Test records of equipment installation at participant´s site

Version 1.0

Deliverable D5.2

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EXECUTIVE SUMMARY

Deliverable 5.2 describes the process and activities that have been carried out in order to equip pilot customers for Demo 4 with intelligent metering systems and control devices to facilitate the integration with the Smart Grid Hub. The field testing phase rests upon having real life customers and their flexible devices on board. Organizing the workflow of installation and solving the technical issues of a full end-2-end integration of residential customers and a DSO´s SCADA have proven to be major challenges towards the future of distribution networks.

This document describes the customer selection and clustering process to prioritize the installation activities. Priority has been given to customers which either are expected to offer a suitable interface to the control box or which are important to create a diversified portfolio of flexibility. Based on these clusters and priorities, customers were then visited and equipped with intelligent metering systems and control devices. Along the way, a number of general and device-specific challenges arose. It turns out that among the most pressing issues are a lack of interoperability and a lack of an appropriate interface for the control device, a smart meter administration and communication service that is still in its technical infancy and in some areas insufficient LTE coverage. For most issues this report offers a description of a solution, for some the result is that not all flexible devices are easily accessible for the DSO.

The report takes the reader through the installation process step by step and concludes with a real life example of a pilot customer in the field testing area of Demo 4.

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1. INTRODUCTION

For the Demonstrator 4 in Germany Interflex has acquired up to 200 pilot customers to carry out the field test phase later in the project. To evaluate and further develop the envisioned use cases it is of utmost importance to have a large number of different flexible devices in private households on board. The use case demonstration with real life pilot customers should not only demonstrate the validity and usefulness of the use cases, but also seek to validate the conjecture that flexibility from residential customers can in fact have an impact on the way DSO´s operate their network in the future.

The challenge with small scale flexibility such as rooftop PV generators, domestic heat pumps, residential battery storage or EV chargers is the relative cost of integration. Points of connection have to have the metering and communication capabilities necessary to be part of a larger pool of flexibility. In order to keep integration costs down while maintaining a maximum of data privacy and IT security it is imperative to leverage existing or soon to be rolled out infrastructure wherever possible. In the case of Interflex the ambitious goal of integrating private flexibility directly with the DSO SCADA introduces an additional challenge, since the SCADA is considered a part of the critical infrastructure which requires additional security measures.

To account for these circumstances and special requirements Interflex has set out to utilize the public smart meter infrastructure. The smart meter roll out across Germany is slowly picking up speed and the federal agency for cyber security has created a comprehensive framework to ensure a maximum of security and interoperability within Germany. In the wake of the public smart meter roll out a large number of potential sources of flexibility will become accessible and it is the goal of Interflex to create the interfaces for seamless interoperability from the start.

To equip pilot customers with their required control devices Interflex will make use of the roll out processes for the ongoing smart meter deployment. An important part of the development of the Smart Grid Hub went into creating the interfaces towards the smart meter infrastructure and gateway administration services on one hand, and the DSO SCADA on the other. Pilot customers will be equipped with a standard intelligent metering system including the smart meter gateway according to federal guidelines. All communication and administration services will be handled by the gateway administrator, just as it would be done in an operational environment in the future.

1.1. Scope of the document

Since the smart meter roll out in Germany has just begun and the required administration and communication services are being developed in parallel, it has proven a major challenge to equip customers with intelligent metering systems and control box and get the system to operate properly. Interflex has dedicated a lot of work and resources to solve these issues and create the processes and solutions it requires to build a DSO-wide pool of small scale flexibility. This document explains the process of selecting pilot customers from a technical perspective and highlights the general challenges along that process. It further goes into detail describing the challenges associated with different types of devices and offers insight into the solutions developed to integrate customers into the Smart Grid Hub architecture. It concludes with an example of an installation of a pilot customers site.

1.2. Notations, abbreviations and acronyms

The table below provides an overview of the notations, abbreviations and acronyms used in the document.

Table 1 - List of Acronyms

AC	Altering Current
CHP	Combined Heat and Power
DER	Distributed Energy Resources
DSO	Distribution System Operator
kW	Kilo Watt
kWp	Kilo Watt peak
PLC	Power Line Communication
PV-System	Photovoltaic- system
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
SCADA	Supervisory Control And Data Acquisition
SGH	Smart Grid Hub
SMGW	Smart Meter Gateway
LTE	Long term evolution telecommunication standard
V	Volt

2. CUSTOMER OVERVIEW

At the beginning of the customer equipment installation process 366 customers had responded positively to Avacon´s previous invitation and accepted the terms & conditions for project participation. To ensure a swift and efficient installation process with minimal interference in the customer’s household, a research process was carried out initially. For this research process customers were clustered into four categories A to D based on the following criteria:

- Type of device
- Relevance of the device to ensure a diversified portfolio of participants
- Compatibility of the device with the control box

For each cluster Avacon would then generate an individual research and installation process to meet the requirements of the different groups.

2.1. Category A:

Category A consists of battery storage systems, wallboxes and charging points for electrical vehicles. This cluster was created based on the fact that batteries and EV charging points are very relevant for a diversified portfolio, but are not necessarily compatible with the control box solution. Hence the individual cluster to allow for the required level of attention to maximize the chance of bringing these devices on board.

In most cases of customer battery storage systems are used as a buffer to increase the electricity own consumption of the photovoltaic system’s produced energy. They are commonly connected between the photovoltaic solar modules and the inverter. In some cases, a storage is connected between the inverter and the electricity meter of the household. Most batteries do not offer the required control box interface, but most have some kind of a bus interface for a supplier API. At this point it remains unclear, how the standard control box interface with 4 relais switches could be connected to a bus interface. Charging stations for electrical vehicles like wallboxes do not have an interface for the control of external devices either. These devices are represented in relatively small numbers in the pilot region and are therefore represented in the project only very rarely. Before the beginning of the installation process Avacon sent technicians to the customers premise to evaluate compatibility and operation ability of the Interflex metering system and control box.

Figure 1: Battery storage systems of potential customers

2.2. Category B:

This category consists of generators and loads which are already able to be controlled by the grid operator. Devices in this group are equipped with a control interface, which enables the receiving of control signals by the DSO.

2.2.1. PV with long wave radio receiver

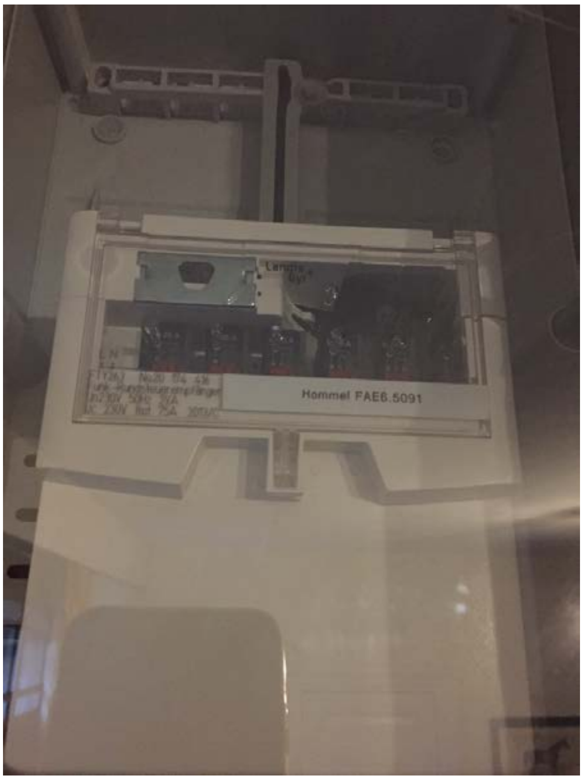
Under current regulation in Germany owners of PV generators are obliged to provide the DSO with access to a curtailment interface of their device. There is one exception for small generators with a rated power of 30 kWp or less, which can opt to generally limit their maximum power output to 70% of peak power instead. Typically, the loss of feed in tariff for energy generated above 70% of peak power is less than the cost of the required long wave radio receiver. Hence we rarely find directly controllable inverters in the lower grid levels, but many 70%-limiters instead. The curtailment actions on the feed in can be carried out any time. The standard interface for the curtailment signal are 4 potential-free 12 V relay contacts. Inverters can accept a set point for their power output based on their nominal maximum power output. Depending on the type of inverter the set point can either be 100%, 60%, 30% or 0% - or just 100% or 0%.

Due to the change of the Renewable Energy Law over the years, the obligation to use a radio receiver differs depending on the year of construction.

Table 2 - Legal regulations for the usage of a radio receiver for photovoltaic owners

	Year of construction	**nominal power**		**Radio receiver**
		from	**to**	
1.)	before 01.01.2012	100 kWp		obligation
2.)	since 01.01.2012[1]	30 kWp	≤ 100 kWp	obligation
3.)	since 01.01.2012		≤ 30 kWp	Customer choice between radio receiver and or 70% feed-in limitation

Figure 2 : Long wave radio receiver



2.2.2. Heat Pumps

Many potential customers offer their domestic heat pump as flexible load for the participation in the project. In the field test area of Lüneburg, heat pumps are mostly used as central heaters or for domestic hot water provision. Due to the special tariff systems and the high efficiency of these devices, heat pumps became competitive to oil and gas heating systems and therefore a popular alternative as primary source of heating. In customers' households heat pumps are used for ambient air heating as well as for water heating. Many heat pumps are equipped with a heat storage system, which allows customers to use the generated heat in the night also during day times. In case of very cold winter days, many devices are equipped with an additional electrical heater. They

[1] Renewable Energy Law (2012) § 6 (2)

have a very short start-up time, which is a major reason for its popularity in the field test region. Additionally, in Germany special electricity tariffs are offered for these devices. For the operation of these devices, InterFlex customers in all cases have one of the following tariffs in use:

1.) A special heating tariff,
2.) A dual tariff with peak and off-peak pricing

The heating tariff is an electricity tariff with a fixed electricity price, which is reduced compared to the normal electricity price to account for the steady and easily predictable load profile and the total annual consumption. Heat pumps with a dual-tariff are charged with two different electricity prices depending on the time of day. During peak windows the electrical consumption will be charged at a high rate electricity price (HT-tariff). During off-peak times, typically during the night, a lesser price is charged (NT-tariff). Usually the HT-tariff-period lasts from 06:00 am to 22:00 pm and NT-tariff-period from 22:00 pm to 06:00 am. Some customers have different tariff-periods, according to the contracts with the grid operator.

The electricity consumption of heat pumps is registered by a separate electricity meter. Customers with a dual-tariff are equipped with a double tariff electricity meter. This meter uses two separated counters, one for the metering of consumption during peak-periods and a different one to register the consumption during off-peak periods. It is the responsibility of the grid operator to trigger the switching between these two meters.

Usually tariff switching between peak and off-peak is carried out via a control command send by the grid operator using ripple control technology. The control signal is modulated to the AC voltage with a frequency of 500 Hz and transmitted utilizing the power grid. Every heat pump customer is equipped with a tone-modulation receiver, which filters the tariff switching signal and converts it into a control signal for the tariff switch in the electricity meter.

The tone-modulation receiver additionally is used by the grid operator as external control device to turn off assets with a rated power of 2 kW or more and to switch off all electrical heaters of all heat pumps. This procedure is used in case of high stress on the grid, for example in situations with exceptional high loads or n-1-configuration caused by maintenance or faults. The right of the DSO to employ these emergency switch offs is limited to a maximum of 2 hours, 3 times per day. Each heat pump is equipped with a potential-free 12 V or 230 V relay contact interface, which is connected to the tone-modulation receiver. Two operating states can be set via the control interface:

1.) Release
2.) Switch-Off

It is important to note that Interflex is employing technologies that allow for a seamless integration with existing technologies in order to keep the potential costs of a company-wide roll out to a minimum. The Interflex control box can be directly connected to the heat pump on the 12 V relay interface. The tone-modulation receiver will be replaced by the control box.

More modern devices are labeled Smart Grid Ready. Those devices have a dedicated interface, which allows an external control of those devices but is not compatible with the control box used in Interflex. In contrast to the standard tone-modulation interface, for external control devices it is possible to trigger different operation modes.

Operation Mode I: Blocking of the system via grid operator
Operation Mode II: standard operation
Operation Mode III: increased operation within the controller
Operation Mode IV: A Startup command, independent of other control signals

Figure 3: Smart Grid Ready label for Smart Heat Pumps

SG Ready Smart Heat Pumps

Figure 4 : Head-Pump and heat storage of a Customer in Embsen

2.2.3. Night-storage heaters

Electric heaters with an offpeak-storage function are treated in much the same way as heat pumps. The receiver of the tariff switching command can be a tone-modulation receiver or a radio receiver. The switch of tariff between peak and off-peak is triggered by the grid operator. For the control by the grid operator these devices offer a 12 Volt or 230 Volt relay contact interface, which is identical to those of heat pumps. Two operating states can be set via the control interface:

1.) Release
2.) Switch-Off

Tariff switching and system switching are triggered via the same channel but use different command codes. This way the heater can be switched off or released independently from the tariff switch in the meter. Small scale night storage heaters with a small heat storage capacity can not store enough heating energy to cover customer's requirement during a full day in cold winter seasons. For this reason, the grid operator additionally activates the heater during the day in high tariff times. The activation lasts a maximum of 120 minutes. On exceptionally cold winter days, heaters could be activated for even longer hours during peak times by the grid operator.

All devices of Group B are flexibilities, which are already being actively controlled or are controllable by the grid operator via radio- or tone-modulation receiver. All devices have a relay contact interface for external control devices, which is compatible to the InterFlex control box. Therefore, the installation of the InterFlex measuring system and control box can be installed almost in a plug-n-play process and does not require a special solution or modifications to the customer system. The electrical meter will be replaced with the new measuring system. The radio receiver or tone-modulation receiver will be replaced by the control box case. The control box itself gets directly connected to the relay contact interface of the device. However, in addition to the aspects of flexibility control, the Smart Grid Hub must also handle all tariff switching events and heater activiations.

Figure 5 : Double-tariff meter of a night stoarage heater

2.3. Category C

Category C includes all PV-generator, which do not have an interface for external controller. These types of inverters can rarely receive external trigger signals for curtailments. They do not have a radio receiver and are not integrated in the feed-in management process of the grid operator, because they opted to limit their maximum output instead according to the Renewable Energy Law (2012) § 6 (2). This category of devices consists of plants constructed before 01.01.2012. All devices have a rated nominal power less than 100 kWp or generators, which were constructed after 01.03.2013 with a nominal power of less than 30 kWp.

Customers with photovoltaic systems with a nominal power of less than 30 kWp and which were commissioned after 01.01.2012 fall under Germany´s “70%-rule”. These customers had the choice to make use of a radio receiver and be integrated in the feed-in management process of the grid operator or to make use of the 70%-rule. Once the customer made the decision for the 70%-rule he has to ensure its pv-system does not exceed 70% of its nominal power output. In most cases of the implementation of 70%-rule was the more attractive alternative. The limitation of feed-in generally is implemented via the inverter maximum nominal power or via software settings.

To utilize power generation beyond the 70% limit, many customers add a battery storage system to their PV installation. The battery is usually connected on the DC side of the system and can not export power to the public grid.

Most of the inverters are not equipped with a control device, nor do they have an interface for external controlling devices. Due to the missing interfaces on the inverters the control box can not be connected directly to the inverter. To tap into this pool of flexibility for the purpose of the Interflex field tests however, these devices can be integrated with a slight modification of their installation by installing a contactor between the control box and the inverter.

2.4. Category D

All flexible loads or generators of customers which need significant alterations of the customer’s installation to make them compatible for the control box and integrate in the project will be allocated in this category. These customers are de-prioritized due to the comparably high costs and efforts required for the implementation of a special solution. This customer group includes all systems, which:

- are not compatible with the control box,
- do not meet the requirements for the installation of the Interflex meter system
- can not be successfully integrated in the communication network (LTE or PLC)

In addition, all customers with combined heat and power plants (CHP) are assigned to this group. This step is necessary, because almost all of customers CHP plants are operated heat-driven. The generated electricity is fed into the grid as by-product. Almost all CHP systems are equipped with a buffer tank with a storage, which meets the heat requirements of the consumer. The buffer tank, however, does not have a sufficient storage size to use the CHP device as a flexible power generator. A shutdown of these systems during use-case applications is excluded in the project. A curtailment of these devices will directly affect the temperature at customers housholds. To avoid any inconvenience to the customer, CHP systems with small storage will not integrated in to project.

3. DESCRIPTION OF INSTALLATION AND COMMISSIONING

3.1. Generic description of installation process

The focus of the installation process is to equip every potential customer with an InterFlex metering and control system. The InterFlex metering and control system consists of a digital meter, a smart meter gateway and a control box. The digital meter measures the power, energy and voltage of each phase. The power flow and energy is measured and recorded in both directions. Therefore, the power and energy of feed-in and consumption can be measured separately. The digital meter is connected to a smart meter gateway. The Smart Meter Gateway (SMGW) is used for a secure and legal transmission of measured values. The measured consumption or feed-in data are sent via a secure encrypted channel fully automatic to the SGH in the grid control SCADA environment. The SMGW also provides the communication channel for digital control commands to the control box. The power supply of SMGW comes from the digital meter. The SMGW is connected to the control box via a RJ-45 communication line. The control box is where ever possible installed next to the SMGW. The SMGW sends encrypted control signals, which are translated in the control box into actionable commands for the local generator, load or battery. The power supply of the control box is usually taken from the digital meter.

Figure 6 : Equipment construction and connections

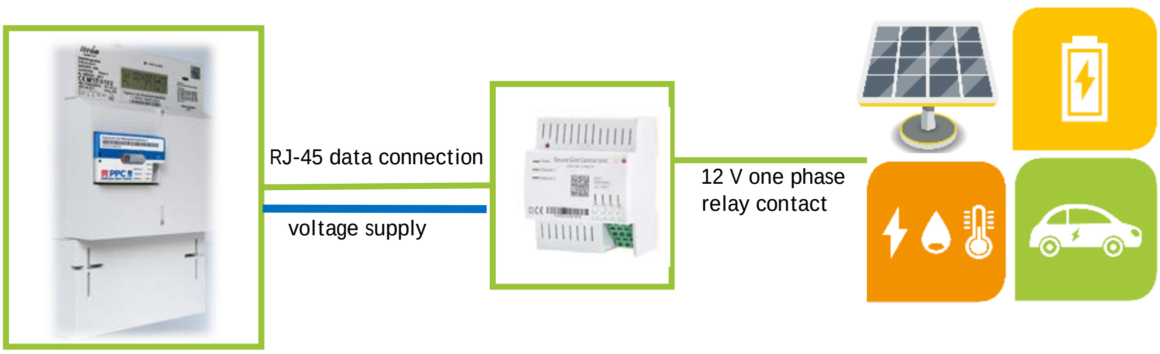
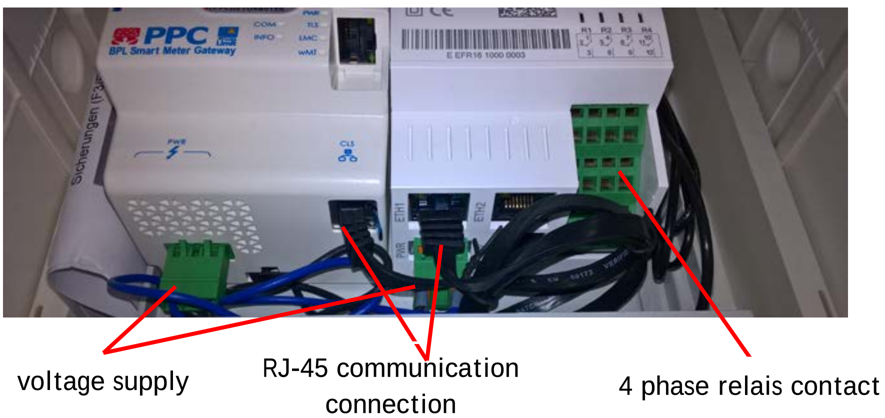


Figure 7 : Cable connections between SMG and control box on a digital meter



3.1.1. Methods of electrical metering

To account for complex remuneration rules for the feed-in of energy and potentially different suppliers for different customers we find several different metering concepts in practice. The selection of the measuring concept basically lies with the plant operator. The network operator has the obligation to use the chosen measurement concept mainly for conformity with the renwable energy law (EEG) and the so-called combined heat and power-law (KWKG) and the technical connection conditions. In the selected circle of customers 3 different electricity metering concepts are applied which differ in following points:

1.) Type of meters used (single tariff, double tariff)
2.) counting directions of power flow (additional generator meter, bidirectional meter)
3.) Number of metering points
4.) Meter placement (house connection meter, generator meter)

The metering method at customer’s premise affects the location of the InterFlex measurement and control systems and has a direct impact on the quality of measured values.

Full Feed-In-Metering

In the case of full feed-in, the producer feeds directly into the power grid. The feed-in metering is carried out via a separate electricity meter, which measures the momentary power flow in both directions, feeding into the grid and consumption from the grid. This current metering concept is used in most cases for customers with photovoltaic systems with radio receiver. In these systems, the old electricity meter will be replaced with the new InterFlex metering system. This measurements concept delivers a high quality measurement value for the use case application, because the measurement takes place directly at the device.

Figure 8 : Full Feed-In-Measurement measurement concept

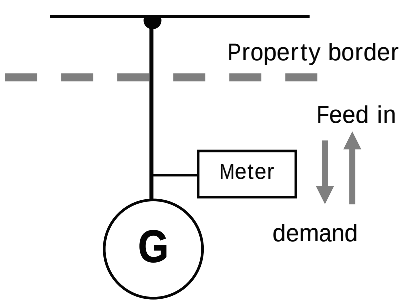
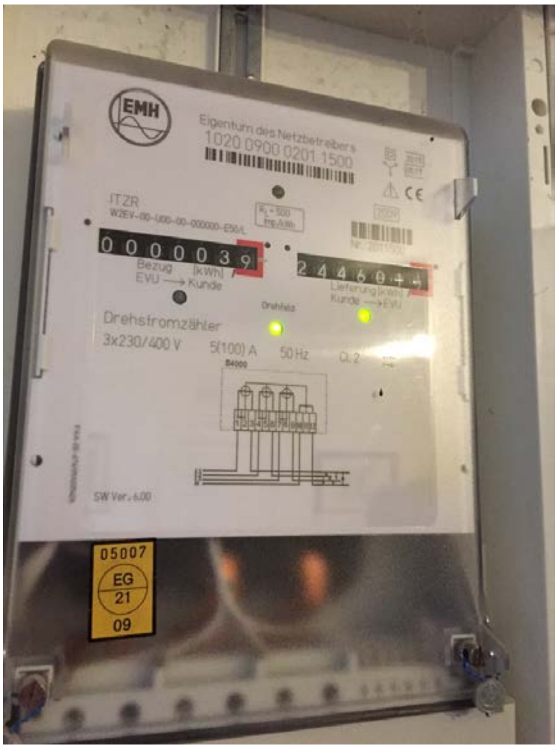


Figure 9 : Bidirectional meter of Full-feed-in producer

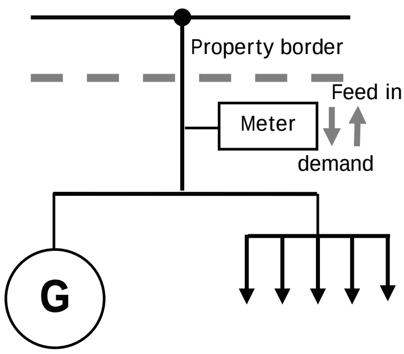


Surplus-Feed-In

The basic idea of this concept is made for customers who want to maximize the use of electricity produced by their own generator and only feed the surplus into the grid. This concept is often used in private households with photovoltaic systems with a 70%-regulation, non-controllable photovoltaic systems and CHPs. The current measurement is taken with a bidirectional meter.

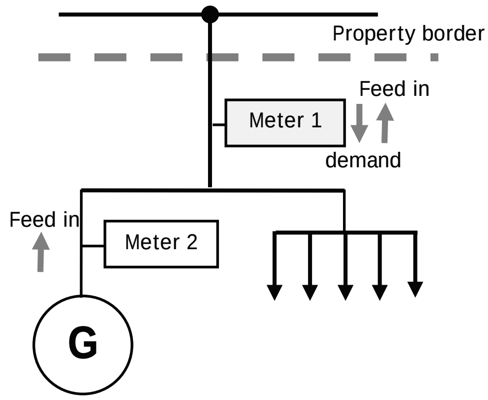
The current meter will be replaced by the InterFlex metering system. This metering method records the flexibility consumption or feed-in indirectly. This means a big disadvantage to the project, because only surplus generation is measured directly, the actual generation however remains unknown.

Figure 10 : Excess-Feed-In measurement concept



Feed-In with separate generation metering: Under this concept the customer installs a second meter to allow for a separate measurement of the generator feed-in and the household consumption. While meter 1 measures the excess feed-in or the residual load, from the grid, meter 2 measures the generated feed-in or power consumption by the generator/consumer. For customers this measurement concept has a huge advantage, because self-consumed DG generation gets remunerated. However, this measuring system is only allowed for customer photovoltaic systems installed after 01.01.2009. If the measurement is carried out by the customer according to this measuring concept, meter 2 is replaced by the new measuring system for a direct measurement of the flexibility feed-in or consumption.

Figure 11: Feed-In with separate generation metering



3.2. Installation process

The installation process of the Interflex measurement and control system is identical for all customer groups and is carried out per the following scheme:

1.) Booking of installation requirement

When customers are selected (via preselection or during the research process) for the installation of the Interflex equipment, in the first step the installation request will be documented in the customer relationship management system (CRM) by linked third party E.Kundenservice Netz GmbH (EKN). In the next step the installation request will be send to the technician of Avacon Netz GmbH for approval. With the confirmation of the technician the installation request gets forwarded in the internal order control system (ASS) and assigned to the technician. Orders will be placed in the ASS containing information regarding:

- Generator address
- Customer address
- Meter number
- A list of all devices which need to be installed or removed
- Customer base data
- The connection object of the customer

2.) Preparation of approach

In the next step technicians make an appointment with the customer. The contact is made via telephone. If customers stated in advance the wish to not be contacted via phone, they will be alternatively contacted via mail, letter or an announcement via mail. The InterFlex devices, digital meter, gateway and control box will be organized. In order to avoid delays in the installation process by delivery times, a sufficient number of devices are kept in store in the warehouse of Lüneburg. Additional equipment for installation, e.g. extension cables, housing for control boxes, contactor or PLC communication devices, will be procured in advance if required.

3.) Inspection of the system on site

Before the replacement of the meter, the customer system must be inspected on site. For this purpose, there is a check for dangers to life and limb according to the 5 safety rules stated in DIN VDE 0105:

- Disconnect mains
- Prevent reconnection
- Test for absence of harmful voltage
- Ground and short cut circuit
- Cover or close of nearby live parts

4.) Exchange of the devices

Steps:

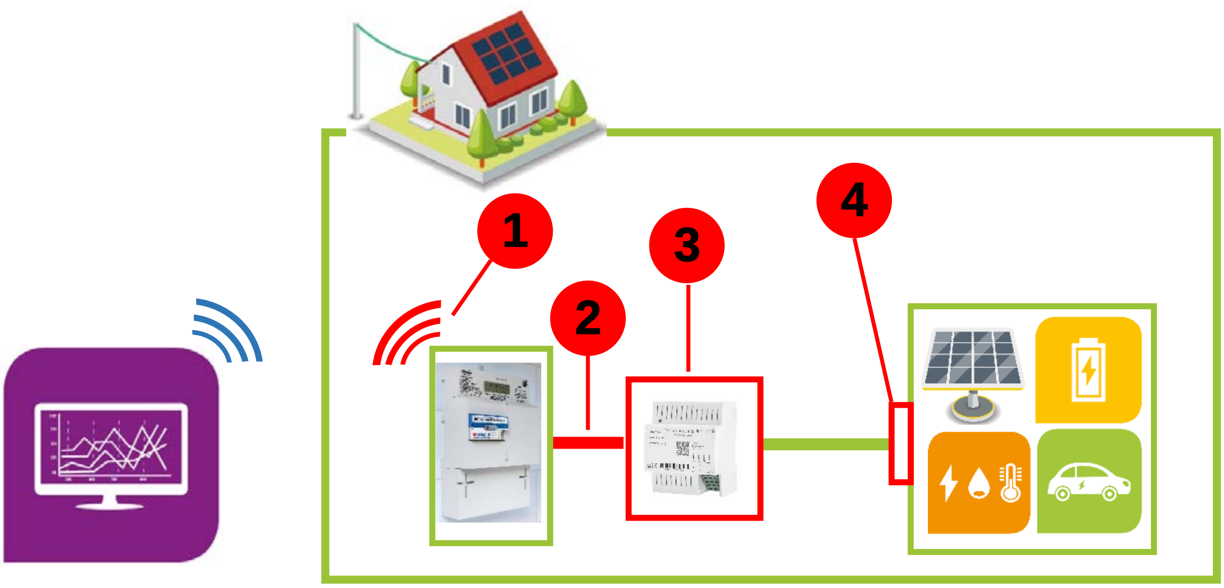
1.) Dismantling of electricity meter
2.) Setting up antenna of the smart meter gateway.
3.) Cable routing from the antenna to meter panel inside the meter cabinet
4.) Mounting of the Interflex digital meter in the meter box of the meter cabinet at the three-point mount.
5.) Mounting of the InterFlex smart meter gateway on top-hat-rail of the new digital meter.
6.) Connection of the smart meter gateway with the digital meter via RJ45 communication cable.
7.) Connecting the voltage to the smart meter gateway.
8.) Mounting of the control box next to the gateway on the top-hat-rail of the digital meter (if possible). If necessary a separate housing will be mounted in or outside of the meter cabinet.
9.) Energizing of the metering system.
10.) Check of measurement meter function:
    i. rotating field check
    ii. communication test
11.) Sealing of the measuring system and control box housing
12.) Report of installation in the ASS platform.
13.) Implementation of connection of smart meter gateway and digital meter via the gateway administration service.

After the successful installation and operation test of the digital meter the customer gets a confirmation of participation of the InterFlex project and becomes an official project member. The confirmation letter will be uploaded and documented in the customer data base of E.ON (I-SU).

3.3. Group-specific challenges

For a successful integration of customers in the project a stable communication link from the smart grid hub to the execution of command must be established. After a closer inspection of technical details of the assets in different categories, four critical problems can be identified for which individual solutions have to be implemented for a successful installation and operation of the system.

Figure 12 : Critical section along the the communication



1 LTE-connection (Customer Category: A, B, C, D)

The field test region Lüneburg has a low to medium population density of 137 inhabitants per km². Many customers live in remote areas with no LTE signal or a signal which is too low to establish a stable communication link to the smart meter gateway. This is a major issue, which effects all customer groups. A solution for this issue could be to equip potential customers with a power line communication system to replace LTE technology. The PLC gateway communicates via the low voltage grid of customer's grid connection. To do so the information data packages are modulated via a high-frequency signal on the mains voltage. The second PLC-gateway and LTE-antenna will be installed in the local network station, which is connected with the household power connection. To reduce the risk of not finding enough pilot customers with sufficient LTE coverage Avacon has decided to extend the scope of the project to PLC based communication. First distribution substations will be equipped with PLC technology over the course of 2018

2 Communication link between digital meter and control box (Customer Category)

Another critical section along the communication channel is the communication link between the smart meter gateway and the control box. In the case of some customers in category C the electricity meter and inverter of the photovoltaic system are not co-located but found in separated rooms. For the communication connection between the control box and the SMGW the RJ-45 cable is not an option because it would require significant modifications to the customer’s home. As a solution, an in-house PLC-system could be installed. For the communication between the SMGW and the control box the household’s internal 230 V power lines can be used. The RJ-45 output of the SMGW and the control box are connected to the PLC gateway modems. The voltage supply will be taken from a contactor, which additionally needs to be installed.

3 Control Box Installation

The installation of the control box is not critical in most cases. However:

Category B:

Residential generators or consumers are equipped with a radio- or tone-modulation receiver. The receivers are installed next to the meter. For the installation of the control box the receivers will be dismounted and replaced by a control box housing. The control box will be installed inside of the housing. The voltage supply of the control box will be taken from the connectors for the voltage supply of the receiver. For the communication, a RJ45-cable will connect SMGW and control box.

Problem 1: Peak-/Off-peak-tariff switching of electricity meter

Effected devices: All heat pumps and night storage heaters
With the dismounting of the double tariff meters and radio- or tone-modulation receiver the function of double-tariff counting and switching of devices has to be carried out by the new equipment.

Solution: The separate counting of energy consumption in peak-times and off-peak-periods can be easily solved by the digital meter and SMGW. Based on the timestamp measured values the SMGW can document Peak-energy consumption and Off-peak-times in separate registers.

Problem 2: Peak-/Off-peak-time switching

Effected devices: night storage heaters with tone-modulation receiver
Night storage heaters are activated and inactivated in sync with the peak-/off-peak tariff switching. Customers switching schedules can be individual. However, with the digital meter no switching trigger is available any more for the activation or inactivation of the heater in time of tariff switching. Now the control box has to trigger the activation and shutdown of heaters according to the peak-/off-peak-switching schedules. Therefore, an individual switching schedule has to be implemented on the control box of each night storage customer during the installation.

Solution: After the installation of the control box an individual switching schedule will be parameterized in the software of the control box. To do so Avacon is developing an application that enables technicians to parametrize the control box on-site. The android-based app provides all variants of switching schedules. For the parameterization, a tablet PC will be connected to the control box via an external network card and a RJ45 connection.

4 Asset interface

Assets of customer group B are equipped with an interface for control of external devices, which are actively used or can be used by the grid operator. These devices a fully compatible with the control box interface. However most of the devices of customer group A, C and D do not have an interface or are equipped with an interface, which is not compatible to the control box.

Customer Category A, D:

Most of these devices are not equipped with an interface. Some of the battery storage systems are equipped with a modbus interface, which is not compatible with the control box. The process of making these systems compatible unfortunately lies outside the scope of the German Demonstrator of Interflex. It will be a challenge for future initiatives and suppliers to ensure full interoperability of these devices.

Category C:
The inverter photovoltaic solar system, which fall under 70%, in most cases have no interface for external control. These devices will be equipped with a contactor, which can receive control signals from the control box and translate into a mechanical opening of circuit to shut down the device (0%) an activate (100%). The contactor will be located between the inverter fuse and inverter. The contactor is fully compatible to the control box.

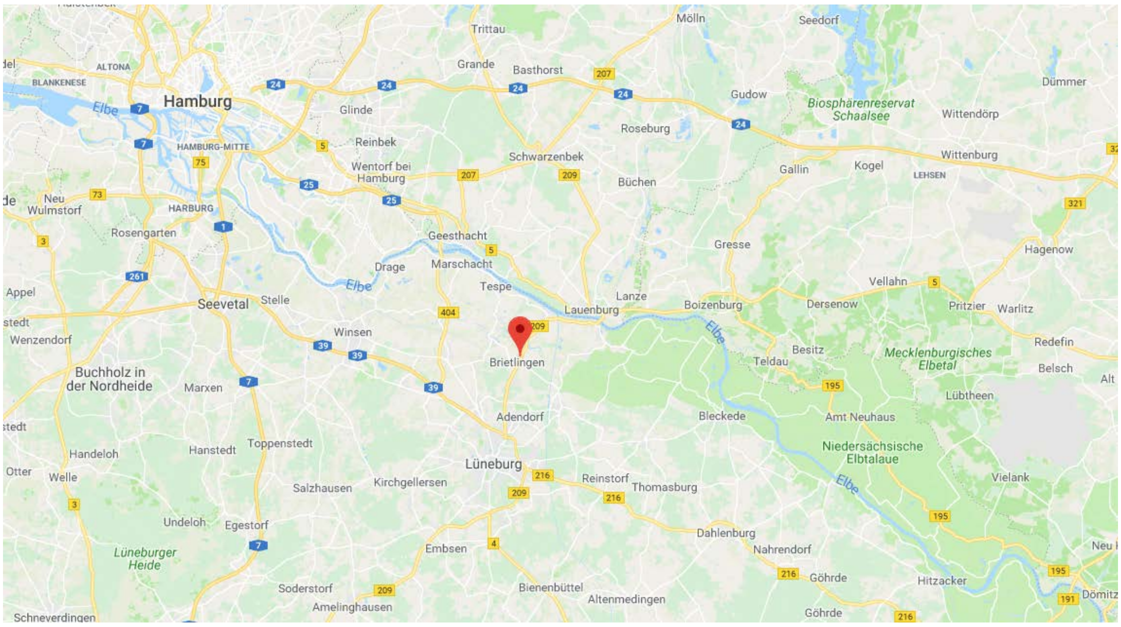
Table 3 - Overview of Challenges and affected customer groups

	Critical section or device	**Description**	**Effected Customer Category**	**Solution**	**Solution for Customer Category**
1	LTE connection	No signal or no sufficient signal	A, B, C, D	Power line communication	A, B, C, D
2	Communication link digital meter and control box	Long distance between control box and interface of asset	C	House internal power line communication	C
3	Control box	Exchange of radio controlled and tone-frequency receiver	B (night storage heaters)	HT/NT-switching schedule on control box	B
4	Asset interface	Some asset have no control interface,	A, C, D	House internal power line communication	C

4. EXAMPLE

The following example describes the process of installation of the InterFlex measurement system and control box of a customer in Brietlingen. It is a small village in a rural field test region, 5 km north of Lüneburg.

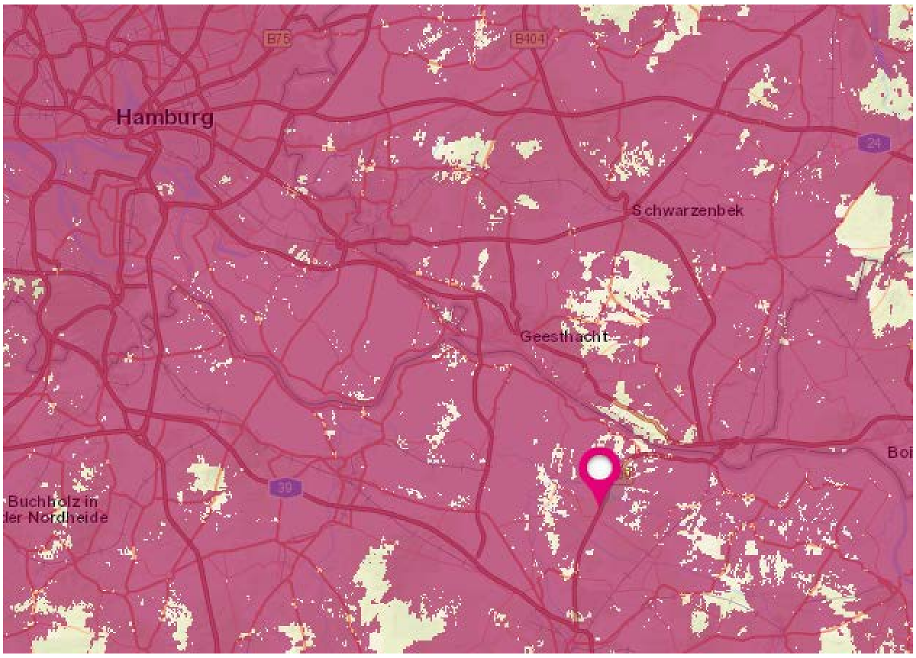
Figure 13 : Customer placement in the field test region of Lüneburg



The customer responded to the project invitation via postcard. He approved the terms and conditions for participation and offered a photovoltaic system for the equipment and integration into the project. An initial research in the renewable database DENEA pointed out, that the photovoltaic system is equipped with a long wave radio receiver. Hence the photovoltaic system is integrated in Avacon's feed-in management process already and can be actively curtailed in times of high stress on the grid. Due to the existing long wave radio receiver, the photovoltaic system is equipped with a controllable inverter with a relay contact interface, which can be directly connected to the InterFlex control box. Therefore, the customer was allocated into customer group B. An on-site research by Avacon's technician or telephone research in advance of the installation was not necessary.

In the next step the address data of the customer were taken for LTE-connection check. Address data of the customers were compared with the LTE network coverage map of the German mobile telecommunications provider Telekom and Vodafone. The review revealed that a LTE signal would be available.

Figure 14 : Telekom-LTE coverage map with customer location



After initial requirements were positively confirmed an Avacon technician contacted the customer for the arrangement of an installation date. A first inspection of the asset condition and metering method on site pointed out following:

1.) Type of metering method: full feed-in,
2.) Type of meters used: single tariff,
3.) counting directions of power flow: additional generator meter and
4.) Number of metering points: 2.

Before the installation of the new meter and control box following critical technical requirements for this customer group were checked in advance.

1 LTE signal strength at location of the meter

The LTE signal power at the meter location was measured. The signal strength for the communication connection of the SMGW in the LTE-network was tested via the mobile app Network Cell Info Lite. The key measures of signal level and quality of LTE networks are Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ). The RSRP measured on the location of the digital meter and SMGW was -109 dB and RSRQ -7 dB. These values indicate a sufficient LTE signal for an applicable operation, which should be at least -140 dB for RSRP and -19,5 dB for RSRQ.

Figure 15 : LTE signal measurement at customers electricity meter

2 Communication link between digital meter and control box and

3 Replacement of radio controlled receiver

The customer has a large meter cabinet, which provided enough space to install an additional control box housing next to the digital meter of the measuring system. At the beginning the radio control receiver was disconnected, dismantled and mounted at a separate location within the meter cabinet for storage and possible later reactivation beyond the project duration. For the power supply of the control box, the power connection of the relocated ripple control receiver was used. The SMGW and control box were connected via an RJ-45 cable behind the meter cabined. For the communication connection between control box and inverter the existing communication cables of the relocated ripple control were connected to the relais contact interface of the control box.

Figure 16 : Customer's electricity meter cabinet

Digital meter with a smart meter gateway for photovoltaic metering

Replaced an inactivated radio control receiver

Control box housing with control box inside

Electrical meter for household consumption

The devices were put into operation and tested for function. Since all devices successfully connect to the mobile network, the installation was completed and ready for operation.

Figure 17: Activated digital meter, Smart Meter Gateway and Control Box