METER DATA MANAGEMENT – FROM THE SMARTER GRID TO FUTURE MARKET PLATFORMS IN LIBERALIZED ENERGY MARKETS

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ABSTRACT

The paper discusses the impacts of the regulatory framework for energy market liberalization in Germany. Especially the liberalization of the metering business, which highly interrelates with further information services, could result in the needed transparency for an efficient energy market. Whilst the status quo of current regulations already enables new business opportunities, the upcoming amendment of the Energy Industry Act could remedy the existing drawbacks. Additionally, we explore the dimensions of metered data exchange within the scenario and stakeholder analysis of smarter grids and future electronic energy marketplaces. Based on the scenario analysis, we define the architecture and functionalities of a meter data management system that satisfies the currently known requirements and can be extended to meet future needs of the smarter grid applications and electronic marketplaces.

INTRODUCTION

The liberalization of the metering business in Germany is fully in progress since the "Act for Opening the Metering of Electricity and Gas for Competition" passed in September 2008. The energy user is now able to choose the metering service provider, whereas in the past, the distribution system operator was responsible for providing the metering service. The bill is accompanied by other acts, such as the obligation to install smart meters since January 2010 and the rights of end users to require monthly bills and variable tariffs the latest in December 2010.

Alongside the regulatory implications, the increasing penetration of distributed energy resources has a positive impact on the metering business. All market actors have an increased need for timely and accurate meter data, in order to realize the new potentials of innovative energy products. The 2011 amendment of the Energy Industry Act will certainly carry on the requirements for enabling better energy efficiency, open markets, and energy supply reliability based on the availability of reliable information on the actual energy quantities. Players in the metering and information services business will truly thrive in the competitive market, if they are able to take on the challenges such as measuring mobile consumption of electric vehicles or distributed feed-in of renewable energy accurately, whilst aggregating actionable information from the massive amounts of meter data. The research in the smart grid domain gained momentum. Incentive-based mechanism such as demand response, feed-in tariffs are considered to be more viable than sheer command and control for a smarter grid – especially in the distribution level. The German E-Energy Program elected six model regions in which such incentive-based paradigms shall be tested. In E-DeMa [1], one of the model regions, the focus lies on the feasibility of a mass roll-out. This requires a high degree of process automation at the business level as well as at the field level. Such automation can only be gained via efficient management of data. In the following sections, we will summarize our scenario and stakeholder analysis and deduct the main requirements for a future-proof meter data management system.

SCENARIO & STAKEHOLDER ANALYSIS

The status quo of the interconnections of processes and data exchange agreements between the market roles [2] is depicted in Figure 1. The challenges of the status quo are recognized both within the third provisions on the European Single Market and accordingly in the proposals for the 2011 amendment of the German Energy Industry Act [3]: Unbundling will be consequently carried out to separate the transmission network from generation and distribution. This additionally increases the data exchange and market communication efforts for the transmission system operators, but will also increase the needed information transparency of the market. It is recognized that variable tariffs enable an active involvement of the end user in the energy market. However, such variable tariffs are only economically viable if smart meters are used for accountability. Hence, faster deployment of meters shall be fostered. Another amendment regarding variable tariffs is that retailers shall be able to use their own forecasts on how much energy will be consumed based on actual metered data instead of standardized load profiles given by the distribution system operator. This also magnifies the independent role that energy retailers should embrace within a liberalized market. In Figure 1 the result of this amendment is depicted by the bold arrows representing the additional data flow from metering service providers to the retailers. Each retailer is then responsible to manage the metered data, especially to forecast the delivery schedule based on the actual metered data and report the schedule to the balance responsible party.

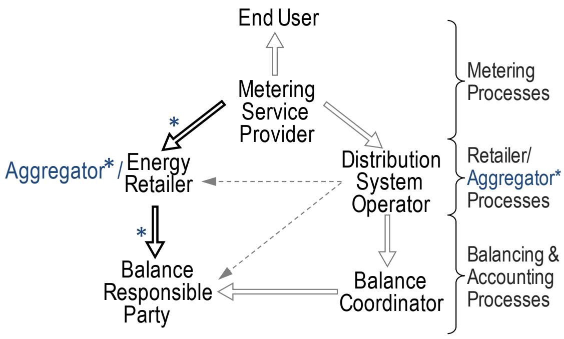

Figure 1. Market roles, data exchange agreements, and associated processes: status quo, the 2011 amendment, and future market roles

Aggregator – The New Market Role

The amendment proposal also favors a contracting of interruptible loads as a commercial opportunity for owners of such loads. Interruptible loads can for example be HVAC, heat pumps, or electric vehicles in the future. Interruptible loads shall be contracted by the distribution system operator. These contracts shall take precedence over emergency disconnects. Contracting interruptible loads not only generates a revenue stream for their owners but also represents a cost-effective contribution to the integration of intermittent energy sources into the market. However, the transactional costs of the contracting may be very high for individual owners as well as for the distribution system operator. In the E-DeMa project, we define a new market role of the aggregator (marked with * in Figure 1), who bundles such interruptible loads into an efficient portfolio. For the contracting parties, the aggregator represents a market role that can take on the financial risk of applying load interruption. For the aggregator that risk is much more manageable than for the individual owner, since the aggregator can manage the bigger portfolio according to forecasts and metered data, whereas individual load owners would have less flexibility.

The aggregator role will also be needed for decentralized energy generation units, such as cogeneration and photovoltaic units, that retire from the renewable energy act and cogeneration act aid programs. The aggregator can then manage a portfolio of the decentralized energy feed-in with a much higher margin on the wholesale market than each individual could. It is to be assumed that such aggregation of distributed feed-in is necessary to be able to enter the wholesale market or even over-the-counter markets.

The aggregator needs to be part of a balancing group per definition. Regarding interruptible loads, the aggregator would disturb the schedule of the retailer of these loads. Either the aggregator needs to compensate for the schedule disturbances caused for the energy retailer, which would lower the margins – or the aggregator needs some sort of partnering with the retailer. The partnering may involve a special delivery tariff for interruptible loads separate from the other loads of the premises. In case of separate tariffs for interruptible loads, there also need to be dedicated smart meters for each contract, which implies increased data exchange efforts – but also a better accountability (arrows marked with * in Figure 1). Special tariffs or compensation for the retailer are necessary if the aggregator manages the interruptible loads according to the requirements of the distribution system operator. Another type of partnering with the retailer would involve that the aggregator is managing the portfolio of interruptible loads according to the requirements of the retailer, e.g. to compensate for schedule forecast errors of the retailer in order to minimize the balance settlement costs. Via the feed-in aggregation of unaided decentralized energy generation, the aggregator can offer such a service to the retailers or the balance group responsible parties.

Future Electronic Energy Market Platforms

The increasing need for accurate and timely metered data preprocessed according to the needs of each market actor could result in close partnerships with metering service providers. Standardization of data exchange processes and data formats are required. However, the quality of this information service is also a differentiation factor between the metering service providers, which on the other hand directly influences the performance of retailers in their customer processes, the forecast for variable tariffs and tariffs for interruptible loads or mobile consumption. Retailers and the new players such as aggregators are not the only parties affected by the quality of metered data exchange. Network operators in their venue to perform under incentive regulation with increased requirements for information transparency and efficiency place a complete set of different requirements on the metering service providers. At the same time, the metering service providers must fulfill the requirements of the end user for more information and increased energy efficiency through metered data transparency. The end user ultimately will choose the metering service provider at the metering point of interest for all other parties involved in accounting and balancing of the energy quantities.

Whilst there is a definitive need for basic standards in metered data exchange, there also are increased business opportunities for information service providers, who create value added information services on top of the metered data. Such information service providers can focus on meter data management according to the needs of each market role and process the smart meter data as well as other data sources according to the specific needs of one or more market actors including the end user. The basic grounds for such an ecosystem would be a data exchange platform, e.g. a data clearing house. With a data exchange platform all parties involved can access the required metered data in a timely and accurate manner. The main purpose of the data exchange platform is to aggregate and route the metered data from multiple metering service providers to the respective recipients. The information service providers can dock onto the platform with specific value added information services for the market partners.

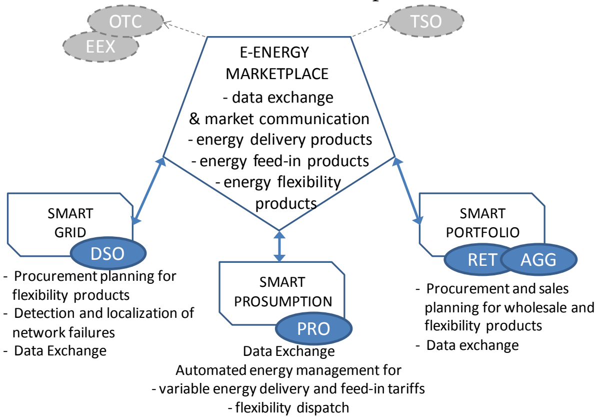

Figure 2. The future scenario of E-Energy marketplaces.

In E-DeMa there is the more advanced concept of an E-Energy Marketplace for 2020 as depicted in Figure 2. In addition to being a data exchange platform according to the requirements of the market communication standards, the E-Energy marketplace also handles contracts for innovative tariffs for both energy delivery and distributed feed-in as well as diverse energy-related services. The electronic marketplace enables new actors to play an important role in the energy market of the future: the energy prosumer (PRO), who is the energy end user with on-site energy generation capabilities and interruptible loads, as well as the aggregator (AGG), who aggregates the resources of the prosumers into dealable blocks of flexibility. Flexibility is the capability to increase or decrease load on the power network as well as the capability to generate additional energy on short notice. Retailers (RET) can also create added value to the resources of prosumers by offering energy products with variable tariffs. Retailers then take advantage of the flexibility of prosumers by means of price signals on which the end users (or their home/building automation facilities) react by shifting load to off-peak times. Retailers could also contract aggregate flexibilities of prosumers in order to compensate for any forecasting errors in their procurement processes. Distribution system operators (DSO) need localized flexibility on short notice, especially in areas with intermittent feed-in of power from renewable energy sources. The distribution system operator can contract aggregated flexibility of end users in an affected area. Additionally, the distribution system operator would also have the possibility of realizing monetary incentives for flexible prosumers through the introduction of variable network usage charges.

The aggregator as a new role realizes a new business model. Based on the demand of retailers and distribution system operators, the aggregator contracts the resources of the prosumers. These resources are any combination of the on-site energy generation and interruptible loads coupled with on-site storage (e.g. electro-vehicles). Through aggregation, these locally small resources become dealable quantities, with which retailers and distribution system operators can counteract the imbalances in their respective systems. In order to handle the resources on a mass-scale the aggregator needs a higher degree of automation in the premises of the prosumers. Such automation can be realized in home or building automation systems, in which the automation gateway is additionally equipped with the logic to control the resources of the prosumer. The control logic optimizes the local energy generation, usage, and storage based on parameters given by the aggregator as well as the preferences of the prosumer. The entire optimization process depends on the metered data to prove the contract fulfilment and to control the parameters to assure a correct settlement. The marketplace may also enable an electronic linkage to the energy exchange (e.g. EEX), over the counter (OTC) systems or the systems of the transmission system operator (TSO).

The prosumer realizes an added value by engaging in contracts with the energy retailers, aggregators and directly or indirectly with the distribution system operators. The home or building automation system on the premises of the prosumer is part of this value network, since it is needed to coordinate the aggregate resources on a mass-scale. Sole dependence on user behaviour is not viable for the scenarios summarized here. The prosumer as well as the automation system depend on metered data to form preferences and to optimally employ the resources on the premises.

In a nutshell all of the actors would profit from metered data when planning ahead, but they also need timely metered data for control, billing and charging of the new products that add value to the flexibility of the prosumer. Whilst information gained through meter data management would reduce forecast and planning errors even today, in the future scenarios such information is indispensible. On the E-Energy marketplace the actors are enabled to exchange their offerings. For this purpose an accurate and timely metered data exchange is needed.

The following Section introduces the meter data management system design that is able to fulfil the requirements of the stakeholders in the scenario of smarter grids and future E-Energy marketplaces.

SYSTEM DESIGN

The summarized stakeholder analysis shows that some meter data management is needed by all of the actors for their different use cases. We cluster these under "value-added services" of a meter data management system. One important feature of the E-Energy marketplace, however, is that it offers actionable metered data on all the contracted activities of the marketplace actors. For this basic service of the marketplace "basic features" are required from the meter data management system. The architecture of the meter data management system must be modular in order to realize all combinable capabilities. One way to realize this modularity is to define a "service bus," which enables a loose coupling of the system modules within one organization as well as between the organizations of the actors. The depiction in Figure 3 shows the modular system architecture. The modular architecture allows for the replacement or enhancements of the individual features and services without compromising the functioning of the whole as a system. This is independent of whether the system modules are deployed by one market role or distributed among the different market roles based on their needs.

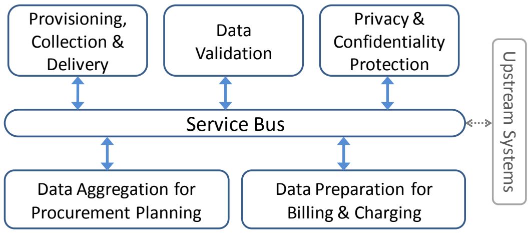

Figure 3. The required modularity of the basic features and advanced value-added services for an extendible meter data management system design.

Basic Features

The basic features ensure the timely collection and validation of the data from smart meters. Whilst collection processes is also concerned with the rest of the advanced metering infrastructure including its provisioning, the validation of data ensures that any errors in configuration or operation of the smart meters are revealed. The data validation must also review the incoming data for events subscribed by the different modules of the meter data management and upstream systems. Another important basic feature is the assurance that information is filtered before being delivered into an upstream system according to the principle of data minimization.

Contract-based Provisioning, Data Collection and Delivery

The meter data management system requires the information about how data needs to be collected from each metering point based on the contract of the metering point. According to the scenarios this can be a contract for energy delivery or feed-in with a variable time- or load-dependent tariff, a variable network usage tariff as well as a flexibility dispatch on energy production or consumption. The meter must record the actual consumption or the actual production in the needed granularity (e.g. 15 minute intervals or event-based). The meter data management system must collect and deliver the data from the meter in the intervals required by the upstream systems of the market roles, e.g. once a day, or event-based. These requirements for data collection and delivery are according to the value-added services that shall be realized based on the metered data. This module of the meter data management realizes the link between the contract (i.e. business process level) and the metering point (i.e. field process level). Such a linkage is indispensible if tariff and retailer changes are to be automated and as fast as required by the deployment of a future E-Energy marketplace.

Data Validation

Considering that each energy market transaction depends on metered data, the validity of meter data is crucial. In the future with complete roll-out of smart meters, increased dynamics through distributed generation and demand response and the deployment of electronic energy marketplaces the importance and challenge of data quality will even increase. Hence, data validation techniques must be easily incorporated into the meter data management system. Context-based data validation will gain more importance as the energy markets depart from the passive consumption patterns to more active and dynamic consumption and productions patterns of the prosumer. The validity of data is indispensible in order to make the innovative E-Energy marketplace products accountable on a mass-scale. Sophisticated algorithms are to be deployed validating the data stream of each meter based on the contract of the metering point, as well as external influences such as weather conditions, manipulation, and other events. For a smarter grid validating the data stream can help detect and localize cascading imbalances or component failures in the distributions system. For this purpose a rule engine within the module must trigger appropriate alarms into an upstream SCADA system in case of anomalies in the data stream. Detecting errors from the data stream through validation also brings about advantages for the metering service provider. Workforce automation can be realized by linking an appropriate trigger to the appropriate data stream patterns. This module of the meter data management system enables upstream systems of the market roles to work with valid data as well as to trigger appropriate processes in case of validation errors.

Privacy and Confidentiality Protection

The future scenarios enable the prosumer to take on an active role in the energy market. However, the requirement of accountability of the offered flexibility products in turn requires more fine-grained data about local consumption and production. In case of private households the concerns about privacy arise. In case of commercial and industrial prosumers there is a concern about confidentiality. Because in both cases the energy consumption and production patterns may reveal a profile that those parties are not willing to share with any other party. This module of the meter data management system acts as a filter. Before data is delivered to another upstream system this module ensures that the amount of data delivered adheres to the principle of data minimization. Data minimization requires that only data needed for a value-add is delivered, and if possible is delivered only in the pseudonymized or anonymized (i.e. aggregate) form.

Value-added Services

Value-added services provided by a meter data management system encompass the processing of raw data into actionable information required by upstream systems of the different market roles. As identified in the scenario analysis, one such upstream system is procurement and sales planning. Procurement planning requires different information when deployed with the different market roles. Especially that what is to be procured varies from role to role. Another important upstream system is billing and charging. Depending on the contract of the metering point, also different contract-based requirements apply for generating billing information from usage and feed-in data.

Data Aggregation for Procurement and Sales Planning

The metered data of interest for procurement and sales planning is historical as well as actual and projected. The procurement planning system would be overwhelmed by the sheer management of data if it was to be delivered without any pre-processing.

Procurement and sales planning for retailers in the future E-Energy marketplace scenario consists of keeping the balance between the forecast consumption and the actual consumption by balancing the flexibilities of the contracted prosumers with the actual available energy. The balancing can be realized either indirectly through an aggregator or directly by influencing the flexibilities of the contracted prosumers via price signals in the variable tariffs for energy delivery. The pre-processing for the retailer procurement and sales planning involves the aggregation of meter data into contract-based groups: i.e. all metering points with a certain type of contract are marked with a retailer-contract-specific identifier only known to the retailer.

The procurement concerning the feed-in contracts of an aggregator is analogue to the procurement and sales planning of the retailer. The procurement of the flexibilities for selling to the distribution system operator, however, differs as it is additionally topology-bound. For the distribution system operator will always demand flexibilities near to network areas that are affected by an imbalance. So in addition to the contract-based group identifiers, the aggregator will use the topology-based identifiers only known to the aggregator.

The balancing function of the future procurement planning system of a distribution system operator takes into account the contracts with aggregators as well as the variable network usage tariffs with the prosumers. Both are topology-based. Hence, the according meter data is to be aggregated based on topology-dependent group identifiers only known to the distribution system operator.

The meter data management system then solely aggregates the meter data in groups of the given identifiers. The information for each group is then delivered as an aggregate to the respective procurement planning system. The information is anonymized and fully satisfies the requirement of the value added service without revealing any personal data of the prosumer or confidential data of the retailer, aggregator or of the distribution system operator.

Data Preparation for Billing and Charging

The metered data of interest for billing and charging is the pre-processed information of total consumed or produced energy according to the specific E-Energy marketplace product. We differentiate between time-dependent, load-dependent, and flexibility dispatch tariffs for both energy consumption and feed-in. Time-dependent variable tariffs will mostly have a predefined time pattern in which the prices may change variably. The respective tariff slots of a product are known and meter data can be aggregated in the given time slots for the entire billing period. The other cases, i.e. with real-time pricing, load-variable tariffs as well as flexibility dispatch, are always event-based. The event, e.g. price change event, power rating limit under-/overshooting event or flexibility dispatch event, may happen at any given time or on notice as short as an hour to 15 minutes for a variable duration. The respective tariff slots of the product are only known at the end of the event and the meter data can only be aggregated after an event is over.

The billing systems of the market roles would be overwhelmed by the sheer amount of meter data and event management if meter data was to be input without any pre-processing. As the examples of innovative products show, meter data needs to be aggregated according to predefined time slots or events by the meter data management system. At the end of the billing period, only the aggregated meter data is delivered into the upstream billing system of each market role according to the tariff identifiers known only to that market role. It is important to note that the meter data management system does not need any knowledge about the confidential price information. In the respective billing system of each market role then the prices of the billing period are overlaid on the aggregated meter data to charge or compensate the prosumer.

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