# SMIM–A Cloud-Based Approach for the Digitisation of Smart Meter Installation Processes

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***Abstract*—A mass smart meter roll-out represents a vast challenge concerning the performing of the corresponding installation processes. Starting from the hypothesis that meter operators would be able to successfully implement a mass smart meter roll-out in Germany under the current conditions, we show that a determined lack of process support by information and communication technology (ICT) indicates that the thesis has to be rejected. In this context, we introduce the Smart Meter Installation Management (SMIM) as a cloud-based approach for improving the capability of smart meter installation processes by use of advanced ICT. The following German-specific results refer to conducted field observations and workshops and will now be presented to the international community.**

***Index Terms*—smart metering, smart meter roll-out, cloud computing, mobile computing, smart meter installation management**

## I. INTRODUCTION

In September 2012, the research group Smart Energy IT Systems (SEITS) at the Information Systems Institute at Leipzig University initiated the research project *10.000 Smart Meters in the Model Region Leipzig* to investigate how smart metering processes could become more efficient due to process optimisation in a two-year time frame. For this purpose, the researchers collaborate with a local meter operator. The contractor is charged to implement the research platform and thus roll-out a large amount of smart meters in the city of Leipzig for the first time. The primary target, among others, is to gain new insights concerning the roll-out itself and management of smart metering systems. Against this backdrop, smart meter processes within the energy value chain will be investigated out of a meter operator's perspective. Furthermore, we develop prototype-based approaches that lead to an efficient process support by use of advanced information and communication technology (ICT).

Therefore, the objective of this paper is to analyse the actual state of implemented smart meter installation processes in Germany with regard to the potential need of a comprehensive ICT support and also to provide the revealed results for the international community. In addition, we want to introduce the Smart Meter Installation Management (SMIM) as an initial research artefact. The SMIM represents a software prototype that supports the back office processes of meter operators. It also enables a mobile and likewise digital capturing and provisioning of installation-relevant data directly on the spot.

Following the design science research paradigm (see also [1]), our work based both field observations and several process workshops. Thus, a strong practical reference is given.

At first, we will give a brief overview of international smart metering actions and of the status quo in Germany particularly. Afterwards, the analysis of an identified smart meter installation process will be conducted. Starting from the potentials revealed due to the analysis, we picture the essential concept of SMIM. Finally the results are being summarised and an outlook of further research tasks is given.

## II. SMART METERING

A wide range of definitions for smart metering exist in literature, but none of them could establish itself so far. In addition, there is a lack of common device specifications, which help to clearly characterise metering devices as smart meters [2]. Reference [3] describes a smart meter as a meter that captures and stores energy consumption data and moreover communicates bidirectional. Thus, the application of advanced ICT enables smart meters to transmit consumption data through a telecommunication network as well as receiving and handling electronic messages. Based upon this bidirectional communication that reference [4], in comparison to analogue meters, emphasises as the essential quality, it is possible to automate the capturing and processing of measured data. In this regard, the term smart metering in the following stands for the processes of automated capturing, transmission, administration and management of energy consumption and production data (cf. [5]-[8]). From a business perspective, it could be understood as a management process that develops innovative business models and increases the company's value through applied smart measuring technique and advanced ICT [9]. The planning and implementation of the infrastructure which is needed to perform smart metering services is called smart meter roll-out. This term describes the substitution of the currently in most countries predominantly applied analogue household meters by smart metering systems [10].

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### A. International Experiences

A great number of countries all over the world already made experiences in implementing a smart meter infrastructure, regardless whether they conducted mass roll-outs or just pilot projects [8].

Sweden and Italy, for example, equipped all or most of their electricity customers with smart meters by 2009 and by 2011 respectively [2]. California performs a pioneering role for the United States and the province Ontario proved that smart metering projects can also be conducted successfully in Canada. Furthermore, millions of devices were rolled out by China as well as by Japan and the United Kingdom currently possessing the highest smart meter application rate so far [8].

### B. Status Quo in Germany

While some countries in Europe already fulfilled the European Union directive that at least 80 % of the consumers shall be equipped with intelligent metering devices by 2020 [11], Germany still lags behind to implement this technology [11], [13].

The currently enacted obligations for the installation of smart metering systems are legally fixed in §21c of the *Energiewirtschaftsgesetz* and do concern[1]:

- New buildings,
- Existing buildings undergoing major renovations,
- Consumers with an annual consumption of more than 6,000kWh,
- Producers with new energy generators that have a capacity of 7kW or more.

These limited regulations show the German government currently does not intend to enforce a mass roll-out and that the venture is led to the market.

For installing smart meters on behalf of the customers, meter operators show up so far. A cost-benefit analysis from [14] recommends that in case of an expansion of the smart meter installation duties meter operators should furthermore take the responsibility for implementing the necessary infrastructure.

The majority of the already conducted smart meter roll-out projects in Germany were just pilot projects with a relatively small amount of installed devices [2], [15]. This is partially attributed to the uncertainty regarding the expectable return of investment [16]. Hence, the current experiences on the part of the actors within the German energy industry relating to a mass smart meter roll-out can mainly be classified as minor. This equally applies for the fitters who are charged with the construction of the physical infrastructure. Because of the innovative smart meter technology [17], the installation process in comparison to the assembly of analogue meters implies a higher process complexity due to the need of additional communication technology [16].

Although the experiences related to a comprehensive implementation of a smart meter infrastructure are mainly minor and asymmetrical distributed, the results of several pilot projects indicate that a mass roll-out in Germany could successfully be realised under the current specific premises at this time [18].

## III. Analysing the Smart Meter Installation Process

In the following, an identified smart meter installation process will be described as well as analysed in regard to the potential need of a comprehensive ICT support. The insights and experiences we gathered rest upon workshops with various experts of the German energy industry as well as on field observations. Both methods were carried out during the research project *10.000 Smart Meters in the Model Region Leipzig*. In March 2013, a meter operator was charged by the Leipzig University to rollout over 600 smart meters for the housing industry within six business days in the city of Leipzig (see Table I).

TABLE I. Overview of the Performed Installations

| Date | Fitter | Application rate | Application rate per fitter |
|---|---|---|---|
| 11/03/13 | 15 | 126 | 8,4 |
| 12/03/13 | 15 | 120 | 8,0 |
| 13/03/13 | 16 | 144 | 9,0 |
| 14/03/13 | 15 | 138 | 9,2 |
| 15/03/13 | 6 | 54 | 9,0 |
| 18/03/13 | 3 | 35 | 11,7 |
| **Ø** | **≈12** | **≈103** | **≈9** |
| **Sum** | | **617** | |

At this time, we took the role of a silent observer, partially accompanied the fitters and documented the installation activities by video recordings[2] that we analysed afterwards.

### A. Process Description

During this first installation wave we focused on the substitution of analogue meters, which capture the energy consumption for shared energy supply units like the heating or lighting system by smart meters.

In view of the energy consumption data transmission, communication modules with GPRS interfaces and corresponding antennas were used. The smart meter parameters setting as well as the plugging of the SIM cards into the communication modules were performed by the meter operator before the components were handed over to the fitters.

In the whole time period the installed hardware and communication technology always remained the same. Therefore the identified smart meter installation process as illustrated[3] in Fig. 1 was proven to be stable.

Before a fitter could process the installation orders he had to get access to the building where the meter replacement should be performed. This could be realised

[1] The obligations depend on the respective technical feasibility.

[2] The researchers were able to record over five hours of video material during the accompaniment of the fitters.

[3] The illustration was derived from a BPMN 2.0 model that can be found at: https://seits.wifa.uni-leipzig.de/10ksm/pub/

by the support of caretakers or tenants. Then he localised the corresponding analogue meter within the building and also checked whether the site conditions comply with the technical specifications of the corresponding grid area (e.g. that the meter box meet DIN-standards) or not.

For reducing the risk of future disconnections, a measurement of the local GPRS signal reception strength was performed by the mechanic in advance of the assembling. Considering signal strength boundary values predefined by the meter operator, the fitter was able to determine if the antenna technology should be installed within or outside the meter box. In addition, the decision whether the installation process should be aborted because of the uncertainty about the stability of the network connection or not could be taken.

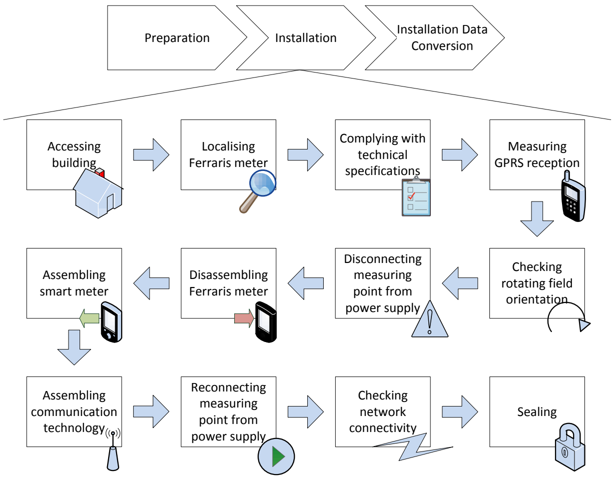


Figure 1. Activities of the smart meter installation process.

If a fitter was going to replace a three phase meter, he had to check the rotating field orientation and changing it as necessary in advance of the smart meter installation. Afterwards the concerned measuring point was disconnected from the power supply for safety reasons and the analogue meter could be disassembled next. Then the smart meter as well as the additional communication technology could be installed and the measuring point was reconnected to the power supply. Thereafter, the mechanic visually checked if the communication module successfully logged into the GPRS backbone, he sealed the meter casing and also filled out an information card[4], which addresses the customer, whereby the installation process was finished.

## B. ICT Support

During a training session in advance of the first installation wave each of the fitters was equipped with a smartphone running the Android operating system. These smartphones were used in combination with a mobile application from the Google Play Store and should enable the measurement of the GPRS reception strength within the respective buildings. The meter operator chose this specific mobile application because of:

- The free of charge availability,
- The intuitive graphical user interface and
- The possibility to capture and record several measuring values during a given time period.

Beyond that, the smart meter installation process was not supported by any advanced ICT in a particular way. Instead, we observed that the installation-relevant data (e.g. the meter readings) were basically manual captured by use of handwritten forms that could be described as installation reports. These forms also provided necessary information, e.g. the meter device number for localising the analogue meter, and served documentation purposes of the assembled respectively disassembled hardware and communication technology. The captured GPRS reception values, occurred problems (e.g. an inaccessible building) as well as the reasons for aborted installation orders were recorded by means of also used paper-based checklists.

## C. Results

The manual installation data recording with handwritten forms and checklists had led to a disproportionate high additional effort and a high risk of errors. We determined by means of video analyses that a smart meter installation could take between 15 to 30 minutes, depending on the capabilities of the respective mechanic. Considering the previously mentioned approach, the processing of one single installation form took between three to five minutes. According to this, the fitters, in the worst case, needed up to one-third of the overall time for recording installation data manually. Projected onto the whole installation wave (cf. Table I), the form filling for 617 installation orders took almost 52 man-hours.

Based on the fact that a variety of forms had to be filled out, there was a high risk that fitters mix up the sheets and data were assigned to the wrong orders. Another risk of errors shows up during the measurement of the GPRS signal reception strength. On the one hand it could not be ensured that all fitters performed the measurement at each time. On the other hand reading errors and inaccuracies through a too short measuring period cannot be excluded. A possible consequence of this circumstance is that labour-intensive fault-clearing actions will arise.

Beyond that, different influences like the repetitive characteristic of the installation tasks that results in decreasing attention and concentration could lead to a faulty capturing of energy consumption data or to an unintentional skipping of certain tasks (e.g. the sealing). Apart from this, a strictly assignment of communication modules to smart meters executed in advance carried the risk that the future transmitted data of modules that were inadvertently assembled on wrong smart meters would be assigned to wrong measuring points during settlement processes.

The potential risks described above were mentioned by the meter operator as the main reasons for expensive

[4] The information card, which was being clamped behind the meter in the meter box, contains the meter readings of the analogue meter as well as these of the smart meter so that the customer was sufficiently informed about the meter replacement.

adjustment actions in the post-processing and can be tracked back to the manual and paper-based working method of the fitters that could lead to poor data quality. However, the highest additional expenses result due to existing media disruptions. Considering the processing of the handwritten forms and checklists, the contractor informed us that following the installation it was initially necessary to convert the given data into a digital format manually which takes an overall workload of more than 40 man-hours. Projected onto an approximate number of 300.000 households in Leipzig in the year 2012 [19], an estimated additional expenditure of more than 2431 man-days would arise. The total costs of this would amount to approximately 972.000 Euros under an assumed gross hourly rate of 50 Euros per employee.

The fact that this kind of working method cannot be classified as efficient for even a small amount of meters to be installed indicates that German meter operators are currently not capable of performing a mass smart meter roll-out so that the initial hypothesis has to be rejected. In this regard, there is a significant need to develop ICT-based approaches that follow the intention to eliminate media disruptions and equally ensure a high data quality to avoid expensive installation data conversion and fault-clearing actions.

## IV. A Cloud-Based Approach

The SMIM designed by the research group SEITS is a cloud-based approach for preventing media disruptions and also to ensure a high data quality during the whole smart meter installation process. With this, the fitters will be enabled to capture the installation-relevant data completely digitally so that the data can be directly provided in the back end systems for post-processing by use of suitable interfaces and without any manual overhead. Hence, the currently applied handwritten forms and checklists are obsolete and the risk of errors as described before can be reduced distinctly.

### A. Development Platform

In the view of reference [20] especially small and medium-sized businesses (SMBs) are often not able to provide the necessary resources for a comprehensive ICT process support by themselves [21] or they are not interested in doing so because their main focus lies on their core competences. Hence, these companies prefer to obtain external ICT services, e.g. in the form of cloud services (see also [22]), and try to benefit from the advantages (see also [23]-[25]) of this strategy.

During our research work we also could observe this preference on meter operators, which were mostly SMBs. As a result, we decided to prototypical evaluate our approach for the ICT process support of smart meter installations by means of a cloud-based information system. Referring to it, SAP Business ByDesign was used as development platform because of the following reasons:

- It was free of charge[5],
- Offers Software-as-a-Service as well as Platform-as-a-service,
- Provides a lot of extensibilities,
- Enables rapid prototyping and
- Its focus lies on SMBs [26].

### B. Architecture

The SMIM is designed as an add-on solution[6] that runs on the SAP Business ByDesign platform and that is also embedded in the existing ByDesign context. So it is capable to use and extend existing concepts and components delivered by SAP or to create new ones (see also [27]). First of all, the application supports the back office processes of meter operators concerning the data management of smart meters, modules (e.g. communication modules) and installation orders. Therefore, it can be regarded as the ICT backbone for mobile order processing.

As shown in Fig. 2 the SMIM contains an additional component that we have named Smart Meter Installation Assistant (SMIA). The SMIA, as a mobile application for android devices, supports the fitters during processing orders and enables the digital capture of installation-relevant data directly on the spot. Due to digital forms, the fitters are being navigated through the several steps of the smart meter installation, whereby manual input is not needed most widely.

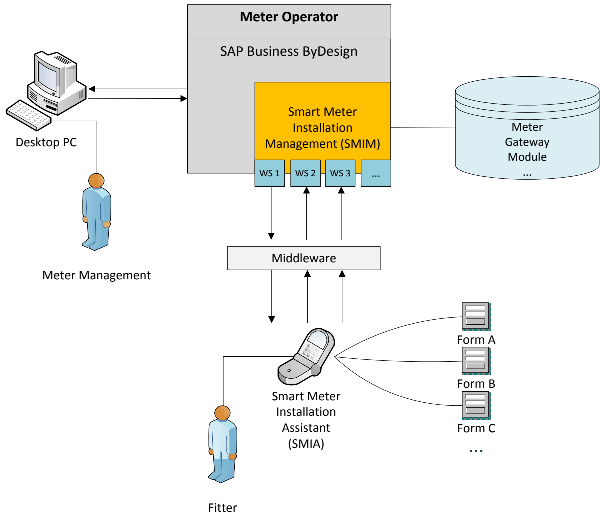


Figure 2. Architecture overview

The data transmission between SMIM and SMIA is realised upon the basis of web services that are generated and provided by the SAP Business ByDesign system.

Although we used standard software, trusted in web standards like SOAP and implemented the mobile client with the widely used programming language Java, we identified compatibility problems during the development phase which results into unpredictable disconnections while synchronising the data between the two applications. Therefore, we had to implement a middleware, which henceforth converts the request

[5] The research group SEITS got a free access to a SAP Business ByDesign instance during an evaluation phase.

[6] Third-party applications that run on the SAP ByDesign platform are called add-on solutions.

messages in a format that can be processed on both sides and also caches the data to ensure its availability.

### C. Implementation

The central paradigm in developing add-on solutions for SAP Business ByDesign is the usage of business objects. Business objects are abstract concepts of the real business world that are be mapped by use of software applications. They encompass specific elements as well as business logic and can be related to other business objects. The specific implementations of a business object are termed as instances, where all instances share the same business object structure [28].

The business objects that were used in the development of SMIM as well as their relationship to each other are shown in Fig. 3. In this connection, we applied the predefined SAP concepts *Customer*, *Employee* and *Business Partner* that are placed in the deployment unit[7] *Foundation* and which addresses the core data management of natural persons and corporate bodies.

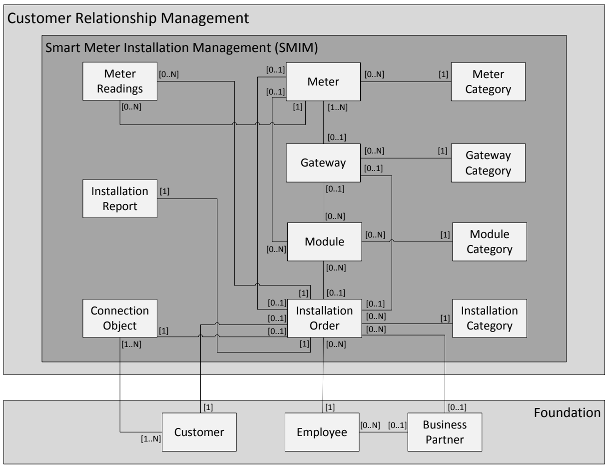


Figure 3. Business objects of SMIM

Starting from the business object design we focused on the data model that was implemented in SMIM and worked out due to an analysis of the handwritten forms as well as during several workshops conducted under the participation of a meter operator. In this connection, we attached importance to the extensibility of the data model so that the SMIM is able to handle different device types and communication technologies.

For the prototype development we used the SAP Cloud Application Studio (formerly known as SAP Solutions OnDemand Studio) that enables third-parties to implement own concepts as business objects. Thus, a developer is capable to define the structure as well as the behaviour of business objects by means of a light-weight scripting language [28].

### D. Results

In July 2013, the SMIM was used in a field test during a second installation wave. The researchers accompanied certain fitters again and ran the application in parallel to the smart meter assemblies. On this occasion, we made sure that the SMIM and its subcomponent SMIA provide an ICT-based alternative to the problematic usage of handwritten forms and checklists for capturing installation-relevant data during smart meter installations. The form-driven and order-related menu guidance as well as the implemented checking mechanisms ensure that all activities will be passed through and that the captured data turns out to be completely. Due to the avoidance of manual inputs, the data quality is increased while staff, time and cost expenses are decreasing.

The field test shows that the SMIM is suitable for capturing data digitally so that expensive data conversion actions following the smart meter installation become superfluous. Therefore, the described cloud-based approach above could contribute to enable meter operators to successfully implement a mass smart meter roll-out in Germany by reducing both costs and time.

## V. Conclusion and Outlook

The insights that were revealed in the course of the research project *10.000 Smart Meters in the Model Region Leipzig* indicate that particularly small-sized meter operators are currently not capable of performing a mass smart meter roll-out in Germany. In the context of this paper this circumstance can be partially ascribed to the usage of handwritten paper-based forms and checklists during the performing of smart meter installation processes. This determined lack of necessary comprehensive ICT process support results into media disruptions and a high risk of errors that lead to expensive data conversion and fault-clearing actions. These efforts turn out to be inefficient and uneconomical, even for low application rates.

Out of this motivation, the SMIM was designed. It enables the fitters to digitally capture the installation-relevant data due to their mobile devices. Once the process has completed, the data is being synchronised between the SMIM and SMIA so that it is ready for further processing in the back end systems. In addition, the data capturing is mostly automated and also checking mechanisms ensure a good data quality which has a great significance for meter operators.

We chose a cloud-based approach because we assume that meter operators as SMBs are not interested in or not capable of providing the necessary ICT resources for process efficiency by themselves. Therefore, the products of cloud service providers like SAP could contribute to reduce costs for both customers and software developers.

In this paper, we only focused on smart meter installations, but in the future, further smart meter processes within the energy value chain should be considered. This will be necessary for gaining a comprehensive and uniform process understanding. On the basis of standardised processes, suitable software applications that could have a positive impact on efficiency and costs can be developed. Thus, we assume that, consequently, the social and economic acceptance of smart metering as a whole would be increased.

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[7] A deployment unit encompasses a wide range of business objects, which can be regarded in the same context (see also [27]).

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