OPERATING THE CHARGING INFRASTRUCTURE FOR ELECTRIC VEHICLES IN DISTRIBUTION GRIDS

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ABSTRACT

The discussion about the future of individual transportation has gained momentum in the last years. Due to the short resources of oil and the large impact that combustion powered vehicles have on the climate, new concepts for the drives of vehicles are currently in development. One of the most promising concepts for the new vehicles are the fully electric vehicles (EV) powered by batteries and the plug-in hybrid electric vehicles (PHEV) powered by batteries and fuel. This recharge infrastructure will be managed by a system that collects information, monitors and manages the recharges

INTRODUCTION

Besides the technical implications this new drive concept has for the design of the vehicles, the charging infrastructure is of special interest in the transformation process of individual mobility. Since the batteries have a limited capacity, an infrastructure is required for re-charging the electric vehicles in public places. Therefore, service providers for electric vehicle mobility set up charging units on streets or parking places.

These service providers use a business model that is oriented at the business model of an infrastructure operator for mobile telephones. Like mobile telephony, the driver of an electric vehicle can charge his car at a charging unit regardless if he has a contract with the service provider operating the charging unit. According to the roaming concept in the communication business, the charging infrastructure service operator opens his system and takes care of the clearing and billing process.

Therefore, the charging infrastructure needs an information and communication backbone supporting the relevant business processes. Its main components are the operation center for electric vehicles and the communication units installed in the charging units.

In general, the operation center has to support three main business processes: First, the charging unit infrastructure has to be managed and the data flow from and to the charging units has to be established. Second, the data needed for the clearing of the financial transactions concerning the charging process has to be taken and to be distributed. And last but not least, the charging processes have to be managed in a manner that the electrical network will not be overloaded or endangered.

This paper presents a solution for the operation system for electric vehicles which covers all of these business processes. It consists of several front-end systems communicating with the charging units, a back-end system keeping the data and performing the business processes and the interfaces to other IT-systems and to the power control systems. The operation center takes care of the authorization processes at the charging units, records the data related to the charging processes and distributes the data to all service providers who are affected. Furthermore, it provides booking and reservation functions for the drivers of the electric vehicles. With the interface to the power control system, the network operator can monitor the charging process and reduce or shed the charging power in case of congestions in the network segments where the charging units are installed.

This paper discusses the different business processes in more detail and describes the technical solution of an already developed operation center. A first implementation of this operation center has been in operation within a major Italian utility since July 2010. First experiences with this system will be presented.

THE SIEMENS E-CAR OPERATION CENTER

Starting from the definition set out by the joint ISO/IEC work group to define a technical and functional standard for electric mobility, this system is defined as: "*a repository structure, physical or virtual, that collects, stores, and disseminates information, metadata and data. It shares information between charge spots, energy providers and grid providers. Exchanged data are contract information for authentication, actual grid usage, and charge detail record for billing*".

The Operation Center developed by Siemens has the objective of managing charge infrastructure and providing semi-processed data to external systems for use in further processes (billing, telematics, etc.) or which manage the grid to which the charge points are connected.
The system manages the charge infrastructure, the end users and the companies involved in electric mobility processes (charge contract providers, charge spot providers, operators in the free energy market, distributors of electricity).
Furthermore, a single system can manage multiple companies and a variety of charge infrastructures, which means that the system is multi-DSO, multi-service provider and multi-energy vendor.
In practice, a single system can offer operation center services to multiple clients entering the electric mobility market, thus reducing running and delivery costs.
The Siemens Operation Center is also known as the

Clearing House, due to its ability to send data on charging and charge-connected services (authorizations, V2G activation, consumption, etc.) to client systems involved in accounting and invoicing the end user.
This clearing process, familiar form the banking industry, has the aim of enabling the interoperability of the charge infrastructure.

The Operation Center, with its intuitive web-based graphic interface for both operators and end users, is divided into three conceptual units as shown in Figure 1.

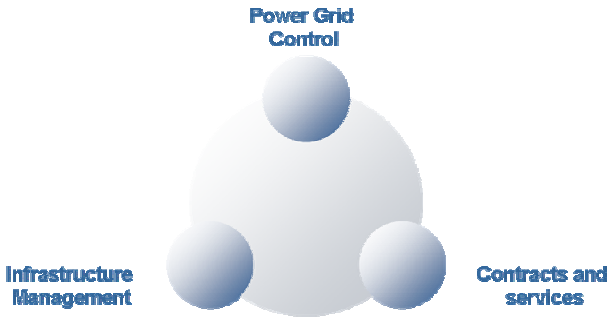

Figure 1: The three modules of the Operation Center

Power Grid Control

The Power Grid Control module dialogues with the grid control system. This means that the control system or SCADA receives notifications from the OC regarding new charge column installations, current charge events and the consumption for each column.
The SCADA uses this information to optimize its grid calculations and generates a return output for the OC. In this way the OC receives information regarding overloads, alarm signals which require action to be taken on current charge events to modulate the load (by interrupting charges or diminishing the energy delivery) or even to invert the flow of energy by switching from charging the vehicle to drawing energy from it. This V2G (Vehicle to Grid) function thus solves the age-old problem of renewable energy by storing electricity in the vehicle batteries and retrieving it when required, for example if the grid is experiencing heavy demand.

Infrastructure Management Module

The infrastructure management module controls the charge infrastructure and ensures constant connection with the columns.
As well as configuring new columns, this system makes them completely available on the web-browser maps (geo-localization). These includes all the information required by the user to locate the columns, check their technical characteristics and availability of charge, as well as offering the option of reserving a column for a given day/time so that the user is certain that it will be available when he needs it.
There are also advanced functions including routing to the nearest free column via an iPhone or any smartphone equipped with internet navigation functions.
Persons using the system on a daily basis to monitor charge service delivery will be able to administer their infrastructure over a purely web-based interface. This means that they will receive - automatically or on request - diagnostics for individual columns, which they will be able to analyse with the aid of integrated alarm systems, as well as being able to analyse current and completed charge events.
Furthermore, operators will be able to act directly on the columns to lock/release the connections, decommission/commission them, stop/start charge events and update the columns' software.
As for managing the charge process, a protocol governing communications between the columns and OC has been set out which enables real-time response to requests from the column, such as authorizations to charge, requests for available services and energy delivery, and column counter readings at configurable intervals (e.g., every fifteen minutes). This channel is encrypted with the most modern public and private key systems with certificate issue/revocation for each column.

Contract Management Module

The contract management module stores and uses the charge contract information.
This means that it enables new contract setups by creating RFID cards for use by end users when they connect to the columns. The system configures the cards in its database and launches the physical card production process, after which the cards are automatically sent to the end user's residence within a few days.
The system also enables the end user to request additional cards, renew cards when they expire (also automatically) and block cards he no longer wishes to use (in case of theft or loss, etc.). When the end user requests a new card he is automatically sent to an e-commerce site to make the payment and activate the new card.
This module also serves as a support to infrastructure management when a charge authorisation is requested. When an end user wants to charge his vehicle, he must swipe his card across the column's sensor, which send its data (encrypted) in real-time to the OC. The OC then uses the contract management module to verify the validity of the RFID and whether it is authorised for charging, and returns the positive or negative response to the column which acts accordingly.
Moreover, once the vehicle is connected to the column, if the RFID has been authorised, the vehicle can be identified a second time, if equipped with the ability to communicate with the column.
This enables the end user to configure his own V2G

(Vehicle to Grid) settings, if activated. He can thus decide when and how the OC can draw energy from his vehicle (e.g. minimum battery charge, times at which the vehicle must be fully charged, etc.), for which he will of course be reimbursed.

Operation center architecture

Figure 2 shows the functional architecture of the Siemens E-car Operation Center and how it interfaces with the world:

- charging infrastructure,
- Power grid SCADA
- Other Operation center
- Clearing house for Operation Centers roaming
- external systems: billing, ERP, AMM, etc.

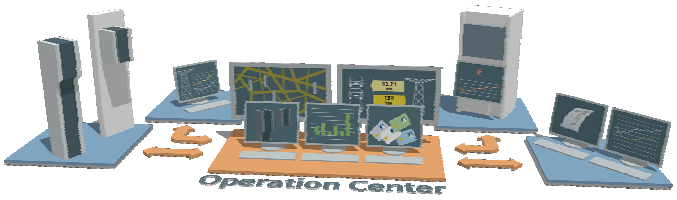

Figure 2 – Operation center architecture

SERVICES PROVIDED BY THE E-CAR OPERATION CENTER

The increase in electric vehicles will lead the market to demand the development of innovative services to meet the needs of the various stakeholders.
Siemens is also considering new types of business which will have to be created to meet such stakeholder requirements (see Fig. 3).

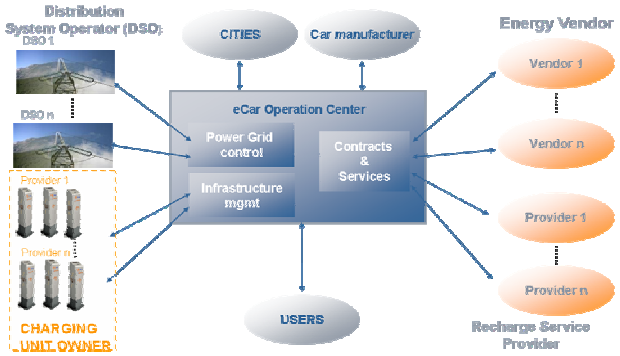

Figure 3 – E-Car business model

AN INNOVATIVE, TECHNOLOGICALLY ADVANCED, RELIABLE, SCALABLE AND SECURE SYSTEM

Siemens offers a communications system that is reliable (for a multitude of servers) and secure. When a vehicle connects to a charge column, it is first identified; then contract information and data regarding the possible duration of the charge are verified, before the charge itself is authorised.
Only after authorisation does the charge itself (which is monitored constantly) initiate.
The Siemens solution is not only easily scalable by adding new, more powerful machines, thanks to the option for clustering e-car servers, but is also portable since it is developed entirely in java and equipped with a multichannel user interface, so that it can be accessed by either normal browsers or via a smartphone.
Siemens also offers automatic monitoring of Operation Center service delivery.

SYSTEM EVOLUTION: TOWARDS ROAMING BETWEEN OPERATORS

Electricity has an enormous advantage: it is available practically everywhere, and this will enable development of large scale charge infrastructure in the near future.
Charge points will soon be an everyday sight in our cities and will allow users to charge their cars in their garages, while visiting shopping centers, while at work or eating out.
One can imagine that there will be columns with different owners operating over the territory, managed by various Operation Centers integrated with each other.
In this case an end user who has a contract with Operation Center A will be able to charge his car from a column managed by Operation Center B.
The two operators will be able to:
- request charge authorisations from each other
- communicate details of charge events

This will open up a competitive market scenario with the service fully available to all users, who will be free to choose charge columns, contracts and services.

Future developments will also include:
o Complete, automatic management of V2G (energy draw from vehicles) combined with grid calculations run by the grid tele-control system
o Standardised digital interfacing of the vehicle with the column to enable complete management of the charge process, using the vehicle itself as part of the interaction
o Real-time pricing of charges based on the updated price (to fifteen minutes) of the energy supply

As an integrated technology company with more than 160 years of experience, Siemens invests billions of euros every year in R&D (3.9 billion in 2009). Thanks to its wide portfolio, its experience and its constant technological innovation, it has an unrivalled capacity to set the foundations for future mobility solutions by managing and coordinating e-car functions and energy flows to and from the grid, thus enabling users to charge the millions of

electric vehicles which will make our road transport quieter and more ecological in the future.