BLOCKCHAIN-BASED LOGGING OF BIDIRECTIONAL EV CHARGING DATA

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Abstract

Bidirectional charging of electric vehicles enables the implementation of various new use cases, which provide additional value to the user or to the electricity grid by charging and discharging according to external signals. These applications require the installation and operation of measurement equipment in order to collect data on e. g. power and energy in high temporal resolution. These data can also be utilized to provide additional value to the customer by implementing services such as warranties. Therefore, transparent and tamper-resilient data storage is important to create a reliable data basis for the implementation of these services. A blockchain-based data logging platform can provide a solution for this challenge since these features are inherent to the technology.

In the research project InDEED, the described platform was developed, which allows automated recording and notarization of data. Subsequently, data which is notarized once can be verified by the platform, which prevents manipulation and also proves the chronological sequence. For data minimization, the collected data from EVs is not notarized directly, but in hashed form, which also improves the scalability of the solution. In the current research implementation, the data is handled through the OEM's backend system and transferred to the notarization platform only afterwards. This is to be improved in a real implementation, since the backend system might be considered as being prone to manipulation.

The services which can be implemented based on the acquired and notarized data include e. g. warranties on the battery dependent on defined usage (for instance energy throughput or charging/discharging cycles), reliable and verifiable data about the battery for reselling or warranties on the performance of charging equipment. Since the platform provides the central infrastructure, synergies between these services are possible. Therefore, the developed system enables to provide additional value to the customer at little additional expense, and thus contributes to an accepted integration of bidirectional EVs in the energy system.

1 Introduction

The ongoing transition of the European energy system to a renewable and decarbonized future requires increased availability of flexibility options in the system to integrate and utilize high shares of solar PV und wind generation. Beyond conventional assets like pumped-storage plants or stationary batteries, electric vehicles (EVs) can contribute substantially to the total supply of flexibility, either by controlled charging strategies according to grid or user requirements, or by bidirectional charging further raising the flexibility potential.

The term bidirectional charging as used in the following refers to charging strategies for EVs which employ charging and discharging of the EV's battery in order to provide added value besides the customer's mobility needs. Several use cases with varying bidirectional charging strategies can be realized based on the basic technical implementation, which mostly use and require the extensive acquisition of data measured on these charging and discharging processes as well as accompanying measurements of e. g. the user's power consumption or the grid state. Besides this primary use, these data can also be utilized to provide additional services to the customer related to their hardware.

These potential services include for instance warranties on the battery or the charging infrastructure dependent on defined usage requirements like charging cycles or the recording of battery data for reselling purposes. All these potential applications require tamper-resilient data acquisition and storage to provide the required level of trust for the involved parties.

In the research project InDEED, a platform for automated recording and notarization of data is implemented and tested. This platform allows verification of notarized data and therefore, prevents data manipulation or alteration of the chronological order. In the project, the platform solution uses blockchain technology to achieve the described features. It enables to showcase the aforementioned notarization and verification process as well as potential applications built upon. [1]

To implement and test the data acquisition process in the field of bidirectional charging, bidirectional EVs and corresponding charging stations of field tests within the research project BDL are used. These field test setups allow to demonstrate the whole process from measurement to verification, and therefore, the viability of the developed use cases. [2]

2 Project Setting

2.1 Data Platforms for Asset Logging

Increasing numbers of decentralized and potentially flexible assets in the energy system, both on the supply side and on the demand side, contribute to raising overall complexity and additional challenges in operation. Yet, at the same time intelligent metering systems and alternative means of highly resolved, digitized measurements at these assets yield important input for the management of the system. Moreover, small-scale and distributed acquisition of data allows for the implementation of novel use cases based on these data, which potentially pose viable business models for the involved stakeholders. [3]

Since these use cases rely heavily on the collected data, it is essential to use reliable infrastructure for implementation of these use cases which prevents manipulation, protects data integrity, and ensures data protection in order to provide a trustable basis. Within the presented research project InDEED, a data platform was developed which fulfills these requirements and enables the realization of data-dependent use cases. The platform was implemented for investigation in field tests. To meet the requirements, the platform uses blockchain technology for immutable storage of data points. The overall structure of the platform system for logging of asset data is depicted in Fig. 1. [1]

At the asset, data is measured and logged by suitable measuring equipment. The asset owner stores the collected raw data in a conventional database, and periodically transfers aggregated hash values of these data, the so-called Merkle root [1], to the blockchain platform, which is based on the system Quorum. Due to the inherent properties of blockchain-based systems, this ensures immutable and time-discrete storage of the calculated hash values.

Since only hash values are stored, no sensitive data about the asset, its operation or its owner are transferred, fulfilling the data protection requirement. Nevertheless, this implies that the measured data in the default case is only available for the asset owner. In case a third party needs access to the data to provide data-based services to the owner, e. g. additional warranties based on operational data, these data are exchanged directly between the parties. Since this is prone to data manipulation at the owner's side, the implemented platform solution provides the functionality to verify the correctness by requesting the Merkle root. Therefore, the system allows for tamper-resistant storage and transfer of asset data, which is referred to as asset logging in this context. [1]

To identify suitable use cases which utilize the described data infrastructure, potential applications were collected, analyzed, and prioritized in the project from the industry perspective, using the expertise of a large number of experts from various areas of the energy sector as well as from the research perspective [4]. In general, this yields three relevant use cases which can potentially be applied to a range of assets:

- Service and maintenance models, where contractual agreements are verified through the tamper-resistant documentation of maintenance data
- Warranty management, where a warranty claim is verified through the tamper-resistant documentation of asset data
- Operation contracting, where the operation of an asset is outsourced and thus documented in a tamper-resistant manner to constitute an indisputable source of information in the case of conflicts between operator and owner [1]

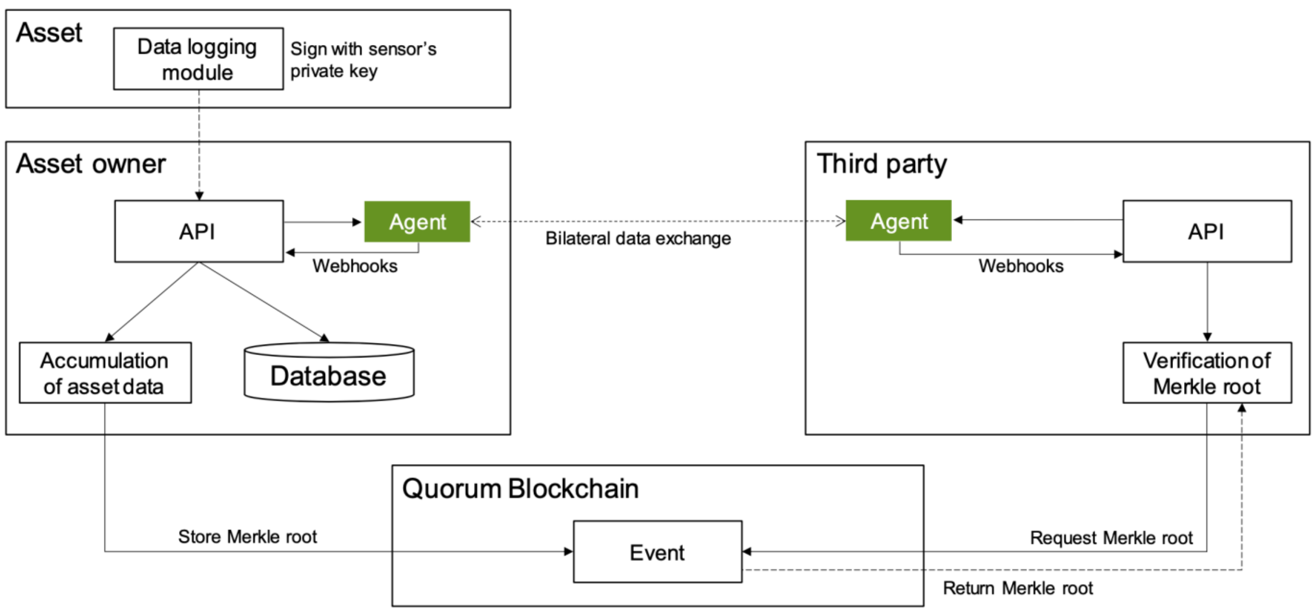

Fig. 1 Platform architecture for asset logging applications [1]

2.2 Bidirectional Charging Management

The transition of fossil fueled vehicles to EVs, battery electric vehicles in particular, causes additional electric consumption in the energy system, but also additional flexibility by employing suitable charging strategies. This contribution to the system's flexibility requirements can be further increased by bidirectional charging, allowing for feeding electric energy back to the grid. In the research project BDL, strategies and use cases for bidirectional charging management are developed both conceptually and technically, and subsequently tested in a field trial in order to assess technical feasibility and economic viability. [2]

In the project, the consortium consisting of several partners from the automotive sector and the energy sector as well as research institutes, defined a selection of potential use cases, i. e. specific applications, for bidirectional charging management. Based on this set, three of these use cases are prioritized for implementation in the field trial:

- Reduction of peak load at a (company) location, where EVs charge at times of low load and discharge at times of highest peak load
- Increase of self-consumption of self-generated electricity (e. g. by a PV system) and reduction of grid usage by temporarily storing the excess electricity in the EV battery and supplying the household from the battery of the bidirectional vehicle
- Aggregation and marketing of the charging and discharging flexibility of bidirectional vehicles on the intraday market [5]

To assess these use cases practically, a comprehensive measurement concept is applied and implemented to collect all potentially relevant data in high quality and temporal resolution. Fig 2 shows this concept for the case of household customers, it analogously applies also to business customers. The integrated uncalibrated measurement equipment of the system's components (UME) is complemented with calibrated metering systems (CME) as well as power quality meters (PQ) to represent and analyze a comprehensive view of the effects on customer, grid, and vehicle. [6]

All collected data are transferred to a central database, where they are checked, validated, interpolated if necessary and stored for further evaluation by the involved project partners. These evaluations are calculated and graphically depicted on a central evaluation platform, which is available for project partners and trial participants. Moreover, the acquired data basis can yield a viable starting point for the development and investigation of further applications, which are not in the primary focus of the described research project, e. g. the implementation of additional data-based use cases for EVs based on the described data platform in section 2.1. [6]

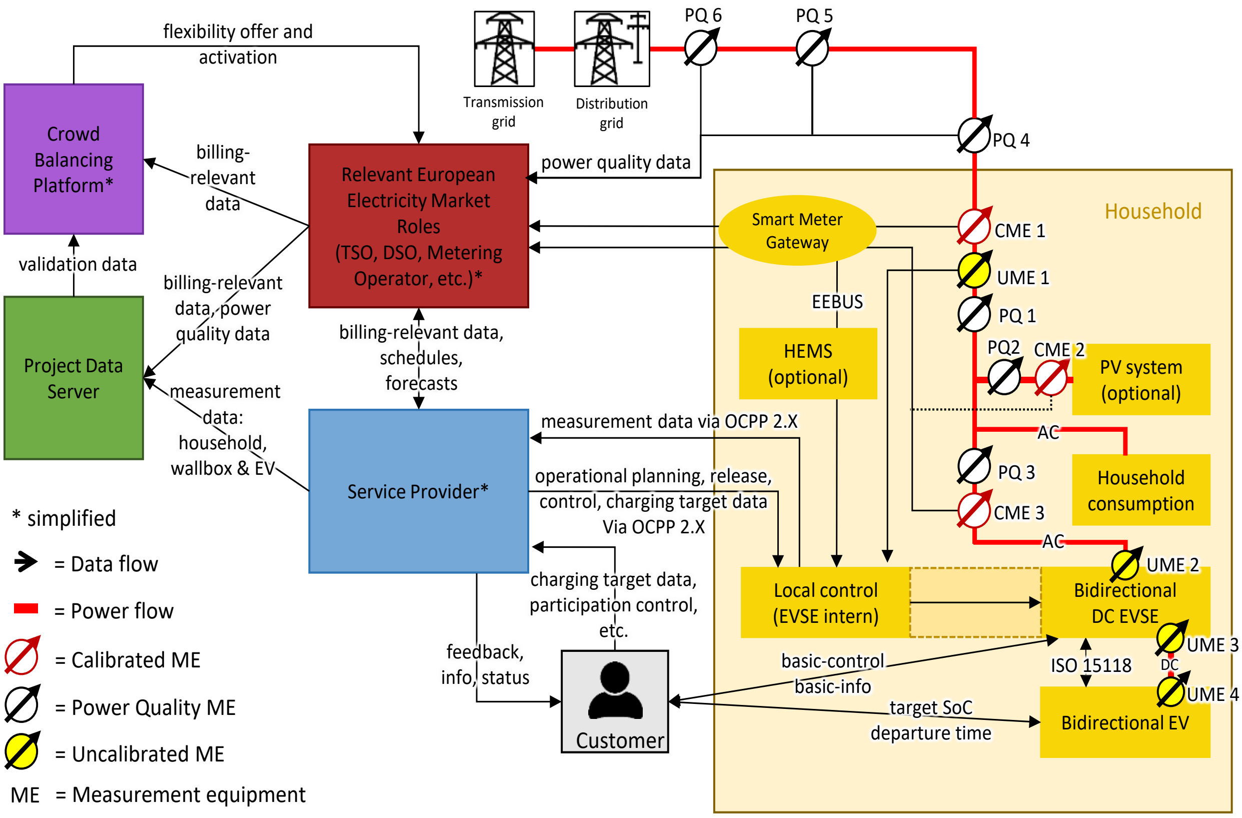

Fig. 2 Measurement concept in the field test for bidirectional charging [6]

3 Data-based use cases for EVs

3.1 Conceptual Design

Based on the pre-selection from section 2.1 and the available data basis described in the previous section 2.2, two assets are considered suitable for the implementation of data-based warranty models which utilize reliable data from the platform. On the one hand, EV batteries typically have guaranteed minimum capacities based on mileage. This can be extended to additional warranties based on charged and potentially discharged energy, particularly relevant for bidirectional vehicles, since mileage is not necessarily proportional to battery usage here.

On the other hand, reliable data about drawn and supplied power of the charging station (referred to as electric vehicle supply equipment, EVSE, in Fig 2) allows determining the achieved efficiency, and therefore, offering warranties on e. g. minimum or mean efficiency of the station. Another possible use case, which is not covered by the described selection, is the recording of battery usage data for reselling purposes, i. e. to prove a defined number of cycles or energy throughput.

For implementation of these three use cases, energy and power data have to be recorded at UME 2 and UME 3, according to Fig 2. These represent measurement on the mains side and on the car side, respectively, and therefore cover the described applications.

3.2 Proof-of-Concept Implementation

The proof-of-concept implementation is based on the described data infrastructure outlined in section 2.2. The required data (energy and power values) from both relevant points of measurement (UME 2 and UME 3) are transferred through the provider backend, where it is also stored, to the central data server, where it is processed and stored. Once a day, a hash value representing the acquired data over one day is calculated and notarized on the data platform using the described blockchain-based implementation.

In case of e. g. a warranty claim, the data from either the service provider or the data server can be utilized to prove the respective claim by verification of the relevant data set, providing the evidence that the data is unaltered since initial storage. Therefore, disputes about reliability of underlying data can be avoided. Thus, this initial implementation poses a basis for the described use cases and enables a simple and efficient connection of various types of assets.

Drawbacks of the proof-of-concept status are the several data transfers and intermediate steps necessary before the hashing and notarization process is performed. For an operative implementation, it is more reasonable to perform this process directly at the point of measurement, excluding the possibility for intentional or unintentional data alteration in the intermediate steps. For an improved implementation, the location and operator of raw data storage is to be defined, since the data server which is used in the current version is only part of the measurement concept for research purposes.

4 Conclusion and Outlook

The presented concept provides the infrastructural basis for the implementation of data-based services for EV customers, which heavily rely on the correctness of collected and stored data. This is achieved by utilizing a central data platform, which ensures the immutability of stored data by technical measures, in this case by application of blockchain technology. The utilization of the data platform for the domain of EV, not initially targeted in the project, demonstrates that the concept can be easily transferred to other domains.

Since the required data needs to be measured and collected during operation of the asset, data platforms allow implementing these additional services with few extra effort and also obtain valuable synergy effects.

As pointed out, the current implementation is in a proof-of-concept status and therefore, the further development to an operative phase still requires several adjustments and decisions. Nevertheless, the general feasibility could be demonstrated, and can be seen as an example and as basis for a wider variety of data-based use cases for flexible assets.

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