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Sustainable Peer-to-Peer Energy Trading Principles and Smart Meter Requirements for Smart Grids

Christina Sigl[1]
Andreas Berl[1]
Miloš Prokýšek[2]

Siegfried Hildebrand[1]
Jakub Geyer[2]

Alexander Faschingbauer[1]
Rudolf Vohnout[2]

ABSTRACT

The sustainability and efficiency of the current and future power grid is an important topic nowadays. The increasing usage of renewable energy sources for the generation of electricity requires a more complex infrastructure to manage generation and demand efficiently. This is not only because of the uncertain predictability of renewable energy sources like solar and wind, but also because of the increasing count of generation points and more dynamic use of the grid. In order to fulfil the demands of the grid participants while stabilizing the power grid, there are different methods for trading energy sources. Especially for smart grid infrastructures, the most interesting approach is to trade energy peer-to-peer. Thus, we consider different peer-to-peer principles in detail, focusing on the cooperating countries Czech Republic and Germany. For fast and accurate trading, the underlying subsystem in particular is critical. That is why smart meters, forming the lowest layer of the system, are one of the most important parts within the grid infrastructure. Their main task is to provide high quality information and services for smart contracting and also for controlling the power grid with regard to efficiency and sustainability. The information provided by smart meters can also be used within a smart energy management to optimize production and consumption times. This demand side management approach helps to prevent overproduction and hence leads to more sustainability in future decentralized power grids. For this purpose, peer-to-peer methods and smart meters have to fulfil dedicated requirements which are considered here in more detail.

Nachhaltigkeit und Effizienz im gegenwärtigen und zukünftigen Stromnetz sind aktuell wichtige Themen. Mit der zunehmenden Nutzung von erneuerbaren Energiequellen zur Stromproduktion wird eine noch komplexere Infrastruktur benötigt, um Erzeugung und Nachfrage effizient aufeinander abzustimmen. Dies kommt nicht nur von der unsicheren Vorhersagbarkeit von regenerativen Energiequellen wie Solar- oder Windenergie, sondern auch von der ansteigenden Zahl an Erzeugungspunkten und dynamischeren Nutzung des Netzes. Um die Bedarfe der Netzteilnehmer erfüllen und das Stromnetz gleichzeitig stabilisieren zu können, gibt es verschiedene Methoden um die Energie zu handeln. Speziell für Smart Grids ist der Peer-to-Peer-Ansatz zum Handeln von Energie interessant. Die verschiedenen Peer-to-Peer-Prinzipien betrachten wir im Detail, wobei wir uns auf die kooperierenden Länder Tschechien und Deutschland konzentrieren. Für einen schnellen und fehlerfreien Handel ist das zugrundeliegende Subsystem kritisch. Aus diesem Grund sind Smart Meter, welche die untersten Ebene des Systems bilden, einer der wichtigsten Bestandteile der Netzinfrastruktur. Ihre Hauptaufgabe ist es, qualitativ hochwertige Informationen und Dienste für Smart Contracts und für die Steuerung des Stromnetzes unter Beachtung von Effizienz und Nachhaltigkeit bereitzustellen. Die Informationen der Smart Meter können auch bei einem intelligenten Energiemanagement verwendet werden, um Produktions- und Verbrauchszeiten zu optimieren. Dieser Demand-Side-Managementansatz trägt dazu bei, Überproduktion zu verhindern und führt somit zu mehr Nachhaltigkeit in zukünftigen dezentralen Stromnetzen. Hierfür müssen Peer-to-Peer-Methoden und Smart Meter spezielle Anforderungen erfüllen, die in dieser Arbeit näher betrachtet werden.

[1] Technische Hochschule Deggendorf
[2] Institute of Applied Informatics, University of South Bohemia, České Budějovice, Czech Republic

KEYWORDS

Smart measuring, data acquisition, load balancing, renewable energy, prosumer

Intelligentes Messen, Datenerfassung, Lastenausgleich, erneuerbare Energie, Prosumer

1. Introduction

Future smart grids include a more sophisticated approach to manage demand and distribution of electricity. Since the amount of electricity generated from renewable energy sources rises, a more distributed and sustainable grid infrastructure shall be a positive outcome. That considers also the drawback of volatile availability of renewable energy by using the demand side management [1] approach.

Figure 1 shows a comparison of the traditional grid with a smart grid. In traditional grid architectures, there are just two types of participants, namely producers and consumers, whereas in a smart grid also renewable energy sources, like wind farms and photovoltaic plants as well as storages for energy are integrated. In particular, a consumer can take the role of a producer as well and can start producing electricity. These participants of the grid are called prosumers. Integrating prosumers into the power grid in order to maximize the usage of renewable energy sources is a necessity that cannot be circumvented.

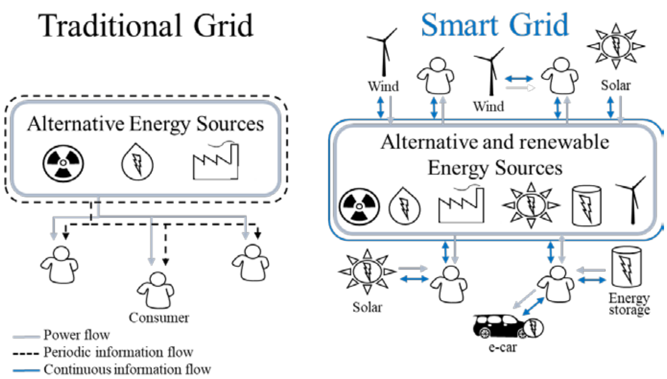

Figure 1: Overview of traditional and smart grids

Computerized measurement as well as the control of the energy supply, transportation and demand build the basis of smart grids. Gathering all information and stabilizing the power grid leads to a much more complex infrastructure. Demand and supply can be controlled by defined system limits in order to balance energy. However, for a trading system and efficient use of volatile energy sources, a much higher level of complexity is needed, especially for the integration of dynamic grid participants like prosumers.

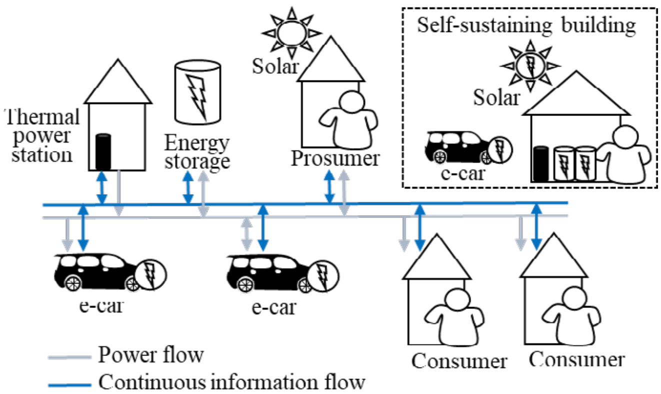

Figure 2: Use cases for energy balancing

From Figure 2 several use cases for energy balancing (dependent or independent of the grid) can be derived. For example, there is a grid including a building with a photovoltaic plant on its roof, batteries for storing, another building that has a thermal power plant, charging stations for electric vehicles alongside the road and ordinary households as consumers. A challenge here would be to consider the integration of thermal power stations with thermal and power energy balancing. Another energy balancing use case could be a self-sustaining building which has to be able to balance (use and store) its generated energy, independent of the grid. Generally, for all use cases, smart metering and control interfaces are very important, as well as a cooperative and distributed control which instantly reacts upon load changes.

As the increasing complexity cannot be avoided and more and more conventional consumers change their behavior into a prosumer, more management and communication functionality is required. Therefore, peer-to-peer (P2P) energy trading is an interesting approach for such a smart grid infrastructure. To enable the system to be dynamic and flexible it needs respective agile components to provide production-consumption control. Thus, smart meters (SMs) are important in such a P2P network for providing information about power consumption and distribution for billing. This requires longer monitoring intervals than in conventional grids, hence more complex software and electronics for information gathering and communication with the grid management system.

Since SMs play this important role within a P2P network, required technologies, protocols and data quality must be analyzed with regard to P2P trading. Thus, a simplified consideration of measurement accuracy is given and some gaps in the measurement chain (e.g., timing issues) are depicted. For P2P trading, business models and means of trustworthy evidence of contracts (e.g., smart contracting, block chain usage) must exist. Hence, P2P systems, business models as well as energy pricing models for a reliable and sustainable smart grid are considered.

The main contribution of this paper is to point out P2P trading principles and their technical requirements for future smart grids in order to enable more renewable energy sources and prosumers to get integrated into smart grids and thus enable a more sustainable grid management.

The paper is organized as follows. The technical background and related work are given in section II. Section III presents a comparison of current energy prices between the cooperating countries Czech Republic (CZ) and Germany (DE), since pricing influences the customer's behavior which in turn influences P2P strategies that have to be taken. Furthermore, different P2P energy trading models are considered in this section. Information that SMs have to provide for P2P trading are shown in section IV. Required technologies and protocols for SMs in P2P energy trading are pointed out in section V. The significance of data quality for P2P trading is stated in section VI. Finally, the paper is concluded in section VII.

2. State of the art

P2P trading, smart contracting and micropayment are modern concepts which are widely used nowadays. There are several pilot projects and examples dealing with this topic. Murkin et al. show an example platform for P2P energy trading using the block chain technology. This makes the trading process accurate, authenticated and secure [2]. Alvaro-Hermana et al. use electric vehicles for P2P energy trading [3]. In general, there are different approaches of P2P energy trading systems on which we will take a closer look in this paper.

Matamoros et al. investigated P2P trading between two micro grids, thus looking at central versus distributed control [4]. Zhang et al. submit that communication and control networks are very important for P2P energy trading. They also show a future scenario of P2P energy trading [5]. For control of the P2P trading system, data from smart metering must be used.

P2P energy trading bases on timing, a reliable communication layer and accurate metering. Marshall et al. did some investigations/simulations about the impact of accurate metering. Most commercial metering systems measure net flow only in intervals of 30 seconds or 30 minutes, which is not always accurate enough. For accurate accounting, sub-second level timing is required. Faster energy fluctuations than the measurement intervals lead to economical inefficiencies and also possible inaccuracies through meter timing [6]. Capodieci et al. present a hardware/software solution for energy trading using agents which use only six time intervals per day for trading [7]. The hardware architecture consists of a real SM which is connected to a SM gateway through a SM interface. The data is sent to an energy trading platform.

Nonetheless, SM accuracy also depends on temperature effects of SMs [8]. SM accuracy is determined considering analog to digital resolution, signal-to-interference ratio (SINAD) and total harmonic distortion (THD) [9]. In the following sections, we take a closer look on energy trading forms and data quality that is required especially for P2P trading.

3. Energy market and trading

In general, there are differences concerning the electricity market including pricing and offers of tariffs in various countries. As an overview over the current situation, we consider the energy markets of the neighboring countries Czech Republic and Germany, the two cooperating countries of the underlying research project of this paper.

In CZ, the current electricity market can be divided into several levels or areas. At first, there is a market for trading energy between producers and suppliers operated by market operator (OTE [10]). There also exists Power Exchange Central Europe (PXE [11]). This market is powered by EEX and provides also services for end-users, especially bigger consumers such as municipalities or SMEs.

In Germany, there are two different business models for the electricity market. The first one is the traditional model, which is divided into producer and consumer. The second one can be called a prosumer model, as it is based upon own production and consumption. Every customer (private / company) is connected to the grid by a distribution network operator (DSO) (e.g., Bayernwerk AG). The DSO is a direct customer of the four transmission system operators (TSO) (e.g., TENNET). Each customer has a contract with an electricity supply company (e.g., E.ON), which does the billing for production and consumption. Electric energy itself is typically traded on the stock market.

A. Current pricing model

As the customer behavior within the grid is mainly influenced by the current pricing model and pricing can vary widely depending on the country, as an example, the prices for energy of the neighboring countries CZ and Germany are regarded further. That is why regulating the demand via pricing models is important for energy balancing. Thus, price disparity can influence the P2P trading spread within a country or region differently.

Electricity for smaller consumers in CZ is delivered by energy suppliers, usually based on an end-user agreement. For households, there are two common pricing models. For smaller consumers, mainly in high density areas with prefabricated houses, the electricity price is rather constant and calculated from several factors. Main factors are the price of power, distribution costs and taxes. For bigger consumers like houses there is a system of high and low tariffs.

In Germany, there are many electricity providers which offer numerous energy tariffs. Hence, a wide variation of tariffs exists. Consumers can choose between them, mainly depending on their location.

Figure 3 shows the price components of the consumed energy for CZ in contrast to Germany. The prices are extracted from E.ON for CZ (distribution rate D01d, 2018 [12]), for Germany see [13]. Fix costs, like a monthly fee per consumption point and reserved input fee, are excluded from the prices. In summary, distribution and consumption costs are almost the same in both countries, but in Germany there are a lot of additional taxes and charges. Thus, the price for energy in Germany is almost twice as high as in CZ. This information can be used by companies or prosumers to identify specific economical potentials in P2P trading.

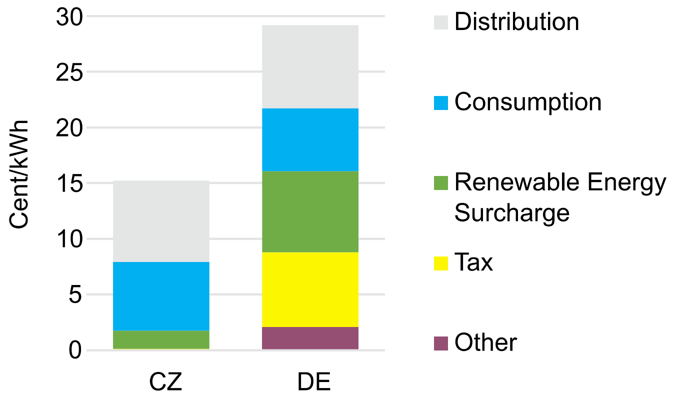

Figure 3: Energy price components (excluding fix costs)

B. P2P energy trading principles

In a smart grid environment, control of consumers' behavior and demand could be based on many things like social influence or responsibility, but the price for energy is the most important factor. Hence, the metering of consumption and production is the crucial part of all P2P trading systems.

Figure 4 shows an overview of the different layers within a P2P system. The subsystem consists of multiple layers. It spans from the physical grid layer to the application layer, where the algorithms for the trading platform are localized.

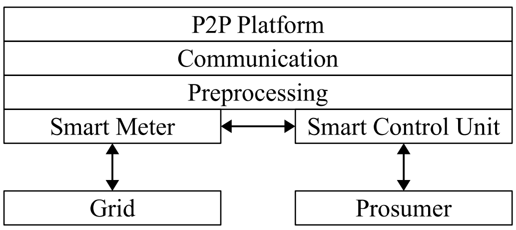

Figure 4: P2P system layers

Table 1 shows an overview of P2P energy trading methods of DE and CZ, described in the following sections. In total, four different P2P energy trading approaches are compared.

1) Scheduled flexible pricing

A flexible pricing model is based on the PXE trading system and uses intraday trades. The system is now usually operated manually or with a low level of automation. This kind of trading system is a good base for further P2P business models and more advanced solutions. The amount of traded energy is based on prediction of consumption and could be supported by data gathering from smart buildings. For trading in PXE a license is required. Therefore, a mediator with license (usually an energy supplier) is an easier choice for end-users.

2) Linking energy production resources

The system of linking/matching produced energy with consumers is based on flexible pricing and fluctuating power production of renewable energy sources (see Figure 5). The idea is to offer cheaper energy to consumers when there is a surplus of energy and provide clear data about how the energy is produced. Consumers can then prioritize from which energy source and for what price they want to buy energy and move some energy consumption tasks accordingly. This allows savings for consumers while it also helps balancing local energy production and consumption.

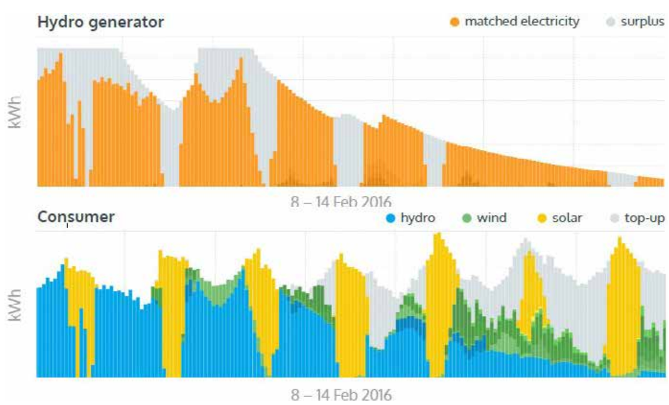

Figure 5: Energy source matching [14]

3) P2P energy market

The P2P energy market is based on a similar idea as the linking of energy production resources, the idea of balancing local energy production and consumption. However, in this case, any consumer can also become producer, a prosumer, and his energy surplus is primarily offered to other local consumers, usually at a better price. If the offer is accepted by another local consumer, the transaction is realized. If no buying customer can be found, or an additional surplus is still left, the surplus is bought by a distribution company according to the agreed pricelist.

	Scheduled Flexible Pricing	**Linking Energy Production Resources**	**P2P Energy Market**	**P2P Energy Trading Platform (with battery storages)**
Companies/ Projects	PRE	Piclo, Vandebron, AmperMarket	TransActive Grid, PeerEnergyCloud	SonnenCommunity, Lichtblick Swarm Energy
Objectives	Dynamic pricing based on estimated electricity production	Linking electricity demand and local energy resources	Direct local energy trading	Distributed energy trading with power reserves and grid balancing capabilities
Peers	Producers – Distributors – Consumers	Producers – (Distributors) – Consumers	Prosumers – Prosumers	Prosumers – Prosumers
Key Features	• Price-driven energy consumption estimates • Weather prediction • Consumption prediction	• Local energy production profiles • User consumption visualization • User energy resources preferences	• Tokenization • P2P payments (block chain)	• P2P payments (block chain) • User consumption prediction • Weather prediction • Grid simulation
Infrastruct-ure Level	Any	Micro-grids / grid-cells	Micro-grids / grid-cells	Any
Smart Meter / Gateway Demands	• Daily / weekly / monthly readings	• Daily / weekly / monthly readings	• Readings several times per hour • P2P market support (online communication)	• Readings several times per hour • P2P market support (online communication) • Gathering user data consumption (profile)
Prosumers Control	Manual / parametric consumption adjustment (scheduled)	Manual / parametric prosumers adjustment (scheduled)	Manual / parametric prosumers adjustment (dynamic)	Dynamic control based on user profile, weather prediction and grid (community) demands
Benefits	• Dynamic pricing for consumers • Load distribution more optimized to production	• Local production and distribution more optimized to production • More transparent billing information • Price reduction for adaptive consumers • Possible direct support of renewable energy sources	• Local consumption and distribution more optimized to production • Price reduction for consumers buying local energy • Higher selling price for prosumers	• Consumption and distribution more optimized to production • Price reduction for consumers buying from prosumers • Higher selling price for prosumers • Peaks shaving • Power reserves • Grid balancing
URLs	• https://www.pre.cz	• https://piclo.uk • https://vandebron.nl • http://www.ampermarket.cz	• https://lo3energy.com (TransActive Grid) • http://www.peerenergycloud.de • http://www.smartmpower.com	• https://sonnenbatterie.de/en/sonnenbatterie • https://www.lichtblick.de

Table 1: Overview of P2P energy trading principles

4) P2P energy trading platform (with battery storages)

A P2P energy trading platform consists of 3 key parts:

- P2P energy market
- Grid simulation with distributed battery storages
- Grid operator / distributor cooperation

Grid simulation is needed for profiling consumer behavior, but also for predicting production necessities and prices. If battery storage is added to a prosumer system, surplus energy can be stored and used in moments of low production. This technique is called peak shaving. Based on the energy consumption profile, which is done by prediction, the stored energy can also be sold. With grid operator or distributor participation this can help balancing, even across multiple grid cells. Figure 6 demonstrates energy production and later consumption with help of battery buffering.

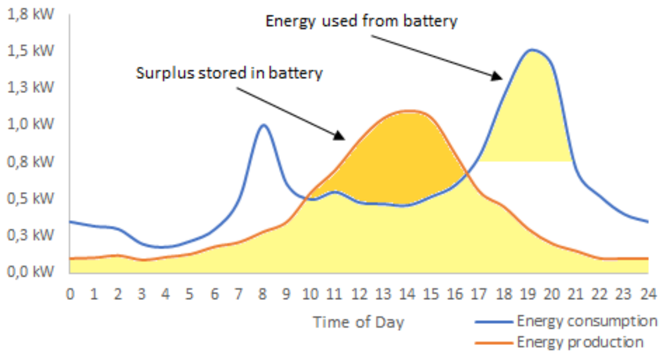

Figure 6. Prosumer energy consumption profile (with photovoltaics and battery)

For P2P trading of energy, SMs on the prosumer side need to meet certain requirements, which are discussed in the following sections.

4. Smart meters in P2P trading

In P2P energy trading systems, customers can consciously decide from whom they want to buy energy. For reasons of sustainability, the energy generated from renewable energy sources should be preferred. Using the data provided by SMs in P2P trading for prediction of supply and demand of renewable energy, customers' consumption of energy could also be adjusted. This would lead to a more sustainable P2P trading system, where existing energy at a certain time is used efficiently which reduces the energy demand at a later time.

Especially in the P2P trading market a smart metering solution is required which is able to actively participate in the shared grid infrastructure. This system has to report electricity consumption values and trends. Additionally, it has to provide information for P2P trading to enable it. Such information is:

- Current demand of power consumption by a household / SME
- Total power budget available for trading in the (micro) grid shared (sub-)infrastructure
- Tariff and / or price per kWh of redundant power to be used
- Price for using / renting the infrastructure (distribution costs) for such a model
- Length of the contract (for example one hour) and smart contract block chain evidence
- Amount of electricity units to be contracted
- Guarantee power supply to be provided for at least contacted time frame and for agreed unit price

The role of SMs in such a situation is to provide control over the implementation phase of a smart P2P contract. As such, the internal real time clock accuracy and synchronization should be not lower than 5 milliseconds. Because of the nature of smart contracts, SMs used in a smart contract enabled grid infrastructure (with tariff less trading) have to be able to store enough historical values. Therefore, ordinary SMs, which are primary oriented on distributed infrastructures and based on tariff templates, will not be suitable for this scenario.

Smart metering solutions available on the market differ in several aspects. After IEC/AS Standard 62053-22, which defines accuracy standards of SMs and IEC/AS Standard 60044-1, which defines accuracy classes for current transformers, the minimum accuracy level (we count only on transformer connected SMs) must be 0.5 S (or better 0.2 S) in order to be able to provide a fair smart contract for parties involved even in low power demand conditions.

5. Technology / protocols

From the standardization point of view, SMs can be divided into two groups:

- SMs using proprietary communication protocols and protection. Backward compatible with SM standard protocols such as Device Language Message Specification (DLMS) or PRIME Alliance.
- SMs using standardized metering devices, certified by DLMS and / or PRIME Alliance.

The first group is mainly intended for island or isolated smart grid installations, where no interactions with other smart grid domains are expected. This usually leads to vendor lock-in situations. Most of the smart grid solutions use standardized and certified interoperable equipment to be able to exchange information not only within the same grid (domain), but also neighboring grids which are supporting the same communication languages. To enable this, xDLMS, a compatible extension to DLMS was introduced in order to provide a business domain-orientated interface model for smart metering devices. However, for P2P trading we only need selected elements of the xDLMS protocol structure and can avoid parts intended for energy distributor purposes.

6. Data quality

Data quality is also an important topic, which shall be regarded in the context of P2P energy trading. All parts of the subsystem can affect data quality. This starts at the very low layer, where the signals are tapped from the grid lines, as can be seen in the upper left part of Figure 7.

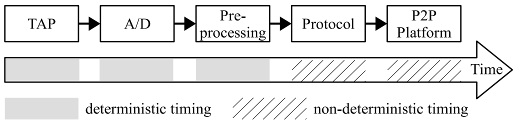

Figure 7: Timing of data acquisition process

Figure 7 shows the complete data acquisition process with the corresponding deterministic and non-deterministic timing. Also the timing of the whole system must be known. Some blocks have non-deterministic timing, which can lead to problems if the fluctuation rate of supply and demand is higher than the data processing by the P2P trading layer.

Besides business-related impacts, like losses on both consumer and producer side, this may also disturb a proper matching of demand and supply, leading to a destabilization of the power grid.

7. Conclusion

In this paper, we discussed P2P trading principles and necessary SM requirements for smart grids. First, the energy pricing for end-users / consumers on the Czech and German energy market are reviewed. The different tax rates are a crucial part for the pricing and performance of P2B energy trading models. But also the components distribution and consumption were identified as an important part of the costs. Their reduction due to innovative trading scenarios could be the crucial motivation factor for the spread of P2P trading.

With the spread of smart metering devices in combination with the necessity to integrate a rising number of renewable energy sources, enabling prosumers and smart appliances can be a main indicator for more sustainability in a future power grid infrastructure. For the different business models of P2P energy trading systems we also considered minimum accuracy levels derived from accuracy standards. Then we proposed minimum protocol requirements for SMs and contracting. Finally, we accentuated the necessity for high data quality during the acquisition process from the smart meters when the data is to be used for P2P trading and also considered possible impacts.

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Christina Sigl (M.Sc.)

Christina Sigl received her M.Sc. degree in Applied Computer Science from Deggendorf Institute of Technology (DIT) in 2018. Since 2014, she is part of the research team Embedded Systems at the Institute for Applied Informatics at Technology Campus Freyung, which is one of DIT's research institutes. There she works in international projects with a research focus in the fields of Machine Learning, Artificial Intelligence, Virtualization, Industry 4.0 and Smart Grids.

Christina Sigl erhielt 2018 ihren M.Sc.-Abschluss in Angewandter Informatik an der Technischen Hochschule Deggendorf (THD). Seit 2014 ist sie Teil der Arbeitsgruppe Eingebettete Systeme am Institut für Angewandte Informatik am Technologie Campus Freyung, welcher eine Einrichtung der THD ist. Dort arbeitet sie in internationalen Projekten mit Forschungsschwerpunkten im Bereich Machine Learning und Künstliche Intelligenz, Virtualisierung, Industrie 4.0 und Smart Grids.

Contact / *Kontakt*
✉ **christina.sigl@th-deg.de**

Dipl.-Inform. Siegfried Hildebrand

After a career in the mechanical engineering sector, Siegfried Hildebrand studied computer science with a minor in business administration at the University of Hagen. In addition to working as a freelance system administrator and developer of tools for DVD/MPEG stream processing, he completed his studies with a focus on computer security and software engineering in 2015. Since March 2016 he works as a research assistant at the DIT. In the project "NePUMuk" he developed experimental (vector) algorithms and industry 4.0 concepts to improve etching quality of the PCB production in Teisnach. In the current project "Smart Grid" at the Technology Campus Freyung, a collaborative industry 4.0 production facility is being researched with regard to demand side management and predictive maintenance. Mr. Hildebrand's research focuses on efficient algorithms, cryptography and computer security, embedded systems and data analysis.

Nach einer Laufbahn im Maschinenbaubereich studierte Siegfried Hildebrand Informatik mit Nebenfach Betriebswirtschaftslehre an der FernUniversität in Hagen. Neben Tätigkeiten als selbstständiger Systemadministrator sowie Entwickler für Tools für die DVD/MPEG-Streamverarbeitung schloss er 2015 sein Studium mit den Schwerpunkten Computersicherheit und Software Engineering ab. Seit März 2016 arbeitet er als wissenschaftlicher Mitarbeiter an der THD. Im Projekt „NePUMuk" entwickelte er experimentelle (Vektor-)Algorithmen und Industrie-4.0-Konzepte zur Verbesserung der Ätzqualität der Leiterplattenfertigung in Teisnach. Im aktuellen Projekt „Smart Grid" wird am Technologie Campus Freyung eine kollaborative Industrie-4.0-Demonstrationsanlage hinsichtlich Demand Side Management und Predictive Maintenance untersucht. Die Forschungsschwerpunkte von Herrn Hildebrand liegen in den Bereichen effiziente Algorithmen, Kryptographie und Computersicherheit, Embedded Systems sowie Datenanalyse.

Contact / *Kontakt*
✉ **siegfried@hildebrand.pro**

Alexander Faschingbauer (M.Sc.)

Alexander Faschingbauer received his M.Sc. in Electrical Engineering and Information Technology at the University of Hagen in 2015. He is leader of the workgroup Embedded Systems at Institute for Applied Informatics at Technology Campus Freyung, one of DIT's research institutes. As a senior scientist, he works in international research projects and is a specialist for signal analysis in combination with software defined radio and machine learning methods.

Alexander Faschingbauer erhielt seinen M.Sc.-Abschluss in Elektrotechnik und Informationstechnik an der FernUniversität Hagen im Jahr 2015. Seitdem leitet er die Arbeitsgruppe Eingebettete Systeme am Institut für Angewandte Informatik am Technologie Campus Freyung der Technischen Hochschule Deggendorf. Als wissenschaftlicher Mitarbeiter ist er in internationalen Forschungsprojekten tätig und auf Signalanalyse und Software Defined Radio in Kombination mit Machine Learning-Methoden spezialisiert.

Contact / *Kontakt*
✉ **alexander.faschingbauer@th-deg.de**

Prof. Dr. Andreas Berl

Andreas Berl has majored in computer science and minored in psychology at the University of Passau in 2005. Subsequently, he was a visiting scientist at the computing department at Lancaster University (United Kingdom), funded by a DAAD scholarship, before he achieved his Ph.D at the University of Passau in 2011. He continued teaching and researching at the University of Passau for several years, mostly in EU funded research projects. Since 2015, he holds a professorship in computer science at DIT's Faculty of Applied Informatics. His research interests comprise computer networks, virtualization, smart grid and electromobility.

Andreas Berl hat sein Studium der Informatik mit dem Nebenfach Psychologie an der Universität Passau im Jahr 2005 abgeschlossen. Nach einem Aufenthalt als Gastwissenschaftler am Computing Department der Lancaster University (Großbritannien), der durch ein DAAD-Stipendium finanziert wurde, schloss er 2011 seine Promotion zum Doktor der Naturwissenschaften an der Universität Passau ab. Anschließend arbeitete er einige Jahre im Bereich der Lehre und Forschung an der Universität Passau, überwiegend in europäischen Drittmittelprojekten. Seit Februar 2015 hat Andreas Berl die Professur für Grundlagen der Informatik an der Fakultät für Angewandte Informatik der THD inne. Seine Schwerpunkte in der Forschung sind Vernetzte Systeme, Virtualisierung, Smart Grid und Elektromobilität.

Contact / *Kontakt*
✉ **andreas.berl@th-deg.de**

Jakub Geyer (Mgr.)

Jakub Geyer received his Master's degree in applied informatics at the University of South Bohemia (USB) in České Budějovice (Faculty of Science) in 2015 and is currently a doctoral student. He worked as a system engineer and IT administrator for CD Cargo, a. s. from 2010 to 2017 and has been working as an assistant lecturer and researcher at the USB since 2017. His fields of expertise are database systems, .NET development (desktop/web applications, SharePoint, Xamarin) and 3D modeling and printing. He has participated in the international research projects SmartGrid, BarkBeeDet, ELIXIR-CZ and MAID.

Jakub Geyer absolvierte 2015 seinen Master-Abschluss in angewandter Informatik an der Südböhmischen Universität Budweis (Naturwissenschaftliche Fakultät) und ist derzeit als Doktorand tätig. Von 2010 bis 2017 arbeitete er als Systemingenieur und IT-Administrator bei CD Cargo, a. s. und ist seit 2017 Lehrbeauftragter und Forscher an der Südböhmischen Universität. Seine Fachgebiete sind Datenbanksysteme, .NET-Entwicklung (Desktop-/Webanwendungen, SharePoint, Xamarin) sowie 3D-Modellierung und -Druck. Er hat an den internationalen Forschungsprojekten SmartGrid, BarkBeeDet, ELIXIR-CZ und MAID mitgewirkt.

Contact / *Kontakt*
✉ **geyer@prf.jcu.cz**

Rudolf Vohnout (Ing. Ph.D.)

Rudolf Vohnout received his M.Sc. degree in the area of transport engineering and control with a focus on transport networks from the Jan Perner Transport Faculty at the University of Pardubice in 2005. In 2014, he obtained his Ph.D. in the field of computer science at the University of Economics Prague (Faculty of Informatics and Statistics). Since 2008 he is an assistant professor at the USB and in 2019 has been promoted to the head department where he is, amongst other duties, responsible for cross-border (DE and AT) research and educational cooperation. Since 2011 he has been working in the optical networks project of the R&D Department of CESNET, a.l.e. He participated in numerous national and international research projects (including FP7 and H2020). He has published several journal papers from the area of optical networks and security.

Rudolf Vohnout absolvierte 2005 an der verkehrswissenschaftlichen Fakultät der Universität Pardubice seinen Master-Abschluss im Bereich Verkehrstechnik und -steuerung mit Schwerpunkt Verkehrsnetze. Im Jahr 2014 promovierte er im Bereich der Informatik an der Wirtschaftsuniversität Prag (Fakultät für Informatik und Statistik). Seit 2008 ist er Assistenzprofessor an der Südböhmischen Universität Budweis und wurde 2019 zum Institutsleiter befördert. In dieser Funktion ist er unter anderem für die grenzüberschreitende (Deutschland und Österreich) Forschung und Bildungszusammenarbeit zuständig. Seit 2011 arbeitet er in einem Projekt zu optischen Netzwerken der F&E-Abteilung von CESNET, a.l.e. Er wirkte in zahlreichen nationalen und internationalen Forschungsprojekten mit (einschließlich FP7 und H2020). Er hat mehrere wissenschaftliche Artikel im Bereich optische Netzwerke und Sicherheit veröffentlicht.

Contact / *Kontakt*
vohnout@prf.jcu.cz

Miloš Prokýšek (PhDr. Ph.D.)

Miloš Prokýšek received his M.Sc. degree from the University of South Bohemia (USB) in České Budějovice (Faculty of Education) in 2004 and his Ph.D. in the field of pedagogy from the Charles University in Prague (Faculty of Education) in 2012. He has been an assistant professor at USB's Faculty of Education since 2005 and at the Faculty of Science since 2009. In his pedagogical works he focuses on technical educational means, especially the role of spatial visualization and its influence on cognitive processes. Additional research focuses are data processing, software development and applied computer science. He participated in many national and international research and cooperation projects (including INTERREG, H2020, TACR). He is also engaged in the Smart City initiative in the town of Písek.

Miloš Prokýšek absolvierte 2004 seinen M.Sc. an der Südböhmischen Universität in České Budějovice (Pädagogische Fakultät) und erhielt 2012 seinen Doktortitel im Bereich Pädagogik an der Pädagogischen Fakultät der Karls-Universität in Prag. Seit 2005 ist er Assistenzprofessor an der Pädagogischen Fakultät und seit 2009 an der Naturwissenschaftlichen Fakultät der Südböhmischen Universität. In seiner pädagogischen Arbeit konzentriert er sich auf technische Hilfsmittel im Bildungsbereich, insbesondere auf die Rolle der räumlichen Visualisierung und deren Einfluss auf kognitive Prozesse. Weitere Forschungsschwerpunkte sind Datenverarbeitung, Softwareentwicklung und angewandte Informatik. Er wirkte in vielen nationalen und internationalen Forschungs- und Kooperationsprojekten mit (u.a. INTERREG, H2020, TACR). Darüber hinaus engagiert er sich im Rahmen der Initiative "Smart City" der Stadt Písek.

Contact / *Kontakt*
prokysek@prf.jcu.cz