Integration of Electric Vehicles in Smart Homes - An ICT-based Solution for V2G Scenarios

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Abstract—**In this paper, we present how electric vehicles (EV) can be flexibly integrated into the energy management of a smart home both in forms of consumer loads and electrical storage systems. Based on a draft for ISO 15118, we implemented an advanced version of a smart charge communication protocol which enables to flexibly control the charging and discharging processes of an EV in a sophisticated way, allowing to match the domestic load demand and the fluctuating energy supply of decentralized energy sources such as photovoltaic panels or a combined heat and power plant with the energy stored in the battery while at the same time guaranteeing a preset driving range adjusted by the user and thus limiting range anxiety.**

I. INTRODUCTION

A worldwide increasing interest in technologies can be observed which help to transform the classical power grid - basically consisting of several big centralized power plants which just react to the power demand - into an intelligent, ICT-based system, which is able to integrate many decentralized power plants and shiftable loads, including e.g. photo-voltaic (PV) and combined heat and power plants (CHP). In a so called smart grid, these components are designed to be able to communicate with a higher authority like the balancing group responsible or the grid operator on the one hand and its load-producing consumers on the other hand. This communication is essential in order to cope with the increasingly difficult task of balancing the load and the fluctuating power supply provided by a progressively growing number of wind and solar based power plants.

A frequently discussed option to facilitate this balancing process is the use of distributed battery storage systems, for example those which can be found in battery electric vehicles (BEV). The National Electromobility Development Plan, proposed by the German Federal Government in August 2009 [1], predicts one million electric vehicles on Germany's roads by 2020. BEVs could provide a great potential to serve as highly flexible demands and to compensate the fluctuating supply, as long as they are not "fuelled up" at charging spots located at points of interest where the only desire is to charge-and-go as fast as possible, thus leaving no space for an optimization of load shifting. We assume that the real potential can be tapped if the charging process takes place when the car is e.g. parked at the office or at home and plugged in for a longer period of time, thus enabling a real grid integration process. Within the context of the research project *MeRegioMobil* [2], a prototype of a smart home focusing on a sophisticated energy management, which is described in detail in Sect. II, has been put in place on the grounds of the Karlsruhe Institute of Technology.

A vehicle-to-grid enabled charging point has also been integrated into this laboratory, so that BEVs can be incorporated into the smart home both in forms of consumer loads and electrical storage systems according to the energy management's instructions. The vehicles used in our scenario as well as the charging point are described in Sect. III, followed by Sect. IV which elaborates on the reasonable ways of integrating a BEV into the described smart home.

An overview of related work is given in Sect. V.

Recent efforts to develop a communication protocol between EVs and charging stations are grouped together in the ISO 15118 standardisation initiative, which is currently in the stage of the first committee draft (CD) [3]. Based on an earlier specification[1] for ISO 15118 [4] developed by Daimler and RWE (German utility), we implemented a communication protocol which fits the basic needs of flexibly integrating a BEV for charging and discharging purposes, as described in Sect. VI.

The paper concludes with a summary and a discussion of future work in Sect. VII.

II. THE KIT SMART HOME

KIT's prototype of a smart home encompasses electric appliances which represent both conventional commercially available devices as well as intelligent and therefore controllable ones including a washing machine, a dryer, and a dish washer. In addition to those consumer loads, decentralized power plants such as PV panels and a CHP have been put in place [5]. With a ground floor area of about 60 m^2, the smart home contains a living area consisting of a combination of living room and kitchen as well as two bedrooms, a supplementary technical room stores e.g. the metering equipment, the CHP, the PV inverter and a smart home management device (SHMD), as can be seen in Fig. 1. The SHMD is the central

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[1] The actual draft used in our implementation and provided by Daimler and EnBW (German utility) in the course of the research project is a more advanced one but may, due to project regulations, not be referenced.

978-1-4577-2159-5/12/$31.00

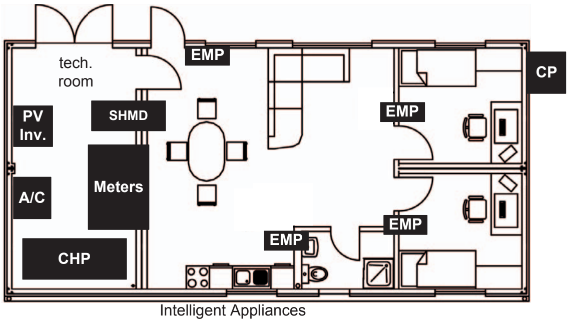

Fig. 1. The KIT smart home layout

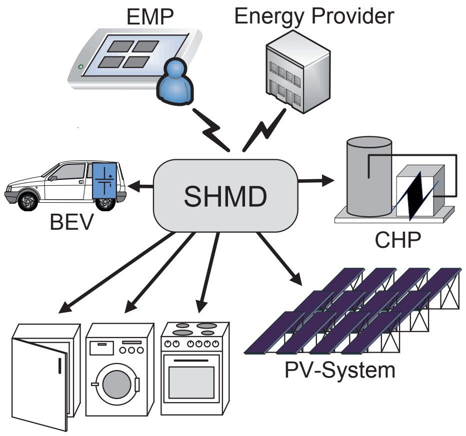

Fig. 2. The smart home energy management setup

component, as shown in Fig. 2, enabling scenarios in which appliances can be observed and controlled according to their current state, which is described in more detail in [6]. External signals, such as variable energy tariffs, are sent from the energy provider to the SHMD, and the residents can configure their preferences using an Energy Management Panel (EMP)[2] on touch screen displays. Based on these signals and the user preferences, an autonomous optimization takes place in the SHMD. The EMP allows the user to observe and manipulate various parameters of the BEV. The resident can for example

- monitor the current state of charge (SoC) given as the approximated range,
- monitor the current charging or discharging power,
- check the time when the EV will be fully charged, and
- check and change the configured departure time (here the same as "end of charge").

A change of the configured departure time via the EMP will trigger a re-evaluation of the scheduled charging time slots and may cause an instant charging process if needed (earlier departure) or result in a higher degree of freedom (later departure) for the scheduling process.

As is obvious from this description, the KIT smart home is focusing on energy aspects only, in particular on demand side management and integration of EVs into the smart grid. Its design did not consider typical home automation scenarios (see e.g. [8]), although these could easily be integrated.

III. ELECTRIC VEHICLE AND CHARGING STATION

Two of the industrial partners cooperating in the project *MeRegioMobil* are the OEMs Opel (German subsidiary of General Motors) and Daimler, each of them providing a BEV (Opel Meriva and A-Class E-CELL) capable of bi-directional charging. In this paper, we focus on the integration tests which have been conducted with an Opel Meriva whose internal combustion engine has been replaced with an electric engine. The electric motor provides 60 kW (82 hp) in eco-mode and 80 kW in sports-mode with 215 Nm of torque. The Lithium-Ion battery pack has a capacity of 16 kWh and allows for a driving range of 64 km, reaching a top speed limited to 130 km/h. The car can be plugged into an outlet of 230 volts and 400 volts, allowing three-phase charging with a maximum power of 11 kVA. The added power inverter enables vehicle-to-grid (V2G) scenarios.

With the charging station, labeled as "CP" (for charging point) in Fig. 1, we focus on conductive AC charging using a *Type 2* charging plug whose interface and technical specification has been standardized in Germany and is currently proposed for the IEC 62196-2 standard [9]. The communication between the BEV and the charging point is realized via a homeplug 1.0 powerline network. The charging point is connected via a local area network to the SHMD, therefore the BEV's charging and feedback process can be observed and controlled by the SHMD.

IV. INTEGRATION SCENARIOS

The integration of a BEV which allows for bi-directional charging within a real smart home such as described in Sect. II is a completely new approach. Early concepts have been defined and tested in [10]. Based on these results and an advanced higher level protocol (see section VI) we are able to flexibly use the BEV either as an additional load or as an energy storage system able to feed back energy when needed. This section now shortly describes the charging and discharging scenarios.

A. Charging the Electric Vehicle

The ever growing interest of German households to install PV panels is a result of Germany's Renewable Energy Sources Act [11], proposed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in 2000, which guarantees a certain payment per supplied kWh to the grid. An amendment to this act from 2010 goes even a step further and creates incentives to not only supply the installed energy to the grid, but use it by oneself. Depending on certain criteria, such as the tariff of the energy provider, and - most importantly - the ratio of the overall electricity production and the amount of own consumption, it can be even more profitable to gain a high rate of own consumption. The legislator grants a profitable tariff as soon as the own consumption exceeds a rate of 30%.

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[2] A practical evaluation of the EMP has been done in [7].

A normal household will have difficulties to reach such a rate of own consumption, unless some additional components are installed which can store the PV energy produced during the day and deliver it when needed in peak load times.

Thus, the BEV may serve as a flexible storage device when connected to the charging station. As soon as the PV panels produce more energy than needed by the household, an automatic mechanism will trigger the charging process of the vehicle, enabling an increase of own consumption on the one hand and supplying the household with "green" energy e.g. in the late evening hours on the other hand - without having to pay a high tariff due to peak load times.

A similar scenario deals with the CHP plant installed in the smart home which can be operated in two ways: a power-controlled or heat-controlled mode. Within the smart home scenario, the combination of both modes can be examined. Primarily, the heating supply of the household has to be satisfied. However, due to the availability of heat storages, a scheduling of the CHP depending on the household energy consumption or the charging process of the BEV is possible. As soon as the CHP is running to produce the needed thermal energy, the surplus electrical energy can be used to charge the vehicle and thus gain an overall high energy yield.

Currently, energy providers are offering mostly fixed tariffs during the day, not adapting the prices to the current or predicted load in the energy system. In this research project, a variety of dynamic day-ahead price signals is evaluated which reflect the energy system load, giving incentives for the residents of the smart home to schedule certain appliances which are not time-critical (e.g. the washing machine, the dryer, or the dish washer) such that loads can be shifted from peak into off-peak times. This can also be done automatically by the SHMD (see [6]) as soon as the resident sets a certain degree of freedom (e.g. the washing machine may run any time from 2pm till 6pm) for those kind of appliances.

Assuming those dynamic tariffs, the BEV can be charged primarily at those time slots where the price falls below a certain threshold, as long as the charging constraints, such as the "end of charge" (see Sect. VI-A), permit a scheduling by the SHMD as introduced in Sect. II. For example, low tariffs may be due to either a low demand in the grid and/or a very high supply of wind energy which needs to be primarily consumed according to the Renewable Sources Energy Act.

B. The EV as a Bi-directional Energy Storage System

The driver of the BEV can configure a minimum SoC via the panel in the BEV. This value will indirectly be communicated via the charging protocol to the charging point (to be precise: to the SHMD controlling the charging point) using the value which represents the amount of energy that can be fed back to the grid (let it be "v2gEAmount", see section VI-A). The intention of this value is to give the driver the assurance that the BEV will be charged as quickly as possible to an adjusted SoC which is high enough for unpredicted emergency drives. As long as the next departure time is providing a time frame big enough for flexibly scheduling the charging process and the v2gEAmount is high enough, we can allow the BEV to act as an additional decentralized energy storage system and supply energy when needed and purchasing energy from one's provider would be more expensive. Depending on how finely the power inverter of the BEV can be adjusted (the Opel differs here from the Daimler BEV), we can quite precisely provide the power needed for the washing machine, the cooking stove or other high power loads.

Another scenario would be to use the BEV as an island system, supplying the household with energy until a power failure has been resolved.

V. RELATED WORK

There are numerous approaches and studies on how EVs, be it battery electric vehicles (BEV) or plugin hybrid electric vehicles (PHEV), can be integrated into the grid and participate in ancillary service markets like frequency regulation or spinning reserves. Kempton et al. showed in [12] how a fully functional, freeway-capable electric vehicle, which was modified by adding controls and logic to make it respond to the real-time signal for frequency regulation by a local independent system operator, can be used both as a load and an energy storage system to balance the system frequency by charging the battery when there is too much generation in the grid and feeding energy back in the inverse case. They claim that the primary revenue in both markets (frequency regulation and spinning reserves) is for capacity rather than energy, meaning that especially the need for quick response times can be satisfied by batteries as storage devices. To control the charging and discharging, an industrial communications gateway also used by convenctional generators providing ancillary services was installed, and software has been designed for device communication by the University of Delaware.

Cvetkovic et al. [13] go a step further and introduce a setup including a bi-directional power converter (BPC) which can perform a full, four-quadrant demand-response service according to the commands received from a power system operator, and a NiMH battery pack which were both mounted on a bench and connected to other system components. The BPC is able to detect a grid outage and generate an stand-alone grid for a ficticial house. The house loads were implemented using resistor banks, switchable load relays emulate the stochastic behaviour of the load in a real house. An additional so-called Power Hub Converter, a supervisory control and data acquisition unit, monitors the system components' voltage, current and other significant data. This system of a future home uninterruptible energy system - including PV elements - is thus able to act as an uninterruptible power supply for the house, work in a stand-alone mode, and resynchronize to the utility grid.

Those approaches are a proof of concept that valuable grid-to-vehicle and vehicle-to-grid scenarios can be realized. However, they have in common that the communication implementations and EVs (or EV-like representations) are proprietary solutions, a standard communication protocol between EVs and charging units could not be used since it has not yet been in place.

Agsten et al. [14] refer to the aforementioned smart charge protocol [4] and present a theoretical system design for load management based on a field test in which 50 BEVs (Mini-E) have been assigned to private users from June 2009 till September 2010. With each BEV, a stationary, remotely observable and controllable charging station has been installed at the respective homes. Using this empirical data as input, they show how a controlled charging could be realized with the goal to reach a high correlation between wind supply and charging demand and to reduce or even avoid additional peak loads.

All presented papers have in common that they do not focus on an in-house scenario where an EV is flexibly integrated into a smart home's energy management as pointed out in section IV. So far, a sophisticated implementation of a communication protocol between an EV and a charging unit as envisioned by the ISO 15118 standard has not yet been realized and will therefore be elaborated on in the following sections.

VI. COMMUNICATION PROTOCOL

A globally standardized communication procotol is, next to a standardized charging plug system, a vital prerequisite to assure that one can have a convenient and easy to use access to the grid, independently of the selected brand of the car and energy provider. These standards are crucial for the successful product placement and market penetration of electric mobility, which represents an enormous market potential. One of the goals of the German Federal Government's National Electromobility Development Plan is to "become a lead market for electric mobility and maintain its cutting edge in science and in the automotive sector and related supplier industries" [1]. A determining factor to establish the conditions for necessary investments is the German Standardisation Roadmap for Electric Mobility [15].

Communication between a BEV and a charging station is needed for several use cases, such as authorisation for and negotiation of grid usage, detection of communication or hardware errors or controlling a battery charging session. We want to focus on the latter and will demonstrate how an advanced integration of BEVs for grid-to-vehicle (G2V) and vehicle-to-grid (V2G) scenarios can be realized based on the aforementioned extension of the draft for the ISO 15118 standard.

A. Charging Constraints

Among all messages exchanged between the client (BEV) and the server (CP) according to [4], only a few contain the relevant parameters which are needed. That is to say, our approach takes into consideration the current and predicted load as well as PV and CHP power of the smart home on the one hand and the bounding parameters of the BEV noted here on the other hand in order to plan the charging and discharging time slots in a sophisticated way. The basic parameters needed and offered by the BEV are:

1) *End of charge (eoc)*
   The point of time until the vehicle should be charged, given as an offset in seconds from the time of sending the corresponding message.
2) *Needed energy amount (eAmount)*
   The amount of energy required by the vehicle, given in Wh. Values for the efficiency and therefore energy loss during the charging process are taken care of in this parameter.
3) *V2G energy amount (v2gEAmount)*
   Energy amount which may be fed back to the grid, given in Wh.
4) *Maximum charging power (pMax)*
   Maximum power requested by the vehicle, given in W.
5) *Maximum discharging power (pMaxDisc)*
   Maximum discharge power the vehicle can support, given in W.
6) *Minimum charging power (pMin)*
   Minimum reasonable power (not zero) which can be requested by the vehicle due to auxiliary electric loads, given in W.

The charging station on the other hand needs to provide the following information:

1) *Maximum voltage (voltage)*
   Line voltage delivered by the charging point.
2) *Maximum current (iMax)*
   Maximum line current the charging point can deliver.
3) *Tariff table*
   A list of tariffs containing entries which communicate the following:
   a) *Tariff start (tariffStart)*
      Time when tariff starts to be valid, given as an offset in seconds from the time of sending this message. Valid until *tariffStart* of the next entry. The last tariff entry has *pMax* set to 0.
   b) *Maximum power (pMax)*
      Maximum power deliverable by the charging point within the current tariff, given in W. Negative values indicate that the vehicle shall feed back energy to the grid.
   c) *Price (ePrice)*
      Price for energy consumed within this tariff, given in a chosen currency.

The tariff table is an essential part of the protocol which has been widely discussed and therefore needs to be addressed more closely.

B. Charging Tariffs - Price Signals vs. Control Signals

The integration of BEVs into the smart grid brings together two industrial sectors which might have conflicting interests in this matter. The energy sector on the one hand, taking the distribution system operator (DSO) for an example, is interested in spinning reserves and frequency regulation on the distribution network level in order to adequately respond to an energy supply shortage or oversupply. Those needs can be satisfied by *controllable*, decentralized loads and intelligent devices. Especially EVs represent such intelligent devices and have an enourmous load-shifting potential. Another important application of EVs is their usage for power factor correction in order to compensate for phase shifts. Going down a level to the domestic energy supply, controlling the charging and discharging processes at a smart home may help to avoid peaks and maximize the yield of energy supplied by renewables such as PV panels.

The automobile industry on the other hand is making great efforts to develop charging electronics which safeguard the sound condition and long-life cycle of the battery - currently the most expensive part of the BEV - by implementing appropriate charging strategies. Those charging strategies take care of an adequate thermal battery management and that the battery will not undergo a deep discharge, for instance.

One approach to resolve these partially conflicting goals is to introduce dynamic tariffs. The basic idea is that the BEV dynamically shifts its energy demand into lower priced time slots, which in turn saves money for the driver and cushions a potentially faster battery ageing. This argument is easier to sell to the customer than controlling the battery charging and discharging processes in order to satisfy the needs of a demand side manager (DSM) such as an DSO.

As Gitte et al. [16] point out in their work, those dynamic prices have a significant problem: The behaviour of an EVs battery management system (BMS) with respect to dynamic prices is unknown, a complex price negotiation between the BMS and the DSM may result in an unsuccessful outcome and thus impede any *reliable* short-term interventions in order to stabilize the grid.

We therefore use a control signal mechanism based on [16] which takes into account the respective battery restrictions while at the same time allowing a DSM (such as the SHMD in the presented smart home) to realiably control the charging and discharging processes. Such an approach is essential for preventing overload situations in segments of the lower voltage grid having several EVs that might be plugged in simultaneously.

C. Communication Scheme

As soon as the BEV is connected to the charging point via the Type 2 charging plug and powerline communication has been established, the communication via the higher level smart charge protocol can commence. The protocol strictly follows a client/server scheme, thus the vehicle may send requests whereas the charging unit may send responses only. However, the charging point is able to trigger a certain request by setting specified flags. An overview of the principal communication scheme is shown in Fig. 3.

The protocol flow can be divided into five composite states:

1) *Initialize Communication Session*
   Initializes the communication on the application layer, exchanges data such as a session ID, the vehicle ID, etc. (Identification Request, depicted as "ID Request").
2) *Discover Services*
   The vehicle triggers the charging point to send information about all offered services, such as ways of payment, which will trigger an exchange of certificates if charging by contract is selected (Service Discovery Request, depicted as "SD Request").
3) *Setup Charging Process*
   This composite state encompasses amongst others the exchange of the vehicle's charging parameters as mentioned in Sect. VI-A. Based on these parameters, the charging point can check its compatibility with the connected vehicle and calculate a tariff table for the requested amount of energy. The vehicle's BMS will take the provided tariff table as input for an internal calculation and then either confirms the suggested combination of timeslots and power values or proposes an alternative which will guarantee the proper use of the battery.
   Before the charging process can begin, the vehicle will request the charging point to lock the connector on the charging point side and to switch the power on.
   Several messages are exchanged in this composite state which have been subsumed in the "SCP Request/Response" messages to give a more clearly presented overview.
4) *Charging Process*
   During the charging process, the vehicle triggers the charging point every 10 seconds to send its current metering status (depicted as "MD Request/Response"). In addition to this data, the charging point sends information encoded in status bits (using the field "cpStatus" which stands for charging point status). By setting a certain status bit to "true" (in this draft it is called "newPowDiscGrid"), the charging point triggers the vehicle to send the message containing the charging parameters again, thus enabling the charging point to send an updated tariff table. This flag is important in order to react on an urgent grid situation - or in our case to match a changed demand which has been detected by the SHMD in the smart home. It can also be used in the setup charging phase, a detailed example for this procedure is described on the next page.
5) *Finalize Charging Process*
   As soon as the vehicle is fully charged, it will initiate the finalizing sequence, requesting the charging point to switch the power off and unlock the charging plug on the charging point side (subsumed in the "FCP Request/Response" messages).

In order to send a tariff table which will be accepted by the BEV, the SHMD needs to gather all relevant information on the BMS' constraints. In addition to the constraints mentioned in Sect. VI-A, there is still one characteristic of the battery which brings in an element of uncertainty with respect to reliable power values available on call: the begin and duration of the constant voltage stage.

Fig. 4 depicts the charging profile of the Opel Meriva's battery, beginning at an SoC of 4%, and shows the two typical stages a Li-Ion battery runs through while charging.

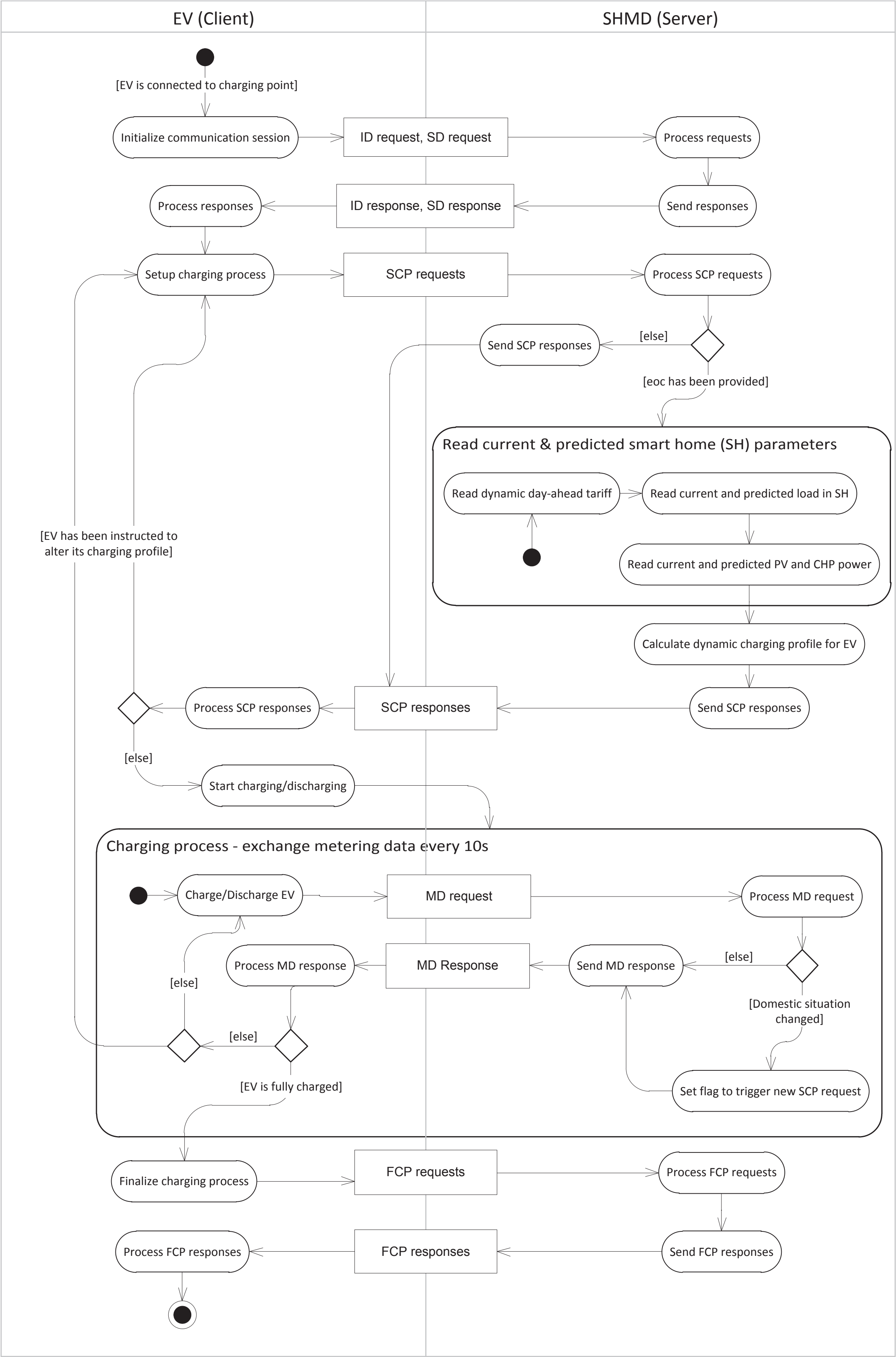

Fig. 3. Communication scheme between the BEV and the SHMD

During the constant current stage, the battery can be charged with the full power of 10 kW (3-phase charging with around 3.4 kW on each phase P_1, P_2, P_3) until a predefined threshold voltage has been reached. In the subsequent constant voltage stage, the voltage regulator takes care of a constant terminal voltage, resulting in an ever decreasing charging current until the battery is fully charged.

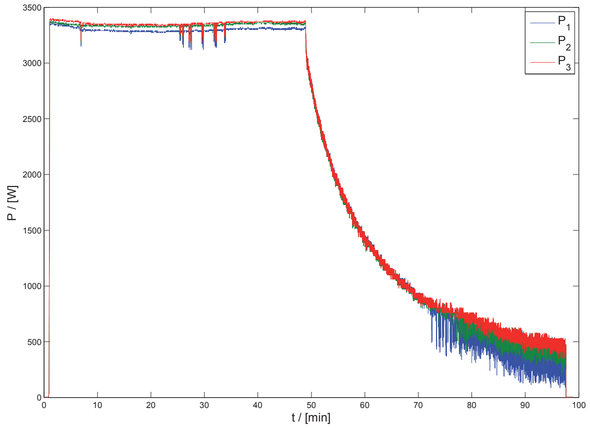

Fig. 4. Charging process at an SoC of 4%: active power

The challenge is now to dynamically determine via the smart charge protocol the point of time when the switch between the constant current and constant voltage stage occurs since a reliable predefined power output can only be expected during the constant current stage.

The solution we implemented in cooperation with Opel and Daimler works as follows: As soon as the BEV has sent its charging parameters, the SHMD will respond with a tariff table containing one tariff entry with a constant power value and costs set to zero (see step 1 in Fig. 5). The BMS will then calculate an optimized charging profile. Since it has the information from the SHMD that the battery may be charged at any time with full power, it will delay its charging process to the very end since from its perspective it is better to charge the vehicle as late as possible. As one can see in step 2, this optimized charging profile now reflects the amount of energy ("eAmount") which will be demanded by the BEV. The shaded area relating to the constant current stage can now be fragmented by the SHMD into several pieces (step 3), having the certainty that the combination of power values and time slots in the updated tariff table - which sum up to an energy value equivalent to this area - will be accepted. That is to say, the BMS will try to satisfy its energy demand going from the adjusted "end of charge" point of time backwards and "fill" the wholes. The residual amount of needed energy (which relates to the constant voltage stage) will be demanded at the very end. Since the current will decrease more and more until and SoC of 100% has been reached, the SHMD can not reliably control the charging process in this time span.

This loop is done in the setup charging process phase and realized by triggering the BEV via the above mentioned "newPowDiscGrid" flag.

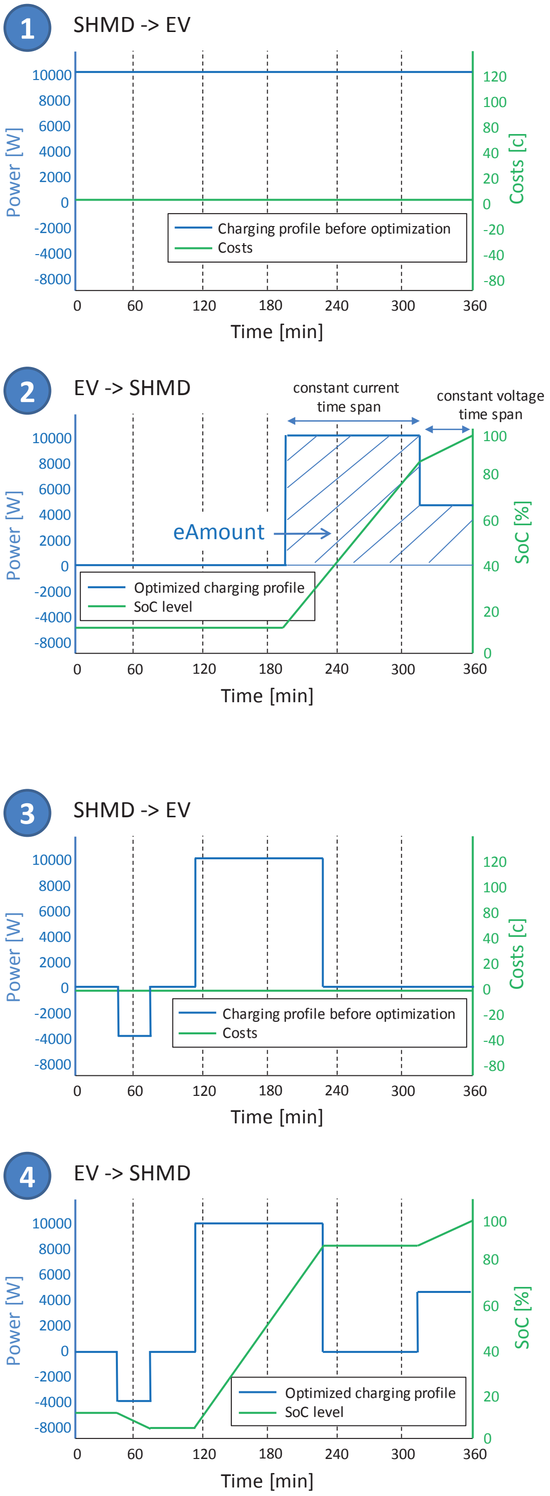

Fig. 5. Handshake for an optimized charging profile

Now let's go back a step. As soon as the SHMD knows about the charging constraints, especially the planned time of departure and thus the period of time available for scheduling the battery, it checks the dynamic tariff which is defined for the next 24 hours and determines the current as well as the predicted load in the smart home and the current energy provided by the PV panels and the CHP. The involvement of a forecast of the available renewable power is a very helpful information as well, but has not yet been realized. This data forms the basis for a sophisticated scheduling algorithm whose output is the aforementioned tariff table. Having regarded the technical parameters of the battery, we don't need to give the BMS a price incentive for certain time slots but can set the field "ePrice" of the tariff table to any given value such as 0 and be sure that the BMS will follow this input. If no desired end of charge has been provided, the SHMD assumes that there is no sliding optimization horizon available and instructs the vehicle to charge instantly.

One additional parameter which needs to be regarded as well is the minimum time period the vehicle will charge or discharge with a certain power value provided. This is a parameter which might be set differently by various BMS but can not be parameterized in the smart charge protocol and must therefore be hard-coded.

During the charging process, the BEV and the SHMD exchange metering data in an interval of 10s. If an unpredicted load situation occurs, the SHMD is able to trigger the vehicle to re-negotiate the charging profile as mentioned above. The situation which may lead to a re-negotiation can be manifolded. It can be induced by a change of the configured departure time via the EMP (reflected by the field "eoc" for end of charge), a high power consumer load like the washing machine which has been turned on unexpectedly and whose energy demand should rather be satisfied by the energy stored in the battery due to a currently high energy price, or the cooking stove to give just a few examples.

VII. CONCLUSION AND OUTLOOK

This paper presents an innovative ICT-based approach to flexibly integrate electric vehicles into the energy management of a future smart home - such as the one which has been built up on the premises of the Karlsruhe Institute of Technology - both in forms of consumer loads and electrical storage systems. The integration has been realized via the implementation of an advanced draft for the ISO 15118 standard, the communication scheme behind this has been clearly presented. This work sets itself apart from similar studies in this matter by having a real world scenario and setup (integration of bidirectional charging electric vehicles in a sophisticated energy management of a smart home) and gathering early experiences with (a draft of) the smart charge communication protocol which is expected to be standardized by 2012.

First tests have shown that we were able to realize a communication between the BEV (Opel Meriva) and the SHMD and thus instruct the vehicle to charge and feed energy back according to the commands sent by the SHMD.

The current draft of the smart charge communication protocol allows for instructions for reactive power in order to facilitate the stabilization of the grid. This ability will be tested in a second stage as soon as exhaustive tests have been conducted and data collected.

A subsequent research project starting in 2012 will give the possibility to test our load management on a larger scale, using a smart car park and fast charging stations.

ACKNOWLEDGEMENT

We gratefully acknowledge the financial support from the Federal Ministry of Economics and Technology for the project *MeRegioMobil* which provided the environment for this paper.

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