

ICT based Performance Evaluation of Control Reserve Provision Using Electric Vehicles

S. Böcker, C. Lewandowski, C. Wietfeld
Communication Networks

Institute

TU Dortmund University, Germany

Email: {stefan.boecker, christian.lewandowski, christian.wietfeld}
@tu-dortmund.de

T. Schlüter, C. Rehtanz

Institute of Energy Systems, Energy

Efficiency and Energy Economics

TU Dortmund University, Germany

Email: {thorsten.schluefer, christian.rehtanz}
@tu-dortmund.de

Abstract—Traditional energy networks with centralized supply are moving towards smart grids with distributed generation. The conventional form of large power plants will be replaced by the nationwide expansion of volatile renewable energies, but is intended to provide comparable or similar monitoring and control options. Concepts of virtual power plants provide an information and communication technology (ICT) linking of distributed systems and thus enable a centralized energy management. In this context electric mobility provides great opportunities to increase the grid stability, by making batteries of electric vehicles (EVs), which are connected to charging infrastructure, available as buffer in the low voltage grid. This paper presents a performance evaluation of an ICT solution for integration of EVs in grid balancing services in the example of Minute Reserve (MR) provision. Therefore, the communication effort is determined using an implemented evaluation tool and simulation environment for analyzing different scenarios. Results show that the evaluated communication effort enables MR provision using EVs in each implemented configuration. Beyond, we illustrate that the implementation of a Local Controller within parking area scenarios reduces the communication effort by 93 %.

Keywords—Smart Grid Automation, Electric Mobility, Powerline Communications

I. INTRODUCTION

As Europe is striving to increase the electricity generation by renewable energy sources (RES) various challenges in electricity system stability arise. The further growth of intermittent generation from wind turbines and solar systems leads to a more volatile residual load structure. To keep the electricity system in balance the transmission system operator (TSO) uses three different kinds of control reserves that are specified in the ENTSO-E operation handbook [1]: primary control reserve (PCR), secondary control reserve (SCR) and Tertiary Control Reserve which is the equivalent of Minute Reserve (MR). For a future German energy scenario, a higher demand for SCR and MR is expected [2]. In particular, this is due to the higher forecast error caused by the increasing amount of installed capacity of RES. A change in the demand for PCR is not expected since the maximum instantaneous power deviation and the total energy production of the German control area remain unchanged. However, a future need for new providers of all kinds of control reserve (CR) can be observed when conventional providers are not able to supply the required amount of CR. In this context conventional providers are technical units that provide a major share of today's demand for the respective kind of CR. New providers denote technical

units that are either not able to offer competitive prices, lack the necessary quantity to provide significant amounts of CR or do not meet today's requirements for the provision of CR. EVs, that are connected to the electric grid form a technical unit that may be used by a prospective provider of CR, hereinafter referred to as Pool Operator (PO). Previous studies show that PCR can be provided by a scale of 10,000 ON/OFF devices, e.g. water heaters with a nominal power consumption of 2 kW to 5 kW each [3]. The delivery of PCR depends on local system frequency measurements, so no near real-time communication from the PO to each device is necessary [1]. Also SCR can be provided theoretically by a large number of decentralized devices like a study with plug-in hybrid electric vehicles (PHEV), controllable thermal household appliance and a combined-heat-and-power generation unit illustrates [4]. This study shows that the typical prequalification tests of the Swiss TSO can be passed and 40 MW of SCR can be offered for a full day with a population of 160,000 individuals and 40,000 PHEV. However, the presence of a pervasive fast communication system is preconditioned in that paper. The German TSOs defined the basic requirements on the information technology of an SCR provider in special guidelines [5]. Thus the delay on the complete transmission path shall be maximum 5 s, starting by the measurement value acquisition of the technical unit to providers control system to TSO. Moreover, the connection of each technical unit as part of a SCR-pool and the connection of the provider control system to the TSO has to be carried out by a separate network. When using public ICT networks (e.g., DSL, GSM, UMTS, LTE) it must be ensured that this is only used by a closed user group. Depending on the TSO, the provider obtains a new set-point every 1-4 s. This signal has to be passed on to every single technical unit in the pool by the provider on his own authority, considering the amount of EVs needed to reach the required minimum of 5 MW SCR [6].

The provision of MR by a pool of technical units is already common practice as the list of providers shows [6]. The requirements on the ICT connection are lower compared to the provision of SCR. The activation confirmation must be received within a period of three minutes after the provider has been contacted by the TSO [7]. The provision of MR by a certain number of EVs is subject of this work. The number of EVs forming the vehicle pool is varied from 500 to 2,000 EVs to reach the required amount of 5 MW in minimum [6]. It is assumed that this number of EVs is connected to the grid since this paper is focusing on the setup of an ICT infrastructure and

not on the stochastic variation of the individual driving pattern. Thus a larger pool compensates the stochastic variations and guarantees the power offered for a continuous bidding period with a higher certainty [8].

To ensure reliable and interoperable interaction between all entities needed to provide CR, the presented system based on standardized communication protocols. Since the interface for processing and activation of MR in Germany (see Section II-A) is open source, the following performance evaluation is executed for the provision of MR using EVs.

After an introduction into the implemented laboratory environment in Section II, the proposed scenarios are explained in Section III. After that the used standardized communication protocols and interfaces are evaluated with respect to the service of MR provision in Section II-B.

II. LAB OVERVIEW

In this paper, the system presented in [9] is taken up again and relevant technical entities, as well as related communication interfaces, are implemented in our electric mobility laboratory using the example for provision of MR. The current laboratory environment is presented in Figure 1. In place of the electric vehicle (EV), we have integrated a Smart Fortwo electric drive (Smart e.d.) in our running system, allowing the evaluation of the implemented service in a real-world scenario.

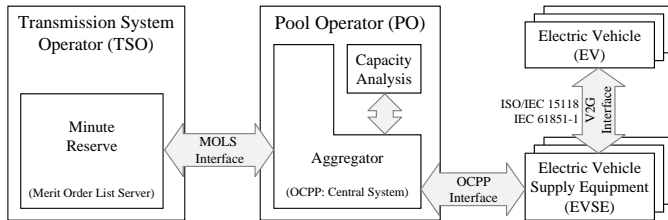


Fig. 1. System overview for realization of minute reserve with EVs.

In case the Smart e.d. is linked to a Electric Vehicle Supply Equipment (EVSE), the EVSE transmits relevant information of regular charging process to PO. PO uses this information for a capacity analysis of its entire pool of connected EVSEs. According to methods, already published in [9], the PO can thereby afford reliable predictions of charging processes. In addition, we have implemented a TSO as grid entity. Following the procedures explained in Section I, PO is linked to the TSO in order provide MR negotiation on behalf of the pool of connected EVSEs.

A. Description of implemented protocols and interfaces

For Vehicle to Grid (V2G) communication we focus on the IEC 61851-1 [10], as well as ISO/IEC 15118 [11]. In addition to the protection of personal safety, the implementation of the IEC 61851-1 low level signalization protocol allows a control of ongoing EV charging processes through the EVSE over PWM duty cycle modification (illustrated in Figure 2). For this purpose the PO forwards a predefined or adapted ongoing charge schedule to the EVSE, which reduces or increases the charging current according to the received input.

As an example of such a control of charging processes based on IEC 61851-1, Figure 3 presents a sample control process, realized in our laboratory environment using the Smart e.d.. In this context the EVSE received a predefined charge schedule

with five tuples of different maximum current values, each lasting 30 minutes.

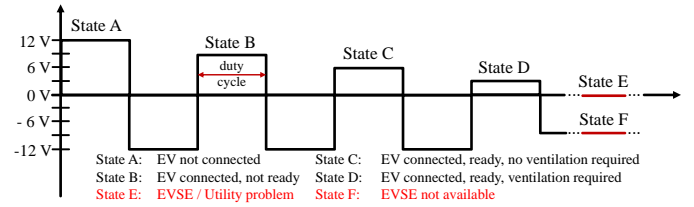


Fig. 2. IEC 61851-1 Pulse Width Modulation (PWM) signal.

The charging profile of the EV is detected by meter value measurement on the EVSEs smart meter and the SoC is read out via a proprietary vehicle interface. It can be shown, that the EV follows our predefined charge schedule up to a State-Of-Charge (SoC) of $\sim 90\%$. From this point, the charging current is reduced continuously by the EV until the battery is fully charged. Thus, we demonstrated that a charge control can be implemented for a present EV model using the IEC 61851-1. However, the IEC 61851-1 does not offer any authentication or accounting mechanisms, which are particularly necessary especially regarding public charging infrastructure, and there is no provision of a bidirectional communication link for the exchange of additional charging information, like departure time or desired energy capacity.

For this reason the ISO/IEC 15118 high-level communication, which is enabled by a mandatory PWM duty cycle of 5%, provides autonomously working charge control mechanisms and therefore enables customer-friendly energy balancing processes based on the plug-and-charge principle. Nevertheless, in this paper we focus on MR provision via IEC 61851-1, due to the reason that most of present EV models do not provide ISO/IEC 15118 integration. Hence, ISO/IEC 15118 integration is part of future work. A detailed description of IEC 61851-1, as well as a detailed message sequence description of ISO/IEC 15118, is given in [9].

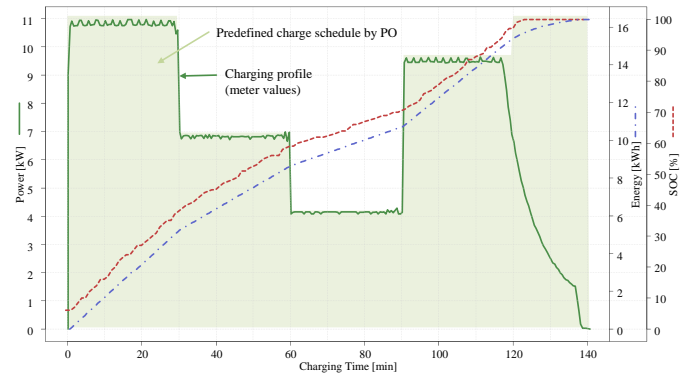


Fig. 3. Controlling a charging process of Smart e.d. using IEC 61851-1.

The communication link between PO and EVSEs is realized by an implementation of the Open Charge Point Protocol (OCPP) 2.0 [12]. In general OCPP is realized as a protocol for communication between a central system unit, located at the PO, and EVSEs. Version 1.5 of OCPP provides operations for basic charging process management, e.g. user authentication or start and stop of charging processes. Schmutzler et al. [13] present an introduction into technical principles and the scope of OCPP 1.5, as well as an evaluation of OCPP 1.5 compared

to IEC 61850. This evaluation supports our choice of OCPP, since the IEC 61850 is focusing especially on grid automation, instead of offering services for charge spot operators with a specific interest in the business domain. The mentioned disadvantage of OCPP, that there is no integrated smart charging support, is now addressed by OCPP 2.0 release. Moreover, the implemented OCPP 2.0 also provides an ISO/IEC 15118 integration, which perfectly completes the interaction to our V2G interface. In this context the presented work in [9] provides a mapping of ISO/IEC 15118 message types and already recommends an OCPP extension to support smart charging use cases in OCPP 1.5 by defining the following message types - *ChargingProfileAnnouncement* and *EnergyAllocation*. Since OCPP 2.0, this recommendation is covered by *SetChargingProfile* and *NotifyEVChargingSchedule* message types. Due to the reason, that the OCPP specification does not clearly formulate any protocol sequences, Table I provides an overview of implemented OCPP messages and their functional description, related to the laboratory environment.

TABLE I. OVERVIEW OF DEPLOYED OCPP OPERATIONS.

Deployed OCPP Operations	Functional Description
Boot Notification	Registration of EVSE at PO
Heartbeat	Indication, that EVSE is still alive
Meter Values	Provision of meter values from EVSE to PO
Start Transaction	Initialization of charging process, including authorization, charging needs, start meter value and charging profile
Stop Transaction	Completion of charging process, including stop meter value
Set Charging Profile	Control of charge limits by PO
Notify EV Charging Schedule	Communication of charging profile from stop meter value

As depicted in Section I, German TSOs coordinate the MR tendering via a central internet platform [6]. For connecting our implemented PO with TSO, in order to provide MR, the Merit Order List Server (MOLS) [7] interface is used. The message exchange between MOLS and MR providers, in our case the PO, is illustrated in Figure 4 and based on the standardized Electronic Data Interchange (EDI) library by ENTSO-E. The actual MOLS specification envisages a communication based on the exchange of messages via SSH-FTP server. A detailed description of the MOLS interface is given in [9].

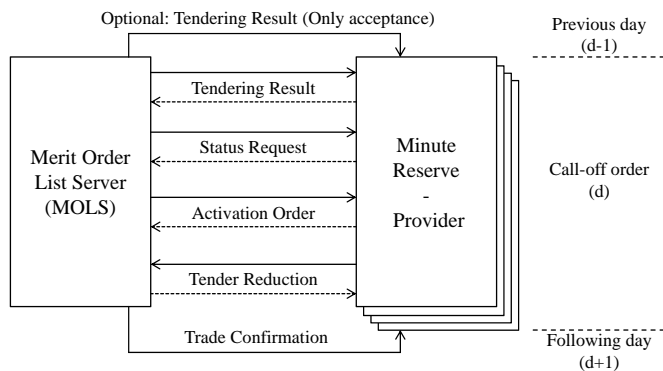


Fig. 4. Merit Order List Server (MOLS) message exchange.

Since, communication based on FTP servers is not state of the art for process automation, we have implemented a REST web service solution based on the defined MOLS specification and included the ENTSO-E messages in our laboratory environment. This has the advantage, that we can easily integrate

the MOLS interface in a fully automated communication service (as illustrated in [9]), which satisfies the security policies and can be easily adapted to other services regarding the energy market. In addition, we have expanded the MOLS interface in our web service implementation by an automated offer submission, instead of uploading an offer on the TSOs internet platform. Table II provides an overview of implemented MOLS message exchange, their functional description, related to the laboratory environment and a mapping referred to Figure 4.

TABLE II. OVERVIEW OF DEPLOYED MOLS OPERATIONS.

Deployed MOLS Operations	Functional Description
Offer Negotiation	MOLS extension by automated submission of tender by PO
Offer Acknowledgment	Delivery of tendering results by PO (Corresponds to <i>Tendering Results</i> message of Figure 4)
Activation Order	Activation of positive or negative minute reserve by TSO of tender by PO
Final Activation Order	Delivery of trade confirmation of tender by PO (Corresponds to <i>Trade Confirmation</i> message of Figure 4)
Status Request	E.g., request for available or activated power and communication test by PO

B. Tooling for Performance Evaluation

The implementation of the described protocols in our laboratory enables the evaluation of the overall presented technical systems in relation to requirements introduced in Section I. For this purpose, we have implemented a special evaluation tool covering all deployed messages, summarized in Table I and II. This tool allows us to record test runs with an adjustable number of messages of each message type and finally provides associated round trip times (RTT), which are analyzed on the basis of the results' median.

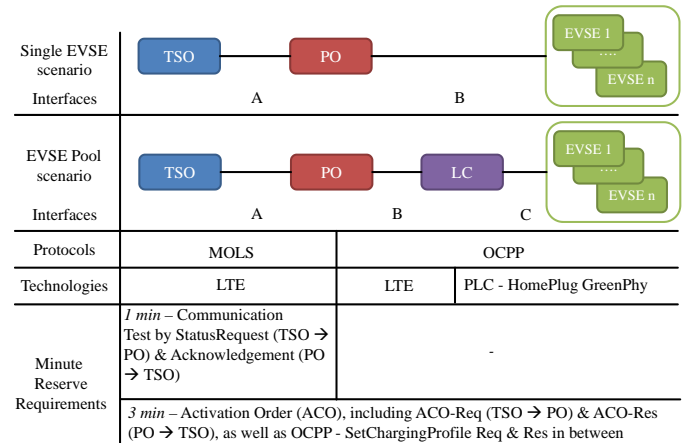


Fig. 5. Overview of setup for performance evaluation.

Figure 5 presents an overview of the setup, which is analyzed in the following sections. The basis of the performance evaluation are two different scenarios. The first one directly connects the PO to several EVSEs and the second one connects the PO to EVSEs through an intermediary unit. A detailed description of each scenario is given in Section III. Furthermore, Figure 5 illustrates the linking between implemented protocol and analyzed communication technology for each interface and finally depicts the minimum requirements, which must be fulfilled by the ICT infrastructure in order to provide MR. In order to generate comparable results for all indicated test

runs, server and client of the evaluation tool are deployed on equivalent test systems (see Table III). In addition, we are generating nearby optimal conditions in terms of the transmission technologies, since we are using our own base station for Long Term Evolution (LTE) and in case of power-line communications (PLC), we have installed a test network without any interferences. This allows us to evaluate the system for a best case communication channel setup, without any interferences of other applications.

TABLE III. PERFORMANCE EVALUATION HARDWARE.

Parameter	Value
OS	Windows 7 x64
CPU	Intel Core i5-2520, 2.5 GHz
RAM	8 GB

In the following section two different test runs for the interfaces (see Figure 5) are evaluated. The first test run is an automated test processing over a period of 2 hours, with a test repetition rate of 3 minutes. Each repetition consists of 100 messages per message type, leading to a total number of 4000 messages for the performance analysis. This test run is performed irrespectively of the protocol for all communication interfaces (referred to the interfaces A, B, C in Figure 5). The second test run is performed for the special case of an *ActivationOrder* by TSO to PO. In this case PO needs to transmit *SetChargingProfileType* messages to all EVSEs with an active charging process and therefore uses LTE as transmission technology (referred to interface B in Figure 5). The performance analysis for interfaces B and C are evaluated with a simulation environment based on the communication network simulator OMNeT++ 4.2.2 in combination with measurements in the laboratory.

III. APPLIED CHARGING SCENARIOS

This paper discusses two different scenarios for connecting the EVSEs to the PO. The interface between TSO and PO is the same (MOLS over LTE) in both scenarios which are illustrated in Figure 6.

The Single EVSE scenario deals with a direct cellular network connection, e.g. LTE between the EVSEs and the PO. Thus, in case of MR activation the PO has to send a *SetCharging-ProfileRequest* to each charge point separately.

In the *EVSE Pool* scenario EVSEs can be pooled and controlled by a central unit (e.g. in a parking area), the so called Local Controller (LC) [12]. The LC pools all EVSEs in a Local Area Network (LAN). In our scenario PLC based on the HomePlug GreenPHY standard [14] is used (High-Speed ROBO Mode), as this standard is utilized in the V2G communication regarding ISO/IEC 15118. Hence, PLC modems are already installed in the EVSEs and can also be used for this purpose. This scenario reduces costs for infrastructure providers, as only one mobile broadband modem for connection to PO is needed for the whole parking area.

IV. PERFORMANCE EVALUATION

This section deals with the performance evaluation of the two described scenarios. First of all in subsection IV-A the interface between TSO and PO is analyzed based on the MOLS interface protocol over LTE. This evaluation is the same for both scenarios. Afterwards the interface between PO and the EVSEs is analyzed in subsection IV-B.

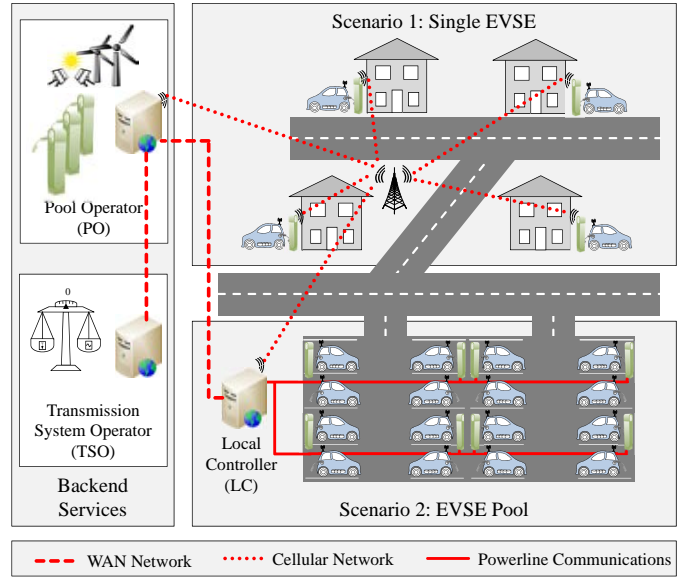


Fig. 6. Realized charging scenarios in the laboratory and in the simulation.

A. Merit Order List Server (MOLS)

Figure 7 presents recorded RTT for each of the implemented MOLS messages and matches them with the message length. The measured RTT are each composed of a request and a response message and thus contain the processing time on the client and the server. In this paper, the processing times are assumed to be negligible, since in several test runs processing times have been identified as ≤ 1 ms. This assumption is supported by the fact that back-end systems at PO and TSO in each case will be powerful server systems.

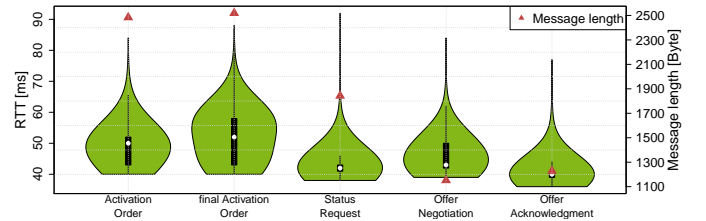


Fig. 7. RTT measurement for MOLS messages in the lab using LTE.

The message length ranges from 1152 Byte (*OfferNegotiation*, ON) to 2519 Byte (*finalActivationOrder*, fAO). In general, the RTT correlate to the message length, whereby the RTT median varies from 40 ms (ON) to 52 ms (fAO). It can be seen, that the RTT of a single message varies related to an increasing message length. This is to explain by processing and communication channel irregularities, which have a stronger impact on larger messages. Although *OfferNegotiation* message has the smallest length for request and response, the RTT is greater than e.g., *OfferAcknowledgment*. Ide et al. showed in [15], that small messages have high overhead when transmitting data over LTE. As the response message only has 186 Bytes, this leads to higher transmission times. Regarding MR provision, the MOLS interface needs to perform a communication test, which is implemented by a *StatusRequest* message, in less than 1min. As the communication between PO and TSO is generally based on a single request response pattern, the

requirement for the MOLS communication is met in each case, since the median of the *StatusRequest* is 42 ms.

B. Open Charge Point Protocol (OCPP)

This section deals with the performance evaluation of OCPP, which is done separately for each scenario.

1) *Single EVSE scenario*: Figure 8 shows the sequence chart for the performance evaluation for *Single EVSE* scenario. After PO receives an ACO, PO has to address all active EVSEs with a *SetChargingProfileReq* message. When receiving the last *SetChargingProfileRes* PO can send an *ActivationResponse* back to TSO.

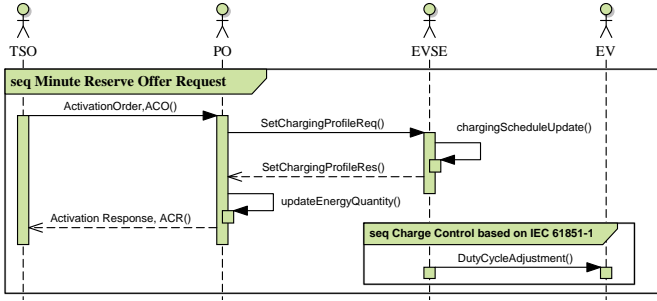


Fig. 8. Sequence Chart for *Single EVSE* scenario.

For analyzing the total delay, first we have measured the RTT of all OCPP messages that are implemented in our laboratory. As mentioned before, the RTTs include processing times on client and server. Results are shown in Figure 9. The median of RTT varies from 21.18 ms for *Heartbeat* message to 29.71 ms for *TransactionStarted* message.

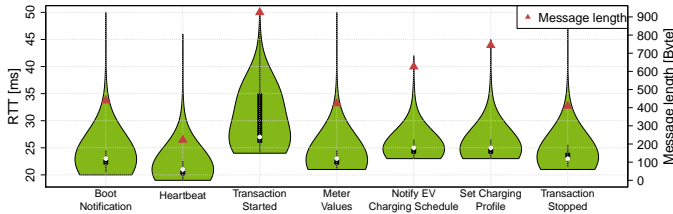


Fig. 9. RTT measurement for OCPP messages in the lab using LTE.

The *SetChargingProfile* (SCP) message for MR service has a median of RTT of 25 ms. This value is subsequently used for calculation of the communication effort for MRL activation t_N with following formula.

$$t_N = \begin{cases} (IDT \cdot N_{EVSEs} - 1) + RTT & \text{for } IDT < \text{for } RTT \\ N_{EVSEs} \cdot RTT & \text{for } IDT > \text{for } RTT \end{cases} \quad (1)$$

IDT is the Inter-Departure-Time of the SCP messages sent from PO to all EVSEs. Hence, 1000 EVSEs can be addressed with $IDT = 10$ ms within $t_{1000} = 5.015$ ms.

As this is only an approximation, we build up a simulation to proof these results for the different scenarios and number of EVSEs. For more realistic representation, in simulation we assume a normal distribution of 12.75 ms with a standard deviation of 1 ms. Results are illustrated in Figure 12.

2) *EVSE pool scenario*: In the *EVSE Pool* scenario an additional instance is introduced in the system, the Local Controller (LC). It is installed, e.g. in parking areas or also in residential areas where multiple EVSEs are available within the range of Local Area Networks (LAN). This reduces complexity for PO, as less SCP messages have to be send. Instead the LC calculates charging schedules for each charge point (with regard to the SCP message) and forwards them to the pooled EVSEs. A sequence chart is shown in Figure 10.

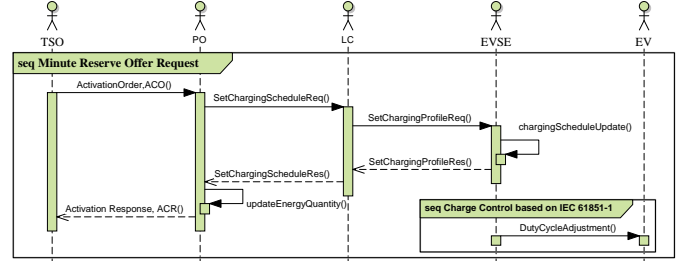


Fig. 10. Sequence Chart for *EVSE Pool* scenario.

Figure 11 shows the measured RTTs for all OCPP messages in our laboratory using HomePlug GreenPHY. It can be seen, that the RTTs are more than 50 % less than RTTs of LTE measurement. Hence, pooling EVSEs in a PLC network can reduce duration for addressing all EVSEs from PO significantly.

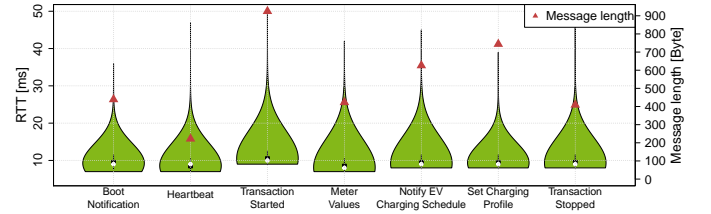


Fig. 11. RTT measurement for OCPP messages in the lab using HomePlug GreenPHY.

To proof this assumption, we build up a simulation environment with a detailed HomePlug GreenPHY model based on [14]. This environment enables precise simulation and timing evaluation for this scenario. The interface between PO and LC is based on the LTE measurements in Section IV-B1 equal to *Single EVSE* scenario simulation. For comparability processing times are included in the PLC simulation, so the RTTs in the simulation match measurements in our lab. Simulation results are shown in Figure 12 and described in the following section.

C. Comparison of scenarios

After simulation of the scenarios the overall system is analyzed, which means that the interaction of different implemented interfaces is considered while analyzing the communication effort of the overall system related to the service of MR provision. Therefore, the RTTs of each individual interface are evaluated by field measurements in Section IV-A and IV-B. In this context Section IV-A illustrates, that the requirement for a MOLS communication test of ≤ 1 min is met in each case. In case of an ACO by TSO, the PO needs to transmit SCP messages to all connected EVSEs, to communicate an ACR to TSO within ≤ 3 min. For the analysis of this requirement, we provide the RTTs of each interface as an input value to an

TABLE IV. COMMUNICATION EFFORT AND PROCESSING TIME EVALUATION OF MR PROVISION BY EVS.

MR activation (3 min.)	1 EVSE		10 EVSEs per parking area		20 EVSEs per parking area	
	comm. effort	remaining proc. time	comm. effort	remaining proc. time	comm. effort	remaining proc. time
500 EVSEs	5.0152 s	174.9848 s	0.7241 s	179.2759 s	0.6732 s	179.3268 s
1000 EVSEs	10.0159 s	169.9841 s	1.2218 s	178.7782 s	0.9243 s	179.0757 s
2000 EVSEs	20.0161 s	159.9839 s	2.2223 s	177.7777 s	1.4216 s	178.5784 s
Status Request (1 min)	comm. effort		remaining proc. time			
All scenarios	0.042 s		59.958 s			

OMNeT++ simulation. Within this simulation several parking area configurations are analyzed regarding scalability effects by different numbers of EVSEs within each parking area. The results of 1, 10 and 20 EVSEs per parking area are presented in Figure 12.

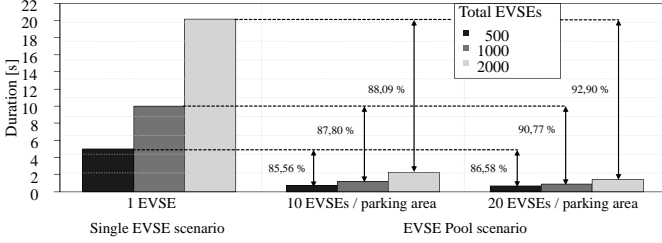


Fig. 12. Communication effort of Minute Reserve activation for several parking area configurations.

Having a look at the absolute values presented in Figure 12, it can be seen that the MOLS requirement for offering MR is met even within the *Single EVSE* scenario. The communication effort for MR activation based on median values of RTT and the remaining processing times are presented in Table IV. That means, that the communication effort provides at least 159.98 s to PO for decomposition of a MR activation to charging profiles for each connected EVSE, which should be a sufficient time when assuming powerful server systems. Furthermore, Figure 12 presents that the *EVSE Pool* scenario (communicating with a LC, which forwards the respective message itself to several connected EVSEs) achieves very high gains in contrast to the *Single EVSE* scenario. The associated gains range from 85,56 % (10 EVSEs on each of 50 parking areas) up to 92,90 % (20 EVSEs on each of 100 parking areas).

V. CONCLUSION

This paper presents an ICT performance evaluation of MR provision using EVs, which is based on standardized communication protocols to ensure interoperability between different stakeholders. To provide MR, EVSEs are pooled by a PO to aggregate a large amount of active charging processes. This enables PO to provide MR negotiation on behalf of the pool of connected EVSEs. All relevant entities are implemented in our laboratory environment, whereby in place of an EV, we have integrated a Smart e.d., allowing an evaluation of the implemented service in a real world scenario. The analysis shows, that the evaluated communication effort enables MR provision using EVs in each implemented configuration. Rather it could be shown that the communication effort provides sufficient processing time for decomposition of a MR activation to charging profiles for each connected EVSE. Moreover the communication effort can be significantly reduced by the use of LC in case EVSE Pool scenarios. In future work, the laboratory environment is extended to the ISO/IEC 15118 implementation between EVSE and the

Smart e.d.. This requires an additional evaluation of the traffic generated by the V2G interface, that will have an impact, particularly in the *EVSE pool* scenario. In addition, the implemented system will be expanded to include and analyze other e-services, such as SCR provision, as well as the impact of background traffic by third applications on our system.

ACKNOWLEDGMENT

The work in this paper was funded by the German Federal Ministry of Economic Affairs and Energy (BMWi) as part of the openECOSPhERE project with reference number 01ME12091. The authors would like to thank the project partners for fruitful discussions during the project.

REFERENCES

- [1] European Network of Transmission System Operators for Electricity (ENTSO-E): "ENTSO-E Operation Handbook: P1 Policy 1: Load-Frequency Control and Performance", Brussels, 2009.
- [2] ef.Ruhr: "dena-Studie Systemdienstleistungen 2030", Berlin, Germany, February 2014.
- [3] B. Biegel, L. Henrik Hansen, P. Andersen, J. Stoustrup, "Primary Control by ON/OFF Demand-Side Devices", IEEE Transactions on Smart Grid, Vol. 4, No. 4, December 2013.
- [4] M. D. Galus, S. Koch, G. Andersson, "Provision of Load Frequency Control by PHEVs, Controllable Loads, and a Cogeneration Unit", IEEE Transactions on Industrial Electronics, Vol. 58, No. 10, October 2011.
- [5] German TSO. "Mindestanforderungen an die Informationstechnik des Anbieters für die Erbringung von Sekundärregelleistung", May 2013.
- [6] German TSO, "Internet platform for tendering of control reserve of the German transmission system operators", Website: <https://www.regelleistung.net/ip/action/index>, last accessed: 16th May 2014.
- [7] German TSO. "Merit-Order-List-Server (MOLS), Beschreibung des Kommunikationsverfahrens MOLS - MRL-Anbieter, Schnittstellenbeschreibung Anbieter-Kommunikation", May 2012.
- [8] D. Dallinger, D. Krampe, M. Wietschel, "Vehicle-to-Grid Regulation Reserves Based on a Dynamic Simulation of Mobility Behavior", IEEE Transactions On Smart Grid, Vol. 2, No. 2, June 2011.
- [9] C. Lewandowski, S. Böcker and C. Wietfeld, "An ICT Solution for Integration of Electric Vehicles in Grid Balancing Services", Proceedings of the 2nd International Conference on Connected Vehicles and Expo (ICCV 2013), Las Vegas, USA, Dec 2013.
- [10] IEC TC 69 IS 61851-1:2010 Ed. 2.0: Electric vehicle conductive charging system - Part 1: General requirements.
- [11] JWG ISO/TC22/SC3 and IEC/TC69, 15118 - Vehicle to grid communication interface, Geneva, Switzerland.
- [12] Open Charge Point Protocol, Website: <http://www.ocpp.nl/>, last accessed: 16th May 2014.
- [13] J. Schmutzler, C. A. Andersen, C. Wietfeld. "Evaluation of OCPP and IEC 61850 for Smart Charging Electric Vehicles", Proceedings of EVS27: 27th Electric Vehicle Symposium, Barcelona, Spain, 2013.
- [14] HomePlug GreenPHY Specification, Release Version 1.00, 14-June 2010.
- [15] C. Ide, B. Dusza, M. Putzke, C. Miller and C. Wietfeld, "Influence of M2M Communication on the Physical Resource Utilization of LTE", Proc. of the 11th Wireless Telecommunications Symposium (WTS 2012), London, UK, Apr 2012.