LOAD MANAGEMENT: A DEMAND RESPONSE B2B SERVICE FOR CORPORATE EV FLEET OPERATORS

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ABSTRACT

These document provides an overview of technical infrastructure jointly developed by Enel and Siemens to enable advanced Smart Grid integration services for EV charging. A class of products related to the dynamic load management of electric vehicles is hereby presented, with proper specifications and demonstration results. Such a class of products is of specific interest for DSOs, EVSE Operators and Fleet Operators to extract value out of EV Drivers flexibility and expand the portfolio of services within electric mobility business.

FUNDAMENTAL GLOSSARY

In order to ensure a smooth readability of this document it is suggested to have a look at the glossary below:

B2B – Business To Business

DSO – Distribution System Operator, entity in charge of operation and maintenance of Low Voltage and Medium Voltage Electricity Grid

EV – Electric Vehicle

EVSE – Electric Vehicle Supply Equipment

EVSE Operator – Electric Vehicle Supply Equipment Operator, also known as Charging Station Operator

EVSP – Electric Vehicle Service Providers, entity in charge of the Customer Relationship Management

Fleet Operator – entity operating a corporate EV fleets, typically customer of a demand response service

LM – Load Management

RES – Renewable Energy Sources

SOC – State Of Charge

TOU – Time Of Use

HMI – Human Machine Interface

INTRODUCTION

As EV sales share is steadily increasing, with a market outlook of 2% of new sales in Europe for 2020 and some EU countries reaching 5 to 6 % already in 2014, a whole set of opportunities will be given to the conventional electricity stakeholders chain, where value could be harvested by brand new products.

Enel Distribuzione is a trail blazer in the deployment of necessary technology for charging infrastructure, particularly in order to minimize electricity grid investments, by allowing EV Customers to access demand response programs for EV charging.

Due to white certificates incentives and corporate taxes discount related to EVs purchase, EV fleet market will reasonably dominate electric mobility in Europe (fleet market currently accounts for more than 30% of Italian EV sales) and a realistic Time To Market for such Demand Response programs for EV charging do exist for Fleet Operators as Service Customers. Therefore the corporate fleets are a very suitable use case fur such application since the fleet operators can take advantage of load modulation scheme, controlled by precise boundary conditions, to reduce the running operational cost of the EV fleet. Key items for this class of product are: DSO, the availability of local RES plants, the Initial and Final State Of Charge of EV Drivers belonging to the fleet, their Time of Departure.

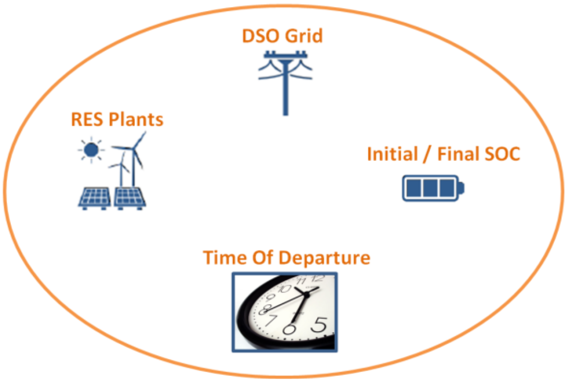

Fig. 1: Boundary actors / variables of a Load Management product

For these reasons, Enel Distribuzione and Siemens are equipping the jointly developed EVSE Operation back-end software system with a capability to perform load management process across the EV charging infrastructure, taking into account DSO, RES and EV Driver preferences, with the aim of extracting value from the availability of EV Drivers to trade time flexibility with discounted tariff and / or the maximization of local RES injection. The use cases at the root of this class of products were studied within the framework of PlanGridEV project, Grant Agreement no. 608957 [3].

Within this document the reference architecture for the provisioning of a demand response program to Fleet Operators is detailed, with the specifications currently implemented for an IT service infrastructure built over the interfaces shown in Figure 1 (interfaces painted in blue). Early results of the proof of concept of such demand response for EV Fleets charging will be also detailed. The demand response program is implemented through an intelligent load management control of the rated power output of charging stations, which could also be seen as a smart charging of EVs. Within industrial and scientific literature ([2], [3]) load management and smart charging often are used for the same class of value added services.

The architecture is designed around the concept of deploying a B2B service to be provided by EVSE Operator/EVSP to the Fleet Operator in order to minimize electricity bills, electrical investments and – wherever feasible – maximize the allocation of local Distributed Energy Resources.

In order to assess this optimization problem, the information regarding the corporate fleet current status (Initial SOC, Final SOC, and Time Of Departure) is acquired by the EVSE Operator, as boundary conditions to aggregate the Fleet Operator flexibility in time-power space. If available, a production curve from local DER installation is acquired in order to be fed in the optimization algorithm as a boundary condition related to the pricing signal, described as a Load Curve with a depth up to 24 hours. The Load Curve could also be processed on the basis of energy marketplace (ToU tariff schemas of the Energy Vendor chosen by the Fleet Operator). Regardless the origin of the pricing signal, the same architectural principles hold true: a selected Target Load Curve is applied to the cluster of charging stations installed at Fleet Operator premises, running an optimization algorithm between Target Load Curve and EV Status information and applying the desired Power Modulation level to the charging stations.

Siemens and Enel have developed together a platform for the management of the entire charging process and of the charging infrastructure, included the delivery of advanced services such as Demand Response. Specifically, this platform allows set point calculation and dispatching, charging process control, smart metering functionalities, real time monitoring of the charging infrastructure status (including alarm management), management of the authorization, end of the recharge and customer billing. In order to implement a proof of the product hereby described, the needed set of interfaces has been established, acquiring and processing the necessary information in order to activate the smart charging processes across the EV fleet and deliver value to the Fleet Operator. Current estimations fit in a 500 to 2000 € yearly savings scenario with a fleet of 3 EVs, depending on the power connections available, local DERs installation and the depth of ToU tariffs contracted by the Fleet Operator.

OVERVIEW OF LOAD MANAGEMENT

The business root of Load Management as a B2B Demand Response product is to allow EV Fleet Operators to reach OpEX savings in the operation of the EV fleets by controlling the EVs charging schedules according to a favourable pricing signal, which could be relying on wholesale market pricing (e.g. TOU tariffs) as well as on the integration of local energy assets (e.g. storage, RES plants).

The operational root of Load Management as a B2B Demand Response is to equip the Fleet Operator, who is the final customer of such a class of product, with a set of technological tools: EVSEs, EVs and EV Driver HMIs that enable the use case of getting EV fleets' charging processes modulated according to a series of boundary conditions.

For the product execution, the EVSE Operation back-end takes into account the available DSO/RES constraints, in terms of a Target Load Curve (see Fig. 1), and the EV Driver preferences, in terms of Initial/Final SOC and Time Of Departure, set as the time by which the EV must be unlocked (see example of EV Driver's HMI reported in Fig. 2).

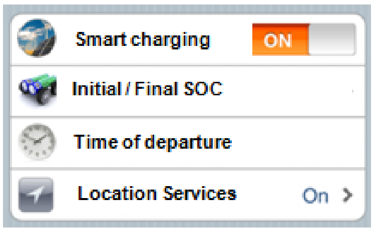

Fig. 2: Example of mobile EV Driver's HMI for setting Load Management (Smart Charging) preferences.

The comprehensive description of the product execution is reported below, referring to the framework of Fig. 3.

A Fleet Operator, having purchased EVs under

favourable conditions within early EV market phase, can access a EV charging contract signed with an EVSP.
From asset perspective, the EVSP manages the CRM with the Fleet Operator by providing it with the necessary number of EVSEs (operated by the EVSP in the role of EVSE Operator), the installation of local RES plants and of a buffering battery for storing the electricity locally produced. The EVSEs are managed by an EVSE Operation back-end which allows the execution of Load Management. From service perspective, the Fleet Operator signs an EV charging contract at favourable conditions compared to the conventional pay-per-use tariffs available from the electricity market. Depending on the assets available, this contract could also include a rental fee of RES and storage. The overall contract's goal is to minimize OpEX of Fleet Operator by reducing the yearly electricity bills for the EV charging.

On a daily basis, EV Drivers of the fleet set their own preferences / schedule for Initial SOC / Final SOC and Time Of Departure. These are met with the DSO / RES constraints and properly managed by an optimization algorithm within the EVSE Operation back-end, in order to satisfy on one side the EV Drivers preferences and on the other side the DSO / RES constraints.

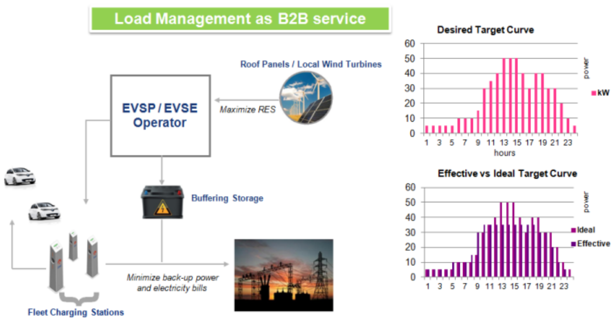

Fig. 3: Framework of Load Management product

As reported in Fig. 3, the value for the Fleet Operator is extracted by matching the Target Curve set by DSO, RES plants or wholesale market pricing conditions, leading to the control of the power output injected in the available EVs that are charging, each of them with specific end of charge timings and desired final SOC constraints to be fulfilled.
Therefore the Load Management could be sold as a Software as a Service additional feature of the EVSE Operation back-end, for which the return on investment is met by producing savings in the yearly electricity bill.

Hereby are reported the requirements for the execution of a Demand Response service applied to EV fleets charging, in compliancy with product's framework described above in Fig. 3 and fueled by the EV Driver's preference set by mobile HMI of Fig. 2.

- The availability of EVSE for EV charging process which allows for load modulation according to ISO/IEC 61851 and / or ISO 15118 through PWM or digital communication;

- The real time connection between EVSE and EVSE Operation back-end in order to forward updates regarding the load modulation of the EV charging as soon as DSO/RES/wholesale market pricing conditions may change over time;

- The availability of real time communication between DSO/RES/wholesale market and the EVSE Operation back-end, in order to receive pricing signals and/or production curve implemented through a Desired Target Curve

- A reliable set of customer preferences to be injected in the optimization algorithm via EV Driver's HMI.

LOAD MANAGEMENT SERVICES SPECIFICATIONS

Load management products can be executed by a set of enabling interfaces as show on Fig. 3 and reported below. Each of them must comply with precise specifications in order to execute power modulation – based services:

1. EV-EVSE interface
2. EVSE-EVSE Operation back-end interface
3. EVSE Operation back-end – DSO/RES interface

Compliancy of Interface 1 with load management product execution is guaranteed provided that the EV and EVSE are compliant to either ISO/IEC 61851 (and, more precisely, the PWM control method for the EV's state machine) or ISO 15118, or both.

Interface 2 is, in a nutshell, the communication protocol between EVSE and EVSE Operation back-end for the operation and maintenance of charging stations. This is not an international standard yet, although some efforts in that sense are reportedly being executed by international associations [1]. For this reason, the EVSE – EVSE Operation back-end communication protocol must comply with the possibility of hosting Business Objects dedicated to the load management product, as they will be specified within Interface 3 description.

Interface 3 includes the necessary exchange of data between the EVSE Operation back-end, who sets the load curve and charging schedule for each controlled EVSE, and all relevant stakeholders that are setting boundary conditions. This is implemented through three independent operations of web services which are specified below, namely: Customer Preferences, Load

Area Update and Load Management Target.

The first web service details and updates the EV driver preferences and notifies the EVSE Operation back-end that there is an upcoming charging request which is participating to a load Management / smart charging program. This web service, specified in the Data Request of Fig. 4, is triggered by end user application as shown in Fig. 2. The customer preferences are fed into the EVSE Operation back-end as an asynchronous stimulus to the charging optimization algorithm running on the fleet operator's cluster of EVSEs.

BO Data Request	Description	Input Details
Time Of Departure	Sets the desired end time of the charging process	HH : MM
Initial SOC	Sets the initial State Of Charge of the EV	Percentage
Final SOC	Sets the desired SOC at the end of charging	Percentage
Smart Charging	Allows participation to the load management program	Boolean

Fig. 4: Specifications for Customer Preferences web service

The second web service, Load Area Update, defines a cluster of EVSEs for each fleet operator and allows other stakeholders to refer to such a cluster when defining incentivized load management programs. In case the desired Target Curve (set by the third web service, Load Management Target) the DSO dynamically defines, over time, Load Areas (LA) within its network (for example based a maximum hosting capacity) and notifies either directly or via the Marketplace the updated Load Areas to the EVSE operation back-end, in order to establish a common language in terms of areas interested by a load, congestion management issue or smart charging programmes. The test cases were executed without interaction with a central routing MarketPlace, but the same principles hold true. In case of a central routing Market Place, multiple DSOs could be virtually exchanging data with multiple EVSE Operators.

BO Data Request	Description	Input Details
POD list	Sets a list of PODs (typically 1 POD for each EVSE)	POD enumeration standard (national level)
LA Name	Sets a name for the cluster of EVSEs (Load Area)	Char
Timestamp	Sets the time of Load Area declaration	Date

Fig. 5: Specifications for Load Area Update web service

The third web service, Load Management Target, allows EVSE Operator to receive the desired Target Load Curve as shown on Fig. 3 in order to set load boundary conditions to the execution of the charging optimization algorithm. The load curve is a BO implemented as a vector power values, typically one power value each 15 minutes and a depth of 24 hours, but can be reprogrammed to a higher granularity. A source of target load curve could be the DSO. Once the EVSE operator has identified which load areas it belongs to, he is ready to provide congestion and load management services at a specific load area belonging to the DSO electricity grid. Energy services can be triggered by the DSO whenever he forecasts, within a maximum forecast depth of 48 hours from the current time, the target power values to be achieved by the EVSE operator using the Load Management Target service, running on the EVSE Operation back-end. Once the EVSE operator has received target curves at load area level from the DSO, it calculates the load profile to be distributed to its EVSEs according to DSO targets and performs load controls. Therefore, the EVSE operator doesn't need to know all the characteristics of the grid, but the DSO will transmit the target load curve for the load area to the EVSE operator, expressed in an understandable way that is in power values. The source of target load curve could also be a local IT system managing the integration of PV/Wind turbine – based renewable plants with a buffering storage battery and the EVSEs. However, same principles applies, as an external stakeholder is feeding load boundary conditions to the optimization algorithm hosted at the EVSE Operation level.

BO Data Request	Description	Input Details
Load Curve	Vector of power values to be tracked during load management	Typical depth 24 hrs
LA Name	Specifies the name for the valid cluster of EVSEs (Load Area) to which	Char
Timestamp	Sets the time of Load Management target service call	Date

Fig. 6: Specifications for Load Management Target web service

The goal of the optimization algorithm is to satisfy the constraints set by Customer Preferences service on one side as well as the constraints set by Load Management Target service.

DEMONSTRATION RESULTS AND MARKET OUTLOOK

A cluster of EVSEs has been used for a validation at lab level of these Load Management products. First step for text execution is the proper exchange of Load Area references between EVSE Operation and DSO systems. In the example shown on Fig. 7, Load Area are being properly declared by external DSO systems in the Enel's

EMM Platform, a multi-tenant IT system serving the purpose of EVSE Operation back-end for 2,000 + charging stations that have been deployed in Italy until end of 2014.

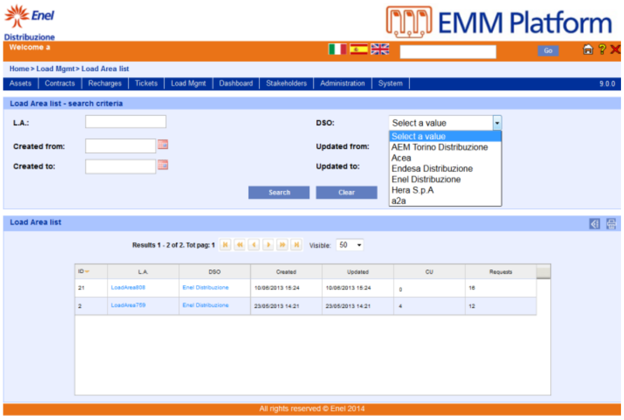

Fig. 7: Declaration of Load Areas for B2B Demand Response

The Load Curve BO issued by external stakeholder (DSO/RES/wholesale market) is injected in the EVSE Operation through the Load Management Target service call (blue signal, Fig. 8). For each EVSEs targeted by the Load Area specified in the Load Management Target service, there must be some Customer Preferences stored, in order to properly execute optimization algorithm and control EV charging (red signal, Fig. 8).

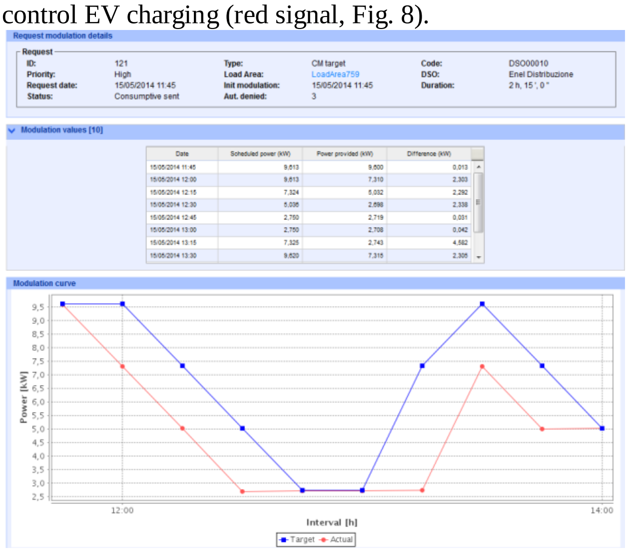

Fig. 8: Execution of Load Management by using a fleet of 2 EVs charging for a 2 hours-long slot.

In the example of Fig. 8, 2 EVs where charging at the cluster of EVSEs identified in the Load Management Target service call, each of them with pre-defined SOC conditions (start SOC and end SOC), and a granularity of applied control of 15 minutes, suitable for low to medium speed EV charging (below 2 hours).

ISO/IEC 61851 was used for controlling the rated power output of the EVs. Due to quantization of PWM control (only 1A granularity is allowed), battery health degradation and the inner variability of actual DC charging current across the SOC – Input Current space for EVs, there is an error signal produced from the optimization process (see distance between Blue and Red curves on Fig. 8) which could be further reduced by improving the exchange of data between EV and EVSEs, moving towards communication protocols at higher complexity. However, the product developed is already reliable to trigger ON / OFF EVs load management.

Once the tracking of the original target load curve is performed by the optimization algorithm hosted at EVSE Operation back-end, the EVSP / EVSE Operator can use the result to claim for remuneration (in case of DSO bidding the product in a wider second-level aggregation marketplace) or properly execute the fully integration of RES (in case the load curve is produced by a local system integrating RES, storage and EVs). Both scenarios aim at the minimization of fleets OpEX in terms of electricity bills.

Future activities with regard to this product development process will include minimization of optimization error, in order to have higher degree of reliability even in the aggregation of small amounts of power and field-trial with a real fleet operator, developing a wider economics analysis needed for a viable go-to-market strategy.

In a wider sense, the software behind this product could be the core of a virtual utility business, potentially provoking a revolution in the way conventional utility manages their customers. A virtual utility approach would make use of this product to widen the services provided the utility customers, improving the customer relationship through the provisioning of enabling transport and energy tools (EV, Storage, PV), minimizing energy drawn for the LV/MV grid, in a cost-effective way for the final customer, especially under regulatory conditions where some of the enabling assets (e.g. EVs and Storage) could be significantly socially and economically incentivized in the short term.

REFERENCES

For a Conference citation:

[1] www.emi3group.com

[2] G. Coppola et al., 2012, "Recommendations over grid supporting opportunities of EVs", Green eMotion Project, Deliverable 4.2

[3] www.plangridev.eu