ENERGY DATA FLOW IN SMART GRIDS - A CONCEPTUAL MODEL FOR ADDRESSING VARIOUS USE CASES

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ABSTRACT

An increased need for intensive data in support of power systems operation and market underlies the changes in the layout of the electrical networks. The availability of the data at the required time and frequency is becoming a necessity, and a model-based approach is needed to regulate the data flow and coordinate the technical and business functions between the different stakeholders in the network stating from the generation and ending at the consumption level. An energy data flow model and mechanism is provided in this paper for the data flow within the smart grid infrastructure in order to organize the integration process of the renewable energy within the existed energy utilities.

INTRODUCTION

The increase in decentralized renewable energy sources has created the need for greater coordination between both market actions and grid operations. The transitioning process for the distribution network from passive mode to active mode requires more coordination between the DSOs and TSOs in order to enhance renewables integration through advanced, scalable and secure ICT systems. Smart grid infrastructure is based on unrestricted data flow between the different parts of the grid in order to ensure flexible and reliable services through the different stages of the operation of the network and different time scales.

Information infrastructure is essential in order to meet the challenges of future business models and technical management in terms of providing connectivity between market actors and devices. This interaction between the different stakeholders should be facilitated through the design of an appropriate data exchange platform. However, this platform is also expected to have the potential to provide a flexible interface between energy data users and energy data sources and transfer data between these two parties. Such an interface can be organized by providing a mechanism that handles the data management in energy networks by providing several use cases and scenarios for the data and energy services.

The high-level use cases for the data flow are defined in this paper as an input for the smart grid conceptual model that was adopted by the National Institute of Standards and Technology (NIST) [1], which shows the interaction among different domains. This interaction between domains in the smart grid could be performed using the Advanced Metering Infrastructure (AMI) that represents the gateway of the access for the different stakeholders such as DER and DG. Although some efforts have been made to define the (AMI) by New York State Electric and Gas Company (NYSEG), there is no specific standardized documents for the AMI operation, which could be an open area for more developments regarding the standards and operations types [2]. Therefore, this paper focuses on creating a conceptual model based on the defined use cases in order to provide a real-time data for the control center or different stakeholders that are associated with the NIST domains.

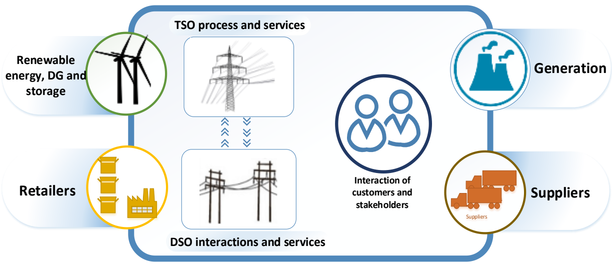

Figure1. The Interaction between the different stakeholders in the electrical energy market

The integration of renewable energy and the continued transformation of distribution networks from passive to active mode increases the need for enhanced cooperation between the DSO and the TSO within a mechanism that reflects the smart grid concept and the new stakeholders' interaction as seen in figure 1. The provided use cases strategy in this paper enhances the coordination of the generation and consumption process between the DSOs, TSOs and generation sector including the existence of the renewable energy sources, in that it supports the bidirectional behavior of the data and energy flows.

USE CASES APPROACH

The Use Case (UC) approach based on the IEC System Committee for Smart Energy does provide a meaningful as well as structured way to elicit requirements for the cooperation between the stakeholders in the energy sectors such as the TSO and DSOs. Various use cases have been provided in the work packages of TDX-ASISST project to and their evaluation will be aligned between the DSO to market as well as DSO-TSO levels [2], [3]. The use cases provide a meaningful way for requirements elicitation, which will then be part of the SGAM modelling of the technologies and, finally, provide the important inputs for the system architecture to be developed in TDX-Assist project [2], [3].

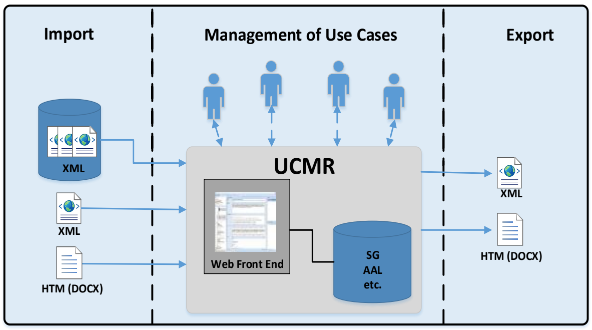

Figure 2. Proposed architecture for UC management

As seen in figure 2, this possible system has been implemented at OFFIS as so-called UCMR (Use Case Management Repository). The Use Case Management Repository (UCMR) is a web-application developed by OFFIS for the creation, management, and exchange of Use Cases as well as further related data, like architecture models, actor and requirement libraries. The template for the Use Cases is based on the IEC 62559-2 Use Case Template. The Use Case Template is used to describe a system behavior in a detailed manner from different perspectives. Therefore, management and technical perspectives are supported to describe the same system behavior in two different but complementary ways.

The main contribution of the introduced Model is to deliver important background and scoping material to the evaluation of the TSO-DSO cooperation. Furthermore, the main objective is to support unlocking the European Electricity Market for DSOs as well as market participants whose access is at distribution level. The envisioned progress beyond the state-of-the-art is the documented interface specifications between DSO and market participants based on IEC 62325 as well as coming up with a Role-Based Access Control (RBAC) towards those data platforms.

DSO TO MARKET INTERACTION

This section elaborates on the current possible DSO to market interactions exploring the clash between functional requirements from individual partners [2], [3] as well as regulatory challenges for a data exchange platform. Figure 3 shows traditional and emerging roles of parties from TDX-ASSIST project's point of view in the context of DSO and market interoperability. DSOs, the regulator, suppliers and the customer can interact as indicated by the solid connections to improve robust customer choice. Further parties are making new influences now, however, as indicated by the dashed connections, in order to facilitate energy transitions. Municipalities pursuing energy masterplans are exerting influence, and can be supported by the deployment of markets and even microgrid developments. Aggregators are playing play a market "facilitator" role, while suppliers increasingly play a market provider role, though mostly for those which are connected to the MV networks. TSOs are increasingly making requests of DSOs, and these entities may have concurrent access to resources, which opens key questions of how the DSOs interact with the market.

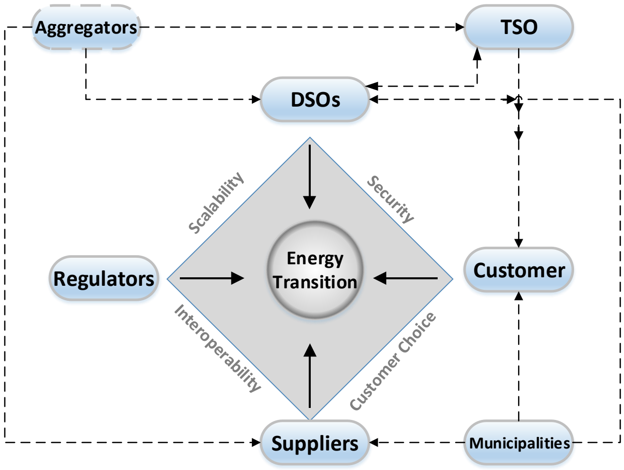

Figure 3. Interaction between the roles on the market

Data exchange platforms can be a tool to improve the coordination between those parties and to drive forth the market functionalities provided to and from the parties. Over the last years, it became apparent that the future efficient operation of smart grids and the emergence of new markets have a strong need for a more sophisticated and extensive data exchange. The aforementioned research and development projects proved that the optimization of operations of the new smart grid system is supported by providing high quality data to various stakeholders [4]. However, the data exchange was only slowly rising on the policy agenda of European regulators until today since ICT is usually only considered a supporting crosscutting function. Providing access to the data and elaborating on the roles needed has become an issue, as central data exchanges have been developed in various countries and shall be further developed in the near future. The integration of the wholesale and retail market as well as the possible customer empowerment can be part of this future development process. However, there is still- due to different regulatory issues, market structures, DSO structures and RES distributions as well as generation in buildings- no one-size-fits-all model for a central platform available. As those platforms become available, people and market players are asking for new emerging energy services to be provided to markets.
With the emerging processes needed for greater cooperation and the accompanying new interfaces being created, a lot of new requirements towards the data exchanges between the parties arise. The consolidated most prominent issues that are needed to be addressed in

UCs approach are as the followings [5], [6]:

- Properly take into account privacy and security
- Facilitate fair competition, virtuous markets and innovation.
- Provide data via a neutral party and ensure to non-discrimination
- Maintain the transparency and auditability of the data exchange.
- Facilitate transparency in the sector via data exchange.
- Offer a cost-efficient solution that is technical and organizationally simple.
- Create and use harmonized standards.

The need for a greater cooperation is driven not mainly by regulators, but by the new processes, and parties involved in the energy transition, and the need to make interactions efficient. Within TDX-ASSIST, we take into account the evolving Smart grid use cases and paradigms and try to adhere to the quality principles for the data being exchanged and propose a solution to achieve those principles.

ENERGY DATA PLATFORMS

The Thema Consulting Group report [5] on data exchange elaborates on three main aspects needed in the scope of DSO to market interaction: 1) what are data requirements of the different stakeholders in the electricity sector, 2) which jurisdictions, transmission and/or distribution, might be involved, and 3) which associated markets exist. In addition, an overview on the status of data exchange platforms (DEP) in the European market is provided and discussed for short-term and long-term requirements. The Thema report provides a good state-of-the-art analysis on the data requirements from various stakeholders, the status quo of the development of DEPs and future requirements. Based on this carefully documented information, TDX-ASSIST can evolve and implement its Data Exchange Platform (DEP) as well as provide answers to some open questions raised by the report on role mapping from Thema Consulting Group [7].

Access levels

The access of the domains could be determined according to the systems, components and technologies as the smart grid consists of systems and subsystems that communicate intelligently to provide reliable energy services. The interaction in the smart grid could be performed using the Advanced Metering Infrastructure (AMI) that represents the gateway of the access for different stakeholders such as DER and DGS. Although some efforts have been done to define the (AMI) by New York State Electric and Gas Company (NYSEG), there is no specific standardized documents for the AMI operation, which could be an open area for more developments regarding the standards and operations types [8]. However, the most significant role for the (AMI) is to provide a real-time data for the control center or the different stakeholders that are associated with the NIST domains. Therefore, the (AMI) has the potential to provide data that supports different technical and business operations such as the outage management, demand response, billing operation, voltage control, EV charging and balancing mechanism [8].

The access levels for the different systems, technologies and applications are specified as in figure 4, whereby the NIST domains are accessed by different components within various communication configurations and layers.

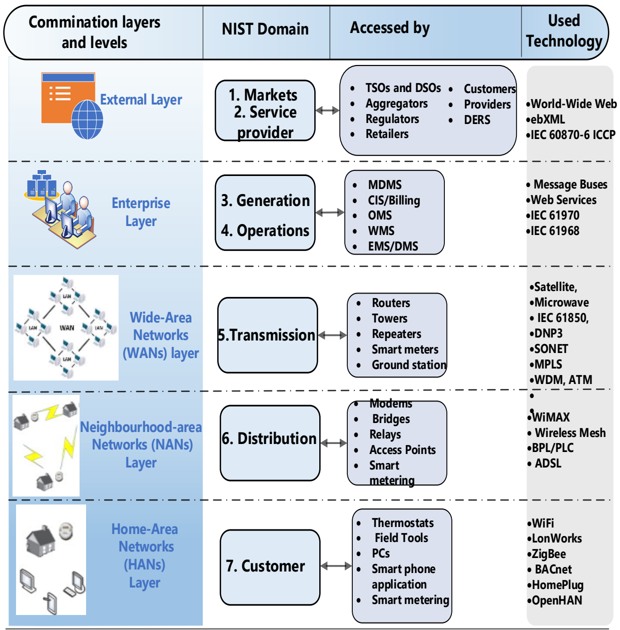

Figure 4. Hierarchical chart for the access levels based on the communication layers

Grid Codes

Grid codes (also described in the context of D1.1) [3] pave the way for these aforementioned changes, by addressing following three main pillars:

- Market design related to cross-border exchange, such as Capacity Allocation and Congestion Management (CACM) and Forward Capacity Allocation (FCA), long term to intraday market coupling, and European-wide system balancing Electricity Balancing Guideline (EBGL);
- Grid connection, allowing new actors, and in particular renewables, storage and demand-side response assets, to connect to the grid and deliver services (RfG, DCC, HVDC);
- System operation, taking into account the new challenges brought by the energy transition, need for deep coordination at regional and European level and the new means brought by further digitization of smart grids.

Such grid codes that are under implementation; will bring important changes to the system, such as; efficient data exchange between TSOs, DSOs and grid users as defined in System Operation Guideline (SOGL), standardization

of technical requirements of new actors connected to the grid (RfG, DCC), and development of flexibility services through a more liquid and efficient market for balancing services, also open to distributed assets (EGBL).
As part of grid codes specification and future thinking, further development will be needed to face the increasing amount of resources that are connected to lower voltage level and impact the grid operation, as well as market drivers and constraints. DSOs will have an important role, together with the TSOs, for market facilitation, making sure new players can access the grid and the markets with reasonable limitations, a fair impact on energy costs, an increase in energy supply quality and resilience, and without endangering the system security. This will require more digitization of the grid down to low voltage level, ensuring observability, controllability and extensive data sharing from all players, together with the development of market-based mechanisms for system management such as congestion management and balancing. Indeed, distributed flexibilities and related services will be needed to ensure an efficient and economical grid operation, while maximizing the value created for the customers and as a whole for the entire community. To that extent, information exchange and development of flexibility services should be considered with a whole system approach, avoiding any market fragmentation but with a strict market regulatory basis.

ENERGY DATA FLOW AND ARCHITECTURE

The high-level use cases in this section provide input to the smart grid concept of data management and the handling with big data infrastructure. Big data means a huge quantity of datasets, which are based on various data formats (structured, semi-structured or unstructured). Moreover, big data rests on the pace for making available timeliness requirements and the value to give the competence to extract the content from the collected datasets. At the end, big data assumes the offering of new data concepts and the accuracy to operate on the trustworthiness of the data [9].

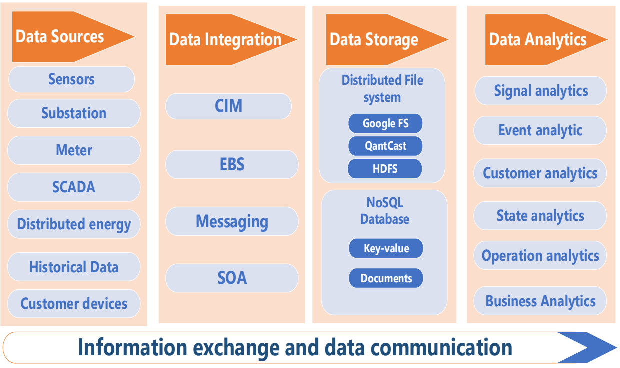

Figure 5. Big data architecture for smart grids operation

In this section, the data analytics, data storage, data sources and the data integration are considered. These four phases build the basis for the "Big Data life cycle" as seen figure 5 [10]. The first phase of the big data life cycle is "data sources", which can be distinguished in the data classes: Operational data, non-operational data, meter usage data, event messages and metadata. Operational data is an electrical grid data, which constitutes active and reactive power flows, demand response capacity, voltage etc., whereas non-operational data is not linked to the grid data. However, non-operational data relates to master data, data on power quality and reliability. Meter usage data relates to power usage and demand values. Event message data is derived from smart grid devices events, such as voltage loss/restoration, fault detection event etc. At last, metadata is needed to organize and interpret all other types of data [10].
The second phase of the big data life cycle is the "data integration". In order to foster smart grid reliability, persistence, efficiency and performance, modern information and communication technology is needed. For ensuring data integration several possibilities, such as Service Oriented Architecture (SOA), Enterprise Service Bus (ESB), Common Information Model (CIM) or Messaging could be used. SOA can be needed in order to make various software work together so that data integration will be easier and more flexible [10].
The third phase of the big data life cycle is "data storage", which is based on the collection of data from different sources and the supply of this data to analytical tools. This happens in fast input/output operations per second (IOPS). Data can be stored through Distributed File Systems (DFS) or Not Only Structured Query Language (NoSQL) databases. DFS enable multiple users on diverse machines to exchange files and to store resources. DFS allow every user to copy the stored data. In contrast to DFS, NoSQL databases is a new concept to cope with the restrictions of traditional relational Structured Query Language (SQL) databases in the case of massive data [10].
The fourth phase of the big data lifecycle is "data analytics", which is important to make the grid more intelligent, efficient and gainful. The collected data should be easily consumable for analytics. There are several models to conduct analytics, such as descriptive, diagnostic, predictive and prescriptive. All the models describe a different place of action in the grid. Descriptive models can be used for analyzing consumer behavior patterns and their decisions in order to predict customer's decisions in the future. Prescriptive models are the high level of analytics due to their impact on marketing and engagement strategies [11].
Afterwards, the data is used and transmitted within a high bandwidth in capacity and speed, data security and privacy. Data transmission is normally based on the one hand on communication technologies, like access network technologies, such as Programmable Logic Controller (PLC), ZigBee and WIFI etc. and on the other hand on area network technologies, like Machine-to-Machine (M2M), cellular network, Ethernet etc. [10]. The data transmission and bidirectional flow for both of the data and energy is

schemed in figure 6, whereby the data flow is synchronized with the bidirectional flow of the energy between the different stakeholders starting from the power generation and ending at the consumption side and vice versa.

The main purpose for the free and bidirectional data flow within the conceptual model for the smart grid is provide an integrated path for the operation of the renewable energy within the existed network infrastructure. The ICT tools are used to facilitate the integration process based on the grid coded and standards. The UCs methodology is addressed in the different scenarios for the coordination between the DSO and market such as seen in D2.2 [12] in TDX-ASSIT project and between the TSOs and DSOs such as seen in D1.2 TDX-ASSIT project [13].

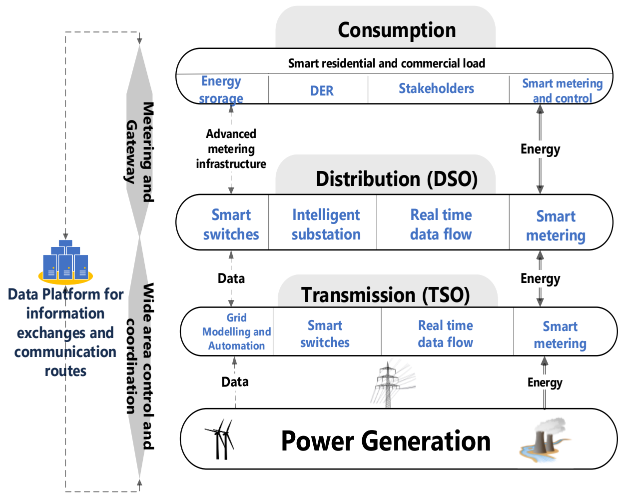

Figure 6. Bidirectional model for the energy data flow within the smart grid concept.

CONCLUSIONS

The smart grid concept could be presented within a reliable coordination for the data exchanges between the DSO and TSOs. A data management mechanism has the potential to facilitate the data flow within the new landscape of the network whereby more information is becoming a necessity for the operation of the power systems and the market process. The electricity system is evolving by the time by changing the production and consumption nature and volume, therefore a smart mechanism is needed to be evolved towards a greater flexibility and reliability in order to preserve the balance between the generation and consumption from technical and business perspectives.

The data flow mechanism is elaborated in this paper as a background for a reliable data management in different use cases that have been discussed in D1.1 and D2.1 (TDX-ASSIT project) [2] [3]. The basic requirements for the data portal design and its specifications are highlighted to reflect the usability of data platform in addressing the coordination between the different stakeholders in the power networks. This kind of consideration for using various data platforms introduces more flexibility reliability and scalability for data exchanges depending on the scenarios, data type, security factors and UC condition

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