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The concept of energy traceability: application to EV electricity charging by Res

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Abstract

The energy sustainability, in the era of sources diversification [1], can be guaranteed by an energy resources utilization most correct, foreseeing no predominance of one source over the others in any area of the world but a proper energy mix, based on locally available resources and needs [2]-[4]. In this scenario, manageable with a smart grid system [5], [6], a virtuous use of RES must be visible, recognizable and quantifiable, in one word traceable [7]. The innovation of the traceability concept consists in the possibility of having information concerning the exact origin of the electricity used for a specific end use, in this case EV charging [8]. The traceability, in a context of increasingly sustainability [9], [10] and smartness city, is an important develop tool because only in this way it is possible to quantify the real emissions produced by EVs and to ensure the real foresight of grid load. This paper wants investigate the real ways to introduce this kind of real energy accounting, through the traceability.

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Keywords: Traceability; Sustainability; Smart Grids; RES; PEVs - Plug-in Electric Vehicle; PHEVs - Plug-in Hybrid Vehicles; BEVs - Battery Electric Vehicles; Energy Vectors.

Nomenclature

B2C Business to customer
BMS Battery Management System
BO Business Object
DER Distributed Energy Resources

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DMS Distribution Management System
DSO Distribution System Operator
EV Electric Vehicle
EVSE Electric Vehicle Supply Equipment
EVSP Electric Vehicle Service Provider
HMI Human - Machine Interface
ICT Information and communications technology
LV Low Voltage
MV Medium Voltage
OEM Original Equipment Manufacturer
POD Point of delivery
REN Renewable Energy Network
REP Renewable Energy producer
RES Renewable Energy Sources
SOC State Of Charge

1 Introduction and concept

The increasingly electrified powertrain is one of the main strategies of the pathway leading to the zero emission renewable energy vehicle [11]-[14] and this trend determines the need for innovative EV charging infrastructure directly linked to the Smart grids and RES.

The innovation of the traceability concept consists in the possibility of having information concerning the exact origin of the electricity used for a specific end use, in this case EV charging. Traceability could became a new concept within the smart grid applications that, by now, are largely studied [[15]-[24]].

Traceability requires the knowledge of the type and location of the real system that at a given moment is supplying the vehicle charging with electricity, quantifying RES proportion. Using traceability concepts would enable the recognition of the origin of the energy used by EVs. At present there are certifications intended to ensure the customer that an amount of energy "equal to" the one he consumed was produced by plants from a renewable source in a certain period of time.

The issue is that stating that it is "equal to" involves a calculation of the energy balance, which, although correct, does not include all the characteristics of "real data". With traceability the user has, in fact, a confirmation concerning the type of plant which at that any given moment is supplying him. By enabling the possibility to trace the sources of the energy needed for charging an EV, a certificate of origin of the energy may be generated.

The traceability aims at certifying that EV battery recharge was made by renewable with self-production (grid connected) or that the grid management is able to guarantee the energy source of production and even the exact installation that produced the energy used in the global energy balance for the charging of the vehicle.

The main concern of traceability in this context is the indication of the specific renewable energy content of EV charging process. 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.

2 Goals

Identification of the objective to be reached: the objectives to be reached by the development and application of a real time traceability protocol in the electrical power production and distribution field are allowing the optimization of RES integration in the grid by the exploitation of controllable load resources and the satisfaction of the end-user by providing a set of data regarding the consumed energy. For pursuing these objectives it is necessary to Define a set of appropriate and useful information, which has to be defined from production to distribution and finally reach end-user and definition of a method for the exchange and the distribution of the information.

Identification of the constraints: on one hand, traceability has to take into account the constraints imposed by the user to the provider and by the provider to the user. These constraints will regard the amount of energy provided, the related timing or the distances. On the other hand, the traceability itself is subject to the constraints related to the information production and exchange. In general, the privacy policies and the security protocols related to the information managing will be a strong constraint in the traceability protocol definition.

Identification of the control variables and degree of freedom: for the energy traceability it is necessary to define a label (set of information related to the energy production and distribution) to be associated to the produced energy (e.g: the plant localization, the source, the plant features, production profile).

The label should be as much possible dynamic: it should be able to contain information variant in time and geographical position. An important point to be defined is the relation in between the label and the labeled object. Contrarily to other fields where the object to be traced contains the features useful for the traceability, the electrical energy do not have useful features which can be employed to discriminate it depending on the origin. The information allowing the tracking process has to be created ad hoc, collected and sent where required.

Degree of freedom: The degrees of freedom related to the tracking process have to be minimized, in order to make the information exchange as much as possible exact, correct and precise. Instead, the exchange process in between the energy provider and the end- user has some degree of freedom that the tracking process will have to be able to handle. In particular, in order to optimize the DER integration via the load management, the freedom degree will be related to the plant localization (minimization of dinstances) and the distribution management of the energy surplus.

Prerequisites and perspectives: To define the application protocol of the traceability concept, different activities are required:

- Method analysis addressing statistical load of EV for distribution networks: analysis of diverse scenarios of EV distribution based on statistical data of the future impact of these vehicles.
- Method analysis addressing statistical load of DER for distribution networks: analysis of the load profile of DER existing system.
- Method analysis addressing to maximize integration of EV and DERs: optimization of the integration between EV and DER [25].

3 Traceability requirements

The main actors are DSO (Distribution System Operator), EVSE (Electric Vehicle Supply Equipment [26]), EVSP (Electric Vehicle Service Provider) and DER (Distributed Energy Resources) Operators.

Moreover it is important to introduce the concept of POD (Point Of Delivery) and Load Area. In the same Load Area, 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). 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 (Fig. 1). 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.

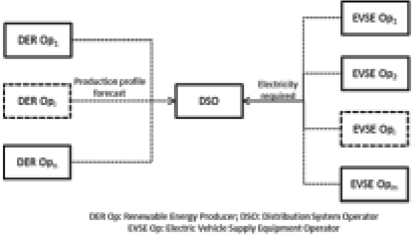

Fig. 1. Forecast production communication by DER Op. and Electricity required by EVSE Op to the DSO on a day-ahead basis

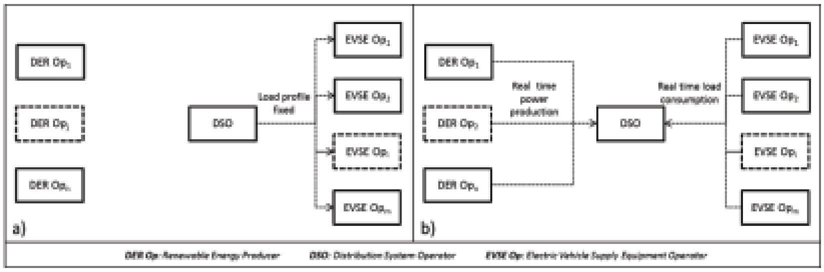

Fig. 2. a) Communication of the Fixed Load profile from the DSO to the EVSE Operators for the day-ahead. b) Real time power production communication by DER Op. and real time load consumption by EVSE Operators to DSO

By using these data the DSO processes the consumption profiles, checks the feasibility of DSO Target Load Curve against the grid current state and forward the DSO Target Load Curve to EVSE Operators (Load Profile Fixed) (**Errore. L'origine riferimento non è stata trovata.**a). This mechanism is implemented by Load Management Target interface, part of the It infrastructure needed for the deployment of smart charging products. The communication of real-time data production (by DER Operator) and consumption (by EVSE Operator) (**Errore. L'origine riferimento non è stata trovata.**b) 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. 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. Business process and technological requirements for traceability might be derived directly from the analysis of Fig. 1, **Errore. L'origine riferimento non è stata trovata.**a and **Errore. L'origine riferimento non è stata trovata.**b.

The three actors involved must acquire the following capabilities:

1) DSO: 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 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[†] the interfaces towards DER Operator to acquire real time tracking of production (**Errore. L'origine riferimento non è stata trovata.**b) and day-ahead forecast (Fig. 1), 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 related to RENs integration.

2) 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 (by electricity storing [27]-[30]).
3) 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.

4 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 (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 is somehow specular: a vector 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.

5 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 [31]. 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.

[†] Source: www.emi3group.com

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. 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. 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. 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 initial and final SOC, and the time of departure.

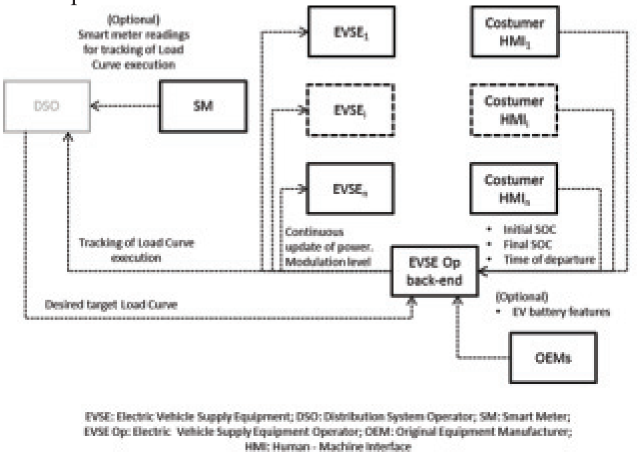

Fig. 3. Data transfer diagram built around the EVSE Operator back-end

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 (Fig. 3.) 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.

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.

6 Conclusion

The concept of traceability, already used and diffused in other industrial sectors, can definitely be applied to energy. Energy traceability could enhance the final customer awareness in the choice of his energy supplier. Thanks to Energy traceability, the energy choices could become consistent with the user's and customer's policy, strategy or personal convincement, not only considering the type of primary source and energy vector, but also the geo-political-economical-environmental value of their origin. The application of the concept of energy traceability to the electric vehicle charging, one of the most complicated applications because of the different actors involved (the main actors are EVSE, EVSP and DER Operators), shows its feasibility and the main flow-chart have been developed and validated with real market operators.

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