM.

The long term actions will be just emphasized in term of simple replacements, the DMS will not suggest to build new networks but just to improve the capability of the actual (replace cable or transformer for example).

<u>Technical and economic analysis</u>

After the verification of customer connection, the evaluation of the certain scenario is made by technical and economic analyses.

Every scenario is presented and implemented on network schematics and all DMS functionality is available. Taking into account the forecasts and the specific time for start of operation of certain projects inside the certain scenario, the complete network state (performance) reports for every scenario and for the prospective time period are available.

The module of economic analysis provides calculations of investments costs for every scenario and every new project. The differences (decreasing) of operating costs of affected parts of the network are taken into account as benefits (decrease in losses, decrease in undelivered electric energy, decrease in maintenance costs of old equipment, etc.). The total increase benefit is calculated adding the growth of revenue due to increase of the distributed electric energy in prospective time period. Finally, the balance of total costs and benefits is provided (cost/benefit analysis) and thus the economic value of every scenario.

<u>Recharge impact management</u>

When the recharging infrastructure is compliant to the execution of smart charging service (e.g. “Planned Demand Response: Enhancement of RENs integration” and is possible to modulate the EV charging load curve through a DSO Target Load Curve, the DMS have to adopt a Target Load Curve that preserve quality of services for the customers in the LV area.

3.3. Traceability requirements

3.3.1. Overview

The concept of traceability is in the chance of implementing a certified, remunerated, proactive appliance (EVs) load control in case of sudden / planned / forecasted cut-in of decentralized power plants which would be otherwise cut-off from electricity grid stability systems.

Traceability sets therefore as a innovation at business process level which brings in necessary and suitable technology in order to support the business process.

To identify the requirements of the traceability concept it is important to focus on the main stakeholders involved in the possible business processes that leverage such a concept.

The traceability is key for the following list of services / products described in Chapter 2:

- Load Management for minimization of grid investments (ref. 2.2.3)
- Planned Demand Response: Enhancement of RENs integration (ref. 2.2.6)
- Quasi Real Time Demand Response: Enhancement of RENs integration (ref. 2.2.7)

The main actors are DSO, EVSE Operators and DER Operators.

Moreover it is important to introduce the concept of POD (Point Of Delivery) and Load Area.

In the same Load Area (ref. Green eMotion, D3.6), which is a geographical and electric Business Object describing a portion of LV area, several PODs (Points Of Delivery)might be available for the deployment of Demand Response services such as smart charging. Each EVSE do embed 1 or more POD (usually each POD is associated with EVSE's plug).
The three actors will interact across the PODs, in the implementation of one of the Smart Charging services that require.

In order to optimize the management of the LV/MV distribution grid on which there is installation of RENs production plants from renewable sources and charging stations for electric vehicles, it is appropriate that the DSO will implement (or outsource as Service Buyer) an intelligent business system / machine able to "match" the prediction of production (from RES) and consumption (vehicle charging) using the programmability of consumption (EVs). With this regard, the DSO could deploy the necessary IT to promote a Smart Charging market where, with the case of Italy's test bed, the planned demand response for the enhancement of RENs integration takes place (Service 2.2.6). Traceability keeps being necessary also in Service 2.2.3, a generalization of 2.2.6, and in Service 2.2.7 In some cases, like Italy's test bed, the DSO might be playing the role as EVSE Operator as well, facilitating the uptake of the "Planned Demand Response: Enhancement of RENs integration" product rollout, at least for what is concerned with public smart charging deployable as regulated asset and remunerated as capital expenses for DSO in order to improve the quality of service and reliability of LV/MV electricity grid. There are no DER Operators directly involved in Italy's test bed, although a realistic set Production curves will be used in order to give the proof of concept of such a service. Obviously, DER Operators are within the intended audience of this business process requirements needed to land to a marketable version of "Planned Demand Response: Enhancement of RENs integration" business service.

In order to make marketable such a product, each DER Operator (also referred as REP) has to provide to the DSO the electricity production profile forecast and each EVSE Operator has to provide to the DSO the electricity required for charging process (Figure 3.4). Usually, the former is information is fixed for what regards the maximum value and depends on the power contract signed with the DSO for EVSE installation. The dynamic update of the electricity required relies on the needs of EV Customer and it could be in principle implemented by the EVSP on behalf of EVSE Operator, hosting the customer preferences (Initial SOC, Final SOC, Time Of Departure) on its own Customer HMI (see the example Customer's smartphone HMI included in Figure 3.2).

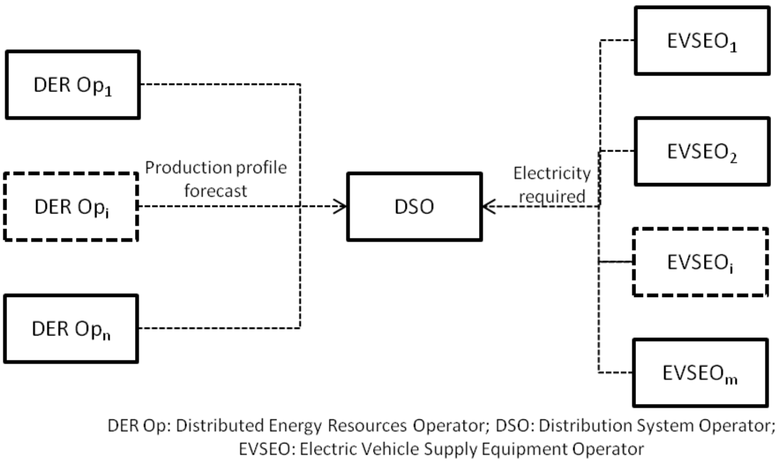

Figure 3.4 Forecast production communication by DER Op. and Electricity required by EVSE Operators to the DSO on a day-ahead basis

By using these data the DSO processes the consumption profiles, checks the feasibility of DSO Target Load Curve against the grid current state (through a LV installation of state estimator such as DMS in Italy's testbed) and forward the DSO Target Load Curve to EVSE Operators (Load Profile Fixed) (Figure 3.5). This mechanism is implemented by Load Management Target interface, part of the It infrastructure needed for the deployment of smart charging products, as specified within Green eMotion proceedings, see Deliverable 3.6.

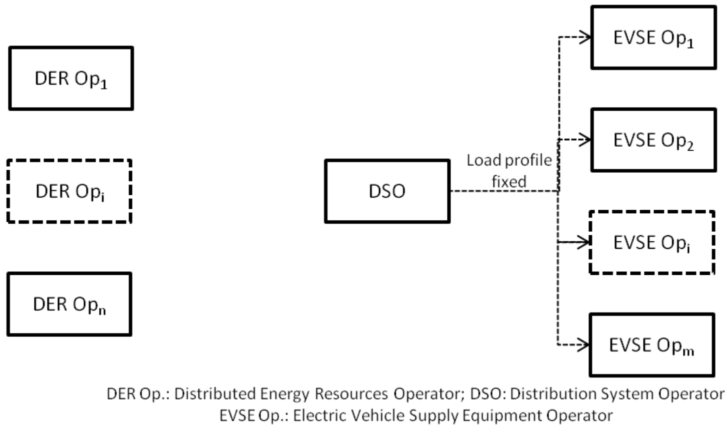

Figure 3.5. Communication of the Fixed Load profile from the DSO to the EVSE Operators for the day-ahead

The communication of real-time data production (by DER Operator) and consumption (by EVSE Operator) (Figure 3.6) allows the formal traceability of electricity from RENs used for charging electric vehicles. The consumption notification mechanism is implemented by Load Management Tracking interface, part of the It infrastructure needed for the deployment of smart charging products, as specified within Green eMotion proceedings, see Deliverable 3.6. By the use of this service, the EVSE Operators notifies how good it has performed for the pursuit of the DSO Target Load Curve, and might receive remuneration according to the error signal between the DSO Target Load Curve and the real result of the Power Modulation applied to the EVs.

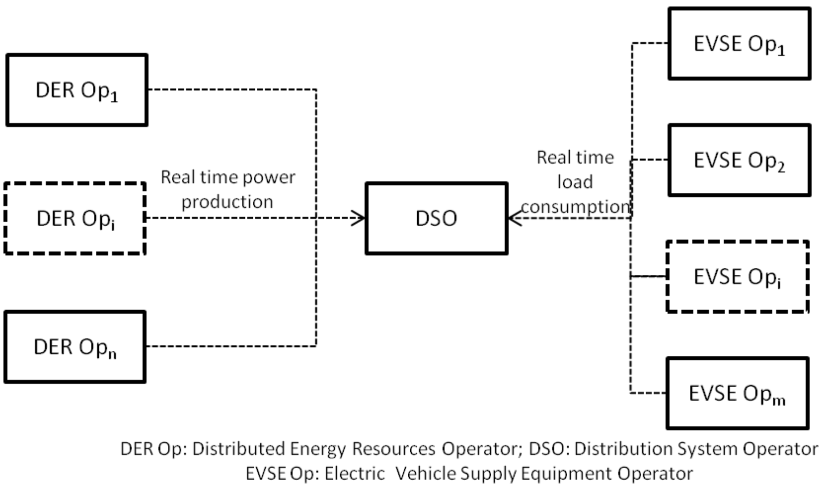

Figure 3.6. Real time power production communication by DER Op. and real time load consumption by EVSE Operators to DSO

Business process and technological requirements for traceability might be derived directly from the analysis of Figure 3.4, Figure 3.5 and Figure 3.6.

The three actors involved must acquire the following capabilities:

DSO (Distribution System Operators)

To adopt/leverage a system of intelligent management able to "match" the forecast of production and consumption for each EVSE operator, in order to provide a fixed load profile on a day-ahead basis. This has an impact on how the DSO procure the needed information (interface to be implemented with DER Operators), how the DSO provides the needed information to other stakeholders (existing IT interfaces established in Green eMotion between DSO and EVSE Operators) and how the DSO validates its candidate Target Load Curve against the physical electricity grid (DMS). Although the interfaces between DSO and EVSE Operators are already implemented and could be generating in the near future a dedicated Open Smart Charging Protocol within eMI3 initiative (www.emi3group.com), the interfaces towards DER Operator to acquire real time tracking of production (Figure 3.6) and day-ahead forecast (Figure 3.4), based on a geographical and electrical common language build on top of the concept of Load Area, are yet to be established and will be required in order to make a marketable product for the class of services of Chapter 2 related to RENs integration (Services 2.2.3, 2.2.6 and 2.2.7).

DER Operator

Somehow this is a mirror of the DSO requirements, the REP must evolve its system in order to cope with the above mentioned interface. This implies the ownership and management of a system able to predict the production profile on day-ahead basis (even shorter timing applies for Service 2.2.7).

EVSE Operator

The EVSE Operator must implement the Load Management Target and Load Management Tracking interfaces in order to acquire DSO Load Target Curve and notify the DSO what really happened once the Power Modulation was executed. Furthermore, the EVSE Operator must comply with the expectations of the EV Customer, hence the EVSE Operator will host somehow an algorithm capable of finding the suitable trade off between EV Customer Preferences and DSO Load Target Curve, two major Business Objects on which the service relies on.

Some possible solutions to meet the requirements listed above will be analyzed in the following paragraphs, in case of gap existing between current implementation and marketability of the service. This implies that the following analysis is only focused on DER Operators and EVSE Operators perspective, as the DSO traceability requirements are simple and straight forward: to be able to properly acquire and retrieve data from and to the DER Operators and EVSE Operators on one side, and to be able to validate a DSO Target Load Curve to be given to other stakeholders against the physical state of its own infrastructure, through systems such as DMS.

3.3.2. Fulfilling DER Operators requirements

As previously described, in order to implement traceability the DER Operators must be able to provide to the DSO their Production Curve as a forecast on day-ahead basis. The Production Curve is a Business Object (BO) whose structure is similar to toe BO Load Curve: a vector of usually 96 points (4 points each hour, 1 point every 15 minutes) of Power values, with a depth of 24 hours, described alongside a specific Load Area, where the RENs are installed. The Load Curve as defined in Green eMotion, Deliverable 3.6 is somehow specular: a vector having usually 96 points (4 points each hour, 1 point every 15 minutes) of Power values, with a depth of 24 hours, described alongside a specific Load Area, where the appliances/EVs to be power-modulated are being connected to the LV/MV electricity infrastructure.

Specifically, the reliability of DER Operators to provide such a Production Curve on a day-ahead basis relies on the type of renewable sources harvested. High reliability should be requested to DER Operators in order to participate in “Planned Demand Response” services / programs.

Thermal solar power generation

In these systems, the presence of a heat storage system eliminates the irregular variations due to weather conditions (cloudiness, humidity, etc..), this makes possible a reliable prediction of the production profile forecast of the next day without substantial changes, provided that the renewable sources could be properly forecasted. Hence, thermal solar power generation provides high reliability on top of the weather forecast needed to properly develop a Production Plan according to sunny days. Although suitable for “Planned Demand Response” services / programs, it is a technology with low maturity, high up-front costs and low market penetration which unlikely will be used with this regard in the next 5 to 10 years.

Photovoltaic generation

With these systems the production of electricity mainly relies on the stochastic parameters of the renewable energy source (Sun), without the smoothing and buffer effect of heat storage systems like in the case below. Power output is variable according to the seasons, because of the regular variations (daily and annual) due to the apparent motion of the sun in the sky, also due to the random of the irregular variations due to weather conditions (cloudiness, humidity, etc.), which prevents a perfect forecast of the production profile on a day-ahead basis without any substantive changes. A good reliability of the forecast of the production profile forecast of the day after can be obtained by equipping the facility of a storage system (batteries) that can "absorb" the irregular variations of solar radiation and smooth the Production Curve fluctuations.

A combination of PV installation and storage systems could provide a reliable technology for a DER

Operator to participate to “Planned Demand Response” services / programs, with good compromise between upfront cost and maturity of equipment, within a timeframe of 10 years. Such a combination of equipment could also be suitable for the implementation of “Quasi-real time demand response: enhancement of RENs integration”. Such a concept will be further developed in PlanGridEV D2.3.

Wind farm

The case of these power plants is similar to the photovoltaic systems: the high uncertainty of the availability (instantaneous) of the renewable source to be harvested prevents from a reliable prediction of the day-ahead Production Curve. Room for improvement also in this case can be achieved by equipping the system with a system of energy storage that can absorb high valued random peaks, without having an impact on the Production Curve bidden in the participation to a Demand Response program. Market outlook and application is similar to the PV case.

Biomass plants

In these plants the production of energy is related to the availability of biomass stored; a simple management of the biomass supply allows a reliable day-ahead Production Curve without any modification of the plant. This could be hardly applied to the household level (such as in “Quasi-real time demand response: enhancement of RENs integration”) due to upfront startup costs, but it is a good candidate for the shortest Time To Market of “Planned Demand Response: Enhancement of RENs integration”.

Hydroelectric plants

Hydroelectric plants that have seasonal variations of production are those flowing water (in basin plant the electricity produced can be expected in the long term) for these the production is related to the flow of water available. This flow, however, may present significant changes only on a seasonal basis, so it is possible a reliably production profile forecast of the next day without any hard changes which would put hazard to the effective participation in “Planned Demand Response” services / programs. Similarly to the biomass case, this could be hardly applied to the household level (such as in “Quasi-real time demand response: enhancement of RENs integration”) due to upfront startup costs, but it is a good candidate for the shortest Time To Market of “Planned Demand Response: Enhancement of RENs integration”, where scaling provided by the installation and operation of several hydroelectric plants could make a positive business case for a DER Operator installing the needed IT technology to let this power plants participate in smart charging marketplace.

3.3.3. Fulfilling EVSE Operators requirements

Usually a charging system is composed by the EV, the connection cable, the EVSE and the input of electricity, usually referred as Point Of Delivery (POD) that is typically linked to a Smart Meter. The capability of EVSE Operator to participate in "Planned Demand Response: Enhancement of RENs integration" relies on the implementation of IT infrastructure services fulfilling the service requirements.

The IT infrastructure services useful for the deployment of "Planned Demand Response: Enhancement of RENs integration" have been detailed in Par. 3.3.1 and are specified in Green eMotion Deliverable 3.6. Further details over IT infrastructure implementation will be summarized in PlanGridEV D5.1, whereas this paragraph serves as an overview of EVSE Operator requirements.

The EVSE usually provides the electric power to the vehicle BMS (Battery Management System) without considering the supply profile or any other constraint set at EVSE Operator level. Nevertheless, several EVSE – EVSE Operator back-end communication protocols (including Enel Distribuzione's proprietary one used for PlanGridEV demo). Insights over the requirements for a general Open Smart Charging Protocol will be given to the value chain stakeholders based on the results of PlanGridEV demonstration.

The smart charging is implemented at EVSE level by using a Power Modulation Business Object, composed by a single level of Power (or Current) that propagates from the EVSE Operator back-end and should be used as top threshold level during the PWM handshake between EVSE and EV, according to ISO/IEC 61851-A.

Similar principles apply to DIN Specifications 70121 for Combo 2 DC Charging, currently a limited marketable version of ISO/IEC 15118 for Powerline communication. Ideally, ISO/IEC 15118 should be used in demonstration of "Planned Demand Response" services, although currently its deployment is not available in marketed products. This implies that PlanGridEV demonstration will be performed relying on PWM handshake through ISO/IEC 61851-A.

The EVSE, in order to ensure the traceability, must be able to follow the continuous update of Power Modulation as indicated by the DSO in the DSO Target Load Curve (see previous paragraph). The EVSE Operator back-end shall be hosting an algorithm capable of finding the tradeoff between DSO and Customer constraints. It is this algorithm that allows a transparent quality of service to the EV Customer, whilst extracting value for all the stakeholders in the value chain.

In order to obtain an optimal load management, the EVSEs should be regulated acting on SOC. Therefore the EVSE Operator, whilst searching for the optimization trade-off, must take into account the EV Customer Preferences, a key Business Object including the following:

- Initial SOC: this is the state of charge that the EV initially has in the moment the EV Customer
- Final SOC: in case the EV Customer doesn't need a full charge, he/she can indicate the minimum SOC desired at the Time Of Departure.

- Time Of Departure: the EV Customer has to indicate the time of departure in order to extract value from his time flexibility against the integral of power to be fed in the EV.

The EVSE Operator receives inputs from other stakeholders, processes the data received according to the trade-off logic and, based on the results of this processing, manages the energy flows (Figure 3.7) controlling the continuous update of the EVSE's Power Modulation level, a BO which shall be included in the EVSE-EVSE back-end communication protocol.

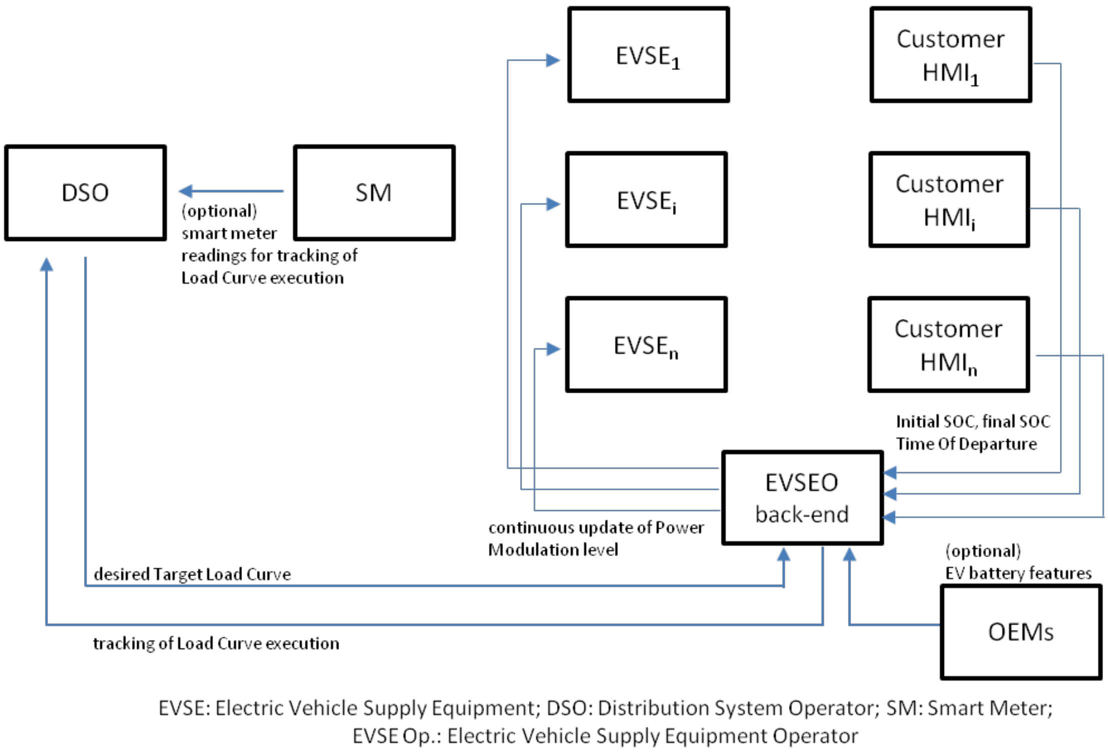

Figure 3.7. Data transfer diagram built around the EVSE Operator back-end

The EVSE Operator information exchange is the following one. At this level, the main hypothesis is that the EV is not capable of implementing any form of data transfer with the charging infrastructure which could useful for such scenario (such as SOC). Therefore, only ISO/IEC 618581-A is available as communication standard with the EV.

- From / To DSO, the Load Curve gets acquired and the results of smart charging process are notified
    - The DSO Target Load Curve, by using the "Load Management Target" web interfaces between EVSE Operator and DSO, where the desired Load Curve to be executed on the list of PODs (EVSEs) belonging to the Load Area is reported.

  - The result of smart charging process, by using the “Load Management Tracking” web interface between EVSE Operator and DSO, where the actual Load Curve executed on the list of PODs (EVSEs) belonging to the Load Area is reported.

- From EV Customer HMI (whose information could be routed through EVSP systems, as the EVSP typically holds the B2C relationship) the “EV Customer Preferences” business object is acquired, which is built in a way that guarantees the EVSE Operator to be aware, for each charging process scheduled at each EVSE belonging to the Load Area, the following parameters:
  - Initial SOC
  - Final SOC
  - Time Of Departure
- To the EVSEs
  - Continuous update of Power Modulation level to adjust the EV charging processes according to the tradeoff between EV Customer Preferences and DSO Target Load Curve as elaborated by the EVSE Operator

Optionally, the EVSE Operator might acquire EV battery features through a repository for which OEMs shall be liable. The information included in such repository (temperature profile of battery parameters, battery health progress against time, etc.) might enable second-order optimization within the EVSE Operator back-end. Furthermore, such a repository is needed from as the same EV model is currently being shipped with different configurations (e.g. amount of maximum rated power allowed by the EV embedded charger). Similarly, the DSO could harvest Smart Meter readings as back-up or additional degree of confidence on top of the process tracking provided by the EVSE Operator through the “Load Management tracking” service.

4. Requirements for EDP field test: managing EV charging and DER peaks by dynamic network reconfiguration

4.1. Overview

Even though the Conventional scenario of Table 3-1 is based on the traditional “build and forget” approach to cope with new or increasing electricity demand, in particular with the new EV loads, EDP in Portugal will aim at demonstrating that in some locations it’s possible to postpone grid investments by simply operating some remote switches as operational method for increasing EV hosting capacity.

Based on the main objectives of PlanGridEV and in particular on what EDP intends to simulate, as a first approach to the operational method of Portugal’s testbed, the following high-level requirements might be outlined:

- ICT and Data Management that allow data access on real-time to DER generation data, EVs charging data and Consumers data, enabling better understanding/characterization of the LV network;
- Remote Controlled Switch in LV network and the ICT equipment needed to enable load transfer between LV feeders;

With knowledge of the above information, having the appropriate ICT systems and the possibility to perform remote operation in the LV network, we will try to demonstrate the possibility to accommodate the different actors (generation and loads) along a day, performing the correct network reconfigurations, avoiding and/or postpone grid investments.

All the information obtained from the LV electricity grid will be used in a second stage to develop short-term operational planning. With the consolidation of the collected information (longer period of data collection), it will be possible to develop network expansion plans in a medium term (mid-term planning rules).All the tests will be performed with the EDP software planning tool “DPlan”.

4.2. Portugal’s test bed description

The LV network will be selected taking into account the presence of public EV charging points and private (home) charging possibility as well as PV generation, along with the conventional loads.

As EDP LV network has radial topology with no possibility of network reconfiguration, the loop topology with a possible reconfiguration scheme will be implemented virtually in the software planning tool in order to perform the reconfiguration tests.

4.2.1. Description of main validation tests

4.2.1.1 Business as usual (BAU)

The Business As Usual tests will be carried out considering that EVs and DERs have no control capability.

The loading/generation scenarios will match what was defined in the Deliverable D1.2 (Future Scenarios).

The tests in EDP test bed will be:

- The representation of the LV grid Test grids in the network simulation software (DPlan) with actual representative loads and micro generation will be simulated;
- Scale up loads by integrating EV as forecast (Future Scenarios);
- Scale up micro production by integrating DER as forecast (Future Scenarios);
- Combine both future loads/generation scenarios and evaluate the capability of switching/reconfiguration to avoid/postpone grid investments;
- Optimal locations for remote controlled switch installation will be determined with the help of DPlan;
- Simulation of optimal reconfigurable operation will be simulated with DPlan to identify possible congestions and/or voltage rise/drop issues.

4.2.1.2 Dynamic Strategy Management (DSM)

Optimal EV and DER control strategies, meaning a set of decisions criteria's to operate the remote control LV switches in order to perform load transfer between LV feeders, will be obtained with the help from the Planning Tool for the InovGrid (FP7 project) Test Bed network.

The DSM tests will then be carried out considering that EVs and DERs are controlled optimally. Optimal reconfigurable operation benefits will be measured by comparing daily simulation results from DPlan under two different situations:

- A static daily configuration (optimized for the expected peak load)A dynamic configuration (optimized periodically during the day)

Finally an evaluation if planned networks are sufficient or if re-planning is generally required will be performed.

5. Requirements for ESB field test: Load & voltage measurement on a rural LV network.

5.1. Overview

This field test will be carried out by ESB Ecars and ESB Networks as part of the PlanGridEV project to study the effects of introducing EV's onto rural LV networks. The study will endeavor to model the impact that wide scale EV growth would have on rural LV groups connected to small 15kVA and 33kVA transformers. The study will also look at the behavior of EV drivers to see when cars are charged with or without usage limitations. ESB have carried out similar studies on urban housing developments and gained good learning on this area. The main focus will be on load and voltage drop and this study will help us to identify what future investments are required in the area of network reinforcement.

5.2. Ireland's Test bed description

The ESB test bed will be based around two specific sites

- A LV group of 2 to 4 houses fed from a 15kVA transformer
- A LV group of 2 to 6 houses fed from a 33kVA transformer

These sites will be fed from either 10 or 20kV backbone lines and it is intended to use two LV groups with a high load. It is planned to trial 2 EV's on the 15kVA trial and 3 EV's on the 33kVA trial. The main purpose of this trial will be to study the effect of the introduction of EV's on a typical single phase rural network. Load and voltage drop will be the principle measurements used and these will be recorded by installing smart meters in houses and power quality transformer meters at the supply point. The smart meters will generate a load profile and give a good idea of the loading in each house. Voltage recorders may also be installed in each house. The trial will then be run with three separate scenarios in place, each for 4 to 8 weeks. These scenario's will be;

1. No EVs connected
2. EVs connected with charging only permitted at night between 11pm and 7am.
3. EVs connected with unlimited 24hr charging.

These scenarios will give a good representation of the affects of EV charging and the possible benefit of future smart grid technologies. It is planned that this trial will lead to a recommendation for future smart grid implementation especially related to EV growth.

Micro-generation will not be included in this trial as it is not widely used in Ireland. However, as part of the conclusions and recommendations we will investigate how micro-generation could benefit a rural installation similar to this trial. The trial will also help to identify the possible benefit of the various types of smart grid technology like intelligent charging protocols, smart meshing, etc. The economic benefit and technical feasibility of these technologies will be investigated to help develop a strategy in this area.

5.3. Preparatory Work Required.

In order to carry out this trial, the following work will be carried out by ESC Ecars & ESB Networks;

- Install 4 to 6 EV Home Chargers capable of 16A charging.
- Install up to 12 Smart Meter Devices
- Install 2 Transformer Power Quality Meters
- Install voltage recorders in some or all of the houses.

For the validation tests ESB can rely on a rural LV radial network supplied by a 10/20kV single phase circuit. The possibility of back-feeding/paralleling of the LV network will also be present. Re-sectionalisation of the network may also be required in order to apply a maximum base load prior to the injection of EVs. In order to validate results Smart Meters will be installed at all dwelling locations fed from the MV-LV transformer, the installation of a PQ meter at the sub location will also be required – installation of other devices/switches may also be required depending the exact specification of the use-case.

6. Requirements for RWE field test: Load management in the LV network through autonomous agents (Smart Operator)

6.1. Description of the process and of the different actors involved

The field test of Germany, run by RWE, will be demonstrating a sub-set of use the cases derived from "Smart Grid" scenario as described in D2.1. In particular, the use cases will be designed around the "Quasi real time demand response: enhancement of RENs integration" service as outlined in Chapter 2.

RWE has established a test bed where a number of smart grid components including renewable generation, grid storage and EVs have been installed. These are controlled and monitored on a substation level according to grid friendly control schemes. The idea behind this test bed, is to increase the hosting capability of the grid for renewables and EVs by using the smartness of forecasts and controllability rather than by putting more copper or aluminum in the ground.

The "Smart Operator" a computer in the substation having measurement values from the grid, forecasts for the load and the generation and profiles of the controllable demands, is the core component of this scenario. I controls the loads according to the actual demands, the forecasts and the available flexibility of the customers.

6.2. Overview

In the field test areas, which represent the test bed for the PlanGridEV project for RWE, the Smart Operator will make use of newly installed grid components to improve the quality of the energy supply. These components can remotely be controlled. They include battery storage systems as well as charging points for EV. The DER production will be forecasted and ad-hoc measured and can preferably be used for charging EV.

The concept of the Smart Operator is covering continuous monitoring and autonomous operation of the LV grid.

Various remotely manageable components are used in the test areas:

- regulated local grid transformers with tap-changers,
- electrochemical storages (batteries), both Pb and Li-Ion in different sizes,
- remotely controlled low voltage switches, for influencing the topology of the LV grid,

- charging stations (public) / charging boxes (home) for electric vehicles.

Besides the intelligent grid components some further devices are used in participating households to control local demand and generation. These are connected to the Smart Operator via a home energy controller (HEC).

The Smart Operator determines the current situation of the grid by taking the measurements of smart meters (in the households) as well as from dedicated measuring devices located at specific places in the grid, which make an automatic state-estimation most reliable.

From the state-estimation, which is re-calculated every 60 seconds, the state of the grid is derived and a decision is taken, whether any action on the manageable components might improve the quality of supply.

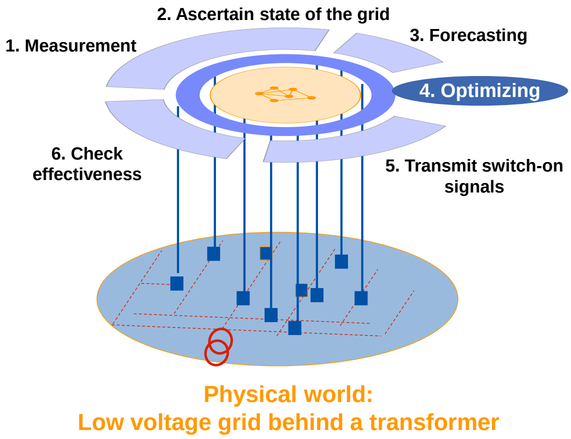

Figure 6.1 Basic concept of the Smart Operator

The smart meters in the households will not only report the consumption data but also the current voltage. At selected points in the grid, especially the bus bar, the battery storages and the end of supply lines, additional measuring instruments are installed and will continuously transfer their data to the Smart Operator. The algorithm running at the Smart Operator is somewhat robust against missing data or erroneous data.

Those grid conditions, which cannot be measured, are estimated by a state-estimation algorithm, which is invoked in a 60-seconds interval.

The expected grid conditions for the next 24 hours are calculated. The basis for this calculation is a combination of grid data from the past and expected weather conditions. This data enables the algorithm to make a prognosis of supply and demand. With this prognosis the operation of the LV grid is managed thus to avoid any critical situation (overload, voltage band violations etc.).

Every command determined by the Smart Operator is checked by a load flow calculation before being actually executed.

Through the continuous monitoring of the grid by means of the measurement data, the forecasts are constantly checked. If any deviations from the forecast are identified, a re-calculation of the grid is carried out and, if required, new switch commands are sent to the grid components. This approach ensures the safe operation of the grid at all times. In the event of a fault in the execution of the Smart Operator algorithm or a severe malfunction of a grid component, an alarm is sent to a superordinate system and all grid components switch from the regulated grid operation to automatic operation. In this way the regulated local grid transformer, e.g. can be controlled by the Smart Operator but it can also independently keep the voltage at the bus bar within allowed limits.

6.3. Work Packages

The activities in the test bed are being coordinated by RWE Deutschland AG. The works are divided into a number of work packages. The overview is depicted in following figure. A detailed description of these packages follows below.

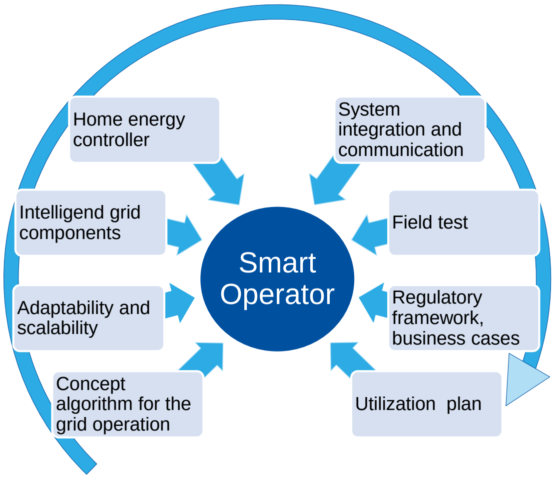

Figure 6.2 Overview of work packages Smart Operator

RWE Deutschland AG is supported by several project partners in the implementation of the Smart Operator project. Following successful simulations and laboratory testing of the autonomous controlling of the low voltage grid in 2013, the field test will be conducted during the year 2014. In evaluating the project equal attention will be paid to economic viability and technical feasibility.

At first, the Smart Operator will be tested in grids in rural areas, because in these grids the decentralized power production through wind and sun is particularly high while the grids have limited capacity. These low voltage grids are located in Wertachau, Kisselbach and Wincheringen in the Western and Southern areas of Germany.

6.3.1. Control Algorithm for the Grid Operation

The Smart Operator has to manage a low voltage grid independently from human interaction. Therefore it is necessary to develop a suitable control algorithm for the operation of the grid, which stipulates how the Smart Operator shall react in certain situations.

The Smart Operator controls the low voltage grid in nearly real-time (60 seconds intervals) and constantly improves its efficiency by learning from historical data. The algorithm is being developed by the IFHT of the RWTH Aachen University.

As a basis for its commands the Smart Operator uses a matrix in which all possible switching options are saved. It randomly selects an option from this matrix and checks the new grid situation with a load-flow calculation. If no overloading or voltage outside the allowed limits is detected, the grid situation will be set accordingly.

When the Smart Operator first goes into operation, all switching options are of equal weight. Whenever a switching option is executed and considered successful, for instance, keeping the voltage within the allowed limits by charging a battery, then this switch option gets a higher weight allocated and the next time it will be the more likely option. In this way the algorithm constantly learns how to optimally control the LV grid.

6.3.2. Adaptability and Scalability

The theoretical research of grid operations with a Smart Operator and practical field tests will be adapted for other low voltage grids. The effects of multiple use of a Smart Operator on medium voltage grid levels will also be investigated. Using the Smart Operator should enable an improved operation of the low voltage grid with positive effects for upstream grid levels to avoid over-loaded grid assets, e.g. in the medium voltage level. At the same time it will be examined whether the Smart Operator can also be used all over the country or only in selected regions.

When the effects of its use at other grid levels have been established it will be possible to analyze the benefit of a central “master” Smart Operator in the medium voltage grid which communicates with the Smart Operators in the low voltage grids. This would make the uncritical operation of the grid both in the low voltage grids and in the medium voltage grids possible.

6.3.3. Intelligent grid Components

In the project various innovative grid components are tested. The Smart Operator shall make optimal use of the abilities of these components, to guarantee stable and safe grid operation.

The local grid transformer will be replaced by a Voltage Controlled Distribution Transformer (VCDT) using an integrated on-load tap changer (OLTC), which can regulate the voltage in 9 steps of 2.5% each to provide a broad range of the possible voltage bandwidth supply.

Such stepping can either be controlled remotely using an internet gateway, or the transformer can operate in an automatic mode, reacting on deviations of the voltage on the bus bar.

The GRIDCON Transformer is delivered by Maschinenfabrik Reinhausen (MR) and enables the Smart Operator to activate the step by step voltage regulation.

Besides the transformer, four different kinds of battery storage systems are introduced.

1) Large grid storage systems with a capacity of 150 kWh are used for peak shaving. The size of the reduction in power and further storage behavior will be examined. For the relation of capacity to power (E2P-ratio), theoretical values are derived from literature. Based on these elaborations, a reduction of a PV peak, e.g. from 60 kW nominal power to 30 kW leveled feed-in (and hence, an E2P-ratio of 150kWh/30kW=5 hours) should be possible. This storage is intended to reduce the burden on the transformer in the event of large PV-feed-in peaks.

2) A further possible application for the grid storage of 150 kWh is to maintain the voltage at the end of the line. Here, depending on the grid conditions active and/ or reactive power can be consumed or supplied.

3) In addition to the large battery systems, smaller units with capacities of 30 kWh are used as decentralized assets in order to contribute to (balanced) voltage levels. For this, these assets are positioned next to selected PV generators. Both types, lead-acid and Lithium-Ion batteries will be tested.

4) Finally, small battery systems are installed in households to increase the flexibility of the consumption/generation, which is enabled by the local battery in the operation of the HEC (see details below).

Grid separation switches are to be used to control the grid topology, so that, if necessary, two branches can be joined together to form a closed ring structure.

These technologies will be selected with respect to the grid area and will be used either in combination or separately. The central management function will be carried out by the Smart Operator.

6.3.4. Home Energy Controller (HEC)

The communication with controllable loads in households takes place via intelligence (Home Energy Controller (HEC)) installed in the households. The HEC controls the loads and producers in the households including among others PV generators, heat pumps, white goods and small battery storages.

For the household appliances the HEC works out an optimal timetable when the usage of energy is preferred. For this, different optimization objectives are applicable, e.g. maximize the self-consumption of locally generated electricity. Furthermore, the HEC may adapt the local energy profile to react on incentives and steering signals provided by the Smart Operator (e.g. in cases of grid problems).

The HEC uses information from weather forecasts and combines it with consumer behaviour patterns to produce a forecast of the consumption/generation profile. Thus, it seeks to optimize usage, so that e.g. a heat pump is preferably switched on at midday and the temperature in the refrigerator is reduced if sufficient PV feed-in is given. Communication between HEC and Smart Operator makes use of “load profiles”, supplied by the HEC and given to the Smart Operator to choose from.If the Smart Operator chooses a load profile for the next few hours the HEC tries to realize it and the schedule is passed on to the components.

The customer can intervene at any time and still has complete freedom to do as he or she pleases, so that the HEC and the Smart Operator have to react on unforeseen customer behaviour. In case the temperature in the refrigerator rises above the permitted level, the refrigerator will start anyway even if this is not foreseen in the HEC’s prognosis.

6.3.5. System Integration and Communication

Communication between the intelligent grid components, the HEC and the Smart Operator as the central communications point takes place via various media and protocols. As the IT requirements in grids will be even more demanding in the future it is very important that communication is not confined to one medium. In the project the use of fiber optics and power line for communication will be tested. Each technology will be considered separately and subjected to field tests later. Apart from the purely technical issues it is also very important to construct secure lines of communication.

It is imperative that the communication cannot be accessed by unauthorized parties both in terms of pure communication between the devices involved in transferring measurements and the control commands from the Smart Operator.

The energy measurements taken in the households are forwarded by the Smart Operator to a data center. The only difference between the Smart Operator and other uses of smart meters in billing customers is the forwarding of the information.

6.3.6. Field Tests

The proof of the Smart Operator’s value in practice will be provided by demonstration grids, which will be set up in 2014. In these grids the various communications media will be installed or retro-fitted. In these grids new substation transformers with on-load tap changers as well as grid storage and all other intelligent grid components will be installed..

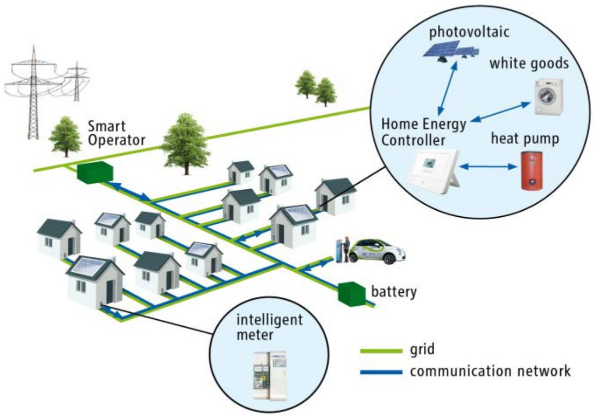

Figure 6.3 Structure of the demonstration grid

In selected demonstration grids the production and consumption in private households will be monitored and overseen by a HEC with the cooperation of the customer. In these cases the customers have declared their willingness to cooperate with the Smart Operator project and to contribute to a successful field test. Figure 6.3 shows the structure of the demonstration grid. The graph shows an example of the structure with the possible components in the grid and the households. Communication will be conducted between all the components and centrally coordinated by the Smart Operator.

For testing the effects induced by increasing e-mobility some electric vehicles and charging stations will be allocated in the demonstration grids. These field tests enable the evaluation of previous simulations of grid operations.

6.3.7. Regulatory Framework and Business Cases

Revealing prospects and risks for the introduction of the Smart Operator is another object of the project. The business cases will show if and how the Smart Operator could be an economic and 'smart' alternative to conventional reinforcements in future grids. For this, it will also be necessary to develop an appropriate regulatory framework. Adjustments will be suggested after considering the results based on the experiences in the field test.

7. References

7.1. Project documents

[DOW] – Description of Work.

[D2.1] – Deliverable 2.1, EVs Grid Integration Business Scenarios (Tecnalia).

[GA] – Grant Agreement.

7.2. External documents

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[2] Eurelectric, *Deploying publicly accessible charging infrastructure for electric vehicles: how to organise the market?.* Eurelectric Concept Paper. July 2013. Available on-line at: http://www.eurelectric.org/media/84461/0702_emobility_market_model_final-2013-030-0501-01-e.pdf [access in December 2013].

[3] Coppola G. et al. *Recommendations on grid-supporting opportunities for EVs,* Green eMotion project deliverable 4.2. 15 November 2012. Available on-line at: http://www.greenemotion-project.eu/upload/pdf/deliverables/D4.2_Recommendations_on_grid-supporting_opportunities_of_EVs_V1.2_March2013.pdf [access in December 2013].

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8. Revisions

Track changes

Name	Date (dd.mm.yyyy)	Version	Changes	
			Subject of change	
Cristina Silvestri	30/04/2014	0.1	Initial draft with ToC	overall
Cristina Silvestri	25/06/2014	0.2	First integration of different contribution	overall
Cristina Silvestri	03/07/2014	0.3	Draft for internal review	overall
Cristina Silvestri et al.	23/07/2014	0.4	Restructured doc	overall
Giovanni Coppola	31/07/2014	1.0	Final for Internal Review	overall
Armin Gaul et al.	11/08/2014	1.0	Overall Review	overall
Giovanni Coppola	18/08/2014	1.1	Final for PC approval	overall
Armin Gaul	19/08/2014	1.1	Overall Review	overall
Cristina Silvestri	19/08/2014	1.2	Final for PC approval	overall
Armin Gaul	20/08/2014	1.2	Overall Review	overall
Cristina Silvestri	21/08/2014	1.2	Final for EC Submission	overall
Armin Gaul	22/08/2014	1.2	Final for EC Submission	overall