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Agile digitalization evolution in the energy sector, taking into account innovative and disruptive technologies

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Abstract. The development of technology and science is decisive in the development of social welfare. We are experiencing the fourth revolution in technological development –after the invention of the steam engine; electricity and process automation; and then computer / IT technology – characterized by an interconnected information network. This revolution will affect all related industries, including the energy sector. New solutions, sensors, devices are available, but the main issue is the use of these devices. So-called smart grid technologies have many advantages, but they also present challenges, whether technologically, economically or sociologically and socially [1].
The answers to these challenges are often not traditional, but creative solutions can mean a breakthrough, changing and accelerating the current progress trends. Such solutions and methods can change and advance all segments and areas, from energy to medicine to the beauty industry.
The digital transformation and its implications will significantly change the support for the basic functions of energy distribution. Nowadays, it is almost impossible to solve any task or complete a simple work phase without a computer or IT tool, location data, work schedule description, parameters, and so on. Long-term operation and design, proper architecture and design framework are crucial for efficient operation. Enterprise architecture management within large companies usually involves a very complex range of activities [2]: business, IT and organizational information infrastructure. The role of enterprise architecture is becoming increasingly important for developing and growing companies [3].
In our article, we show how recent decades have helped improve the efficiency of network management and how digitalization is becoming an indispensable player in a sustainable, renewable-based vision.

Keywords. IT, digitalization, sustainability, innovation, automatization.

1. Introduction

Transformation is critical for any organization to succeed. The technological change, and the change it supports, will broadly stimulate competition and hopefully increase customer satisfaction. Effective leadership is a critical success factor for such changes, and the associated changes are not only expected to be addressed by technology, but are built on people and processes alike [4]. Furthermore, digitalization allows us to extend our experiential knowledge to most areas of our daily lives [5]. The interdisciplinary approach and the consideration of cognitive aspects are increasingly in the focus of research. With the immanent opportunities and threats of digital business transformation, the internal IT function is increasingly expected to provide support for digital value creation in addition to traditional IT services [6]. At the same time, this dual focus holds the potential: traditional enterprise IT requires stability, reliability, and the utilization of existing resources. Leonhardt et al [7] examined the role of two key capabilities – IT responsiveness and IT "versatility". A survey of 258 IT executives found that IT agility is a major driver of the digitization capability of an IT function. Furthermore, their results showed that a "multilateral" focus on digitization functions is best suited to finding a balance between conflicting needs.
The work of Verhoef and co-authors [8] also supports the hypothesis that the digital transformation requires specific organizational structures, as well as having an impact on performance metrics. In their work, they identified three phases of digital transformation: 'digitization, digitalization and digital transformation'.
Elliot [9] has taken a three-phase approach of selecting, analysing, and synthesizing relevant literature to develop a holistic, transdisciplinary, integrative framework for IT-based business transformation. They have focused on business transformation, because business is notoriously critical to meeting the challenges of environmental sustainability due to its potential for innovation and change – locally, nationally and globally. This research will also serve as a resource for other researchers to embark on significant information systems and

multidisciplinary work to achieve environmental sustainability. The framework addresses the main issues of uncertainty in the selection and analysis of illustrative examples of the work of 12 main disciplines in 6 main categories: (1) What does environmental sustainability mean? (2) What are the key challenges? (3) What are they doing about these challenges? (4) Based on what roadmap? It can be stated and confirmed through the review that the fundamental driving force of sustainable development is the transformation supported by digital solutions [10].

In the following topic, we searched for the mechanisms and patterns of the change and optimization of software architectures along the relevant research reports, mainly after the transformation of the corporate framework [11]. Speed in responding to change and continuity are key prerequisites for the next generation of IT solutions. Currently, we are witnessing an unimaginable expansion of technology in everyday life, on the one hand, the continuous increase in the speed of software delivery; and on the other hand, the significantly increased expectations have contributed to the adoption of agile methods and practices. Transforming the traditional and agile approach to software development is a new approach that uses agility to adapt to changing needs. Techniques that provide a change-tolerant architecture are the result of an iterative-incremental design of the agile process of software development. In recent years, instead of process-oriented operation in practice and research, there is a growing interest in integration technologies, so-called micro-services and software, which has led to new architectural and design solutions. One of the marked consequences of the emergence and development of new approaches is the agile architecture that emerged in 2006, such as continuous architecture optimization, lean architecture, or evolutionary architecture, which have essentially the same goals. In order to better understand the new role of concept and agile architecture in the digital age, it is necessary to examine the genesis of agility in the approach to architecture and software development [12]. Going further, the agile structure of enterprise architecture (EA) management is the next step in this process. EA management provides the engineering approach to continuous improvement across the enterprise [13]. The large number of stakeholders, the components and the dense networks of interdependence are major challenges. Agile architecture design aims to create results quickly, while maintaining flexibility in the design goals to be achieved. Buckl et al [14] examined the extent to which the agile method can be applied de facto in EA management. In doing so, challenges were identified for an agile EA management approach and the extent to which scrum can be used in a day-to-day practice in a large enterprise environment was examined.

Yang et al [15] already analysed the application of the agile framework. The unified agile security analysis and development platform consists of six frameworks. These six frameworks have start-up profiles that need to be tested, expanded and refined when applied in collaborative knowledge development practices. These exercises identify and analyse the open problems of the participating organizations, analyse the effectiveness and rational characteristics of the company's existing solutions, and create rational eligibility criteria to solve the problems. Their goal was to turn these initial six framework tools into effective tools that uniquely focus on rational design. Rick Dove [16] argues that the future of public services is increasingly characterized by the development of global digital platforms that support the Internet. First, the use of open standards and standards-separating architectures, the business logic of supporting applications, allows the kind of control to drive a supplier agnostic, freeing the company from over-reliance on systems and vendors. Second, over time, open standards and increased market choice will encourage both: innovation and gradual convergence towards cheaper, standard "utility" public services. Fishenden et al. [17] is linked to this line of thinking, according to which digital technology accelerates innovation and improves social well-being and industrial efficiency. Stakeholders in both the social and industrial sectors recognize that encrypted applications will not support the exploitation of digital technologies along an agile approach. Outstanding solutions and a dynamic work environment are needed to meet the challenging needs. Emerging solutions require flexibility in both approach and methodology, enabled by open network, enterprise platforms, and activity in terms of knowledge architecture. The new architecture enables an active knowledge architecture: a model-based, architect-driven, agile approach. Adaptive methods are needed, in which active models and user-driven modelling play a key role. Avkhadieva [18] adds that open, extensible platforms, supported by modern ICT trends and capabilities, will also play an important role.

Is there a pattern in digitally-driven corporate development so that the next levels of development can be predicted?

Fereidoon [19] says digitalization will change customer behaviour, consumer needs, business models, competition, or at least have a huge impact on every sector. But digitization offers opportunities for optimized processes, the development of new digital products and services, and the development of new data-driven business models. In the energy sector, existing business models are unsustainable in the long run. This industry is at a turning point in multiple change. Changes in the share of renewable and decentralized energy production will lead to an increase in distributed energy production. Energy as a commodity is about to expire. Customers want to disconnect from the network and expect service providers to care about their individual interests and needs. New entrants are entering the energy market and information and communication technologies, the Internet of Things (IoT) and digital technologies are laying the groundwork for these new entrants to enter the energy market. The traditionally very high entry threshold is thus significantly lower. ICT / IoT plays a central role in the transition of ICT in the energy sector [20]. The proposed business model targets customers of electricity suppliers by segment. The design of the proposed system is modular and different disciplines, previously uncharacteristic, play a significant role, such as ICT, energy efficiency, behavioural economics, education and gamification [21]. The proposed system will facilitate communication between individual energy consumers, virtual energy communities, utilities and other less directly interested parties [22]. In the field of energy, many researchers and practitioners are exploring business model innovation to find innovative ways to create and capture value through digital technologies. Loock [23], for example, argues that digital technologies facilitate business model innovation. In addition, business model innovation may be able to address these bottlenecks. As a result, business model innovation based on digitization appears in four types. Each type stimulates new standards for innovation-based research and practice of the business model and its sustainable management.

With the increasing availability of renewable energy sources and all kinds of rapid interconnection, the traditional one-way flow from centralized production to end consumers is changing, the two-way energy flow, multi-directional energy network is changing the relationship between central production and distributed customers. Ying [24] provides a systematic overview of how the Internet of Things (IoT) promotes the digitization of transactive energy informatics and how the blockchain enables decentralization. It discusses the challenges and future trends extensively, including the energetic physical space, the data cyberspace, and the human social space.

However, technologies alone will not generate a change in attitude or culture. Technology is an opportunity, a tool that can be used well – which is always subjective – and less well or less effectively. This paper translates the expressed "feelings" into scientific language using measurable methods based on metrics and key performance indices (KPIs), and to draw reliable conclusions from it.

2. Method and vision

The last decades show that the development of IT technology and the evolution of the application area have been an exciting process. Either the business demand forced it to have adequate support, or the exploitation of an emerging technology boosted the business processes and operations. We have gone from manual electromechanical relays to a network that can be considered as a fully autonomous, complex system today.

In the following, we summarize the innovative solutions we have been involved in in each area, and in the concluding chapter, we provide an overview of the future we can envision along the smart grid architecture model (SGAM) structure. Using these results and their correlations, we provide an overview of the expected future trends.

A. DSO business capability model

Figure 1 depicts the proposed landscape for a DSO IT architecture, organized around business capabilities (functions). The left box consists of the asset management functions. 1.1 is the network development strategy, which is a long-term assessment of the grid. Due to regulatory changes, DSOs around Europe now have to conduct development plans in cooperation with the Transmission System Operator which is approved by the National Regulatory Authority. This phase includes the analysis of trends (load and generation forecasts, new connection requirements etc.) and aims to keep the optimal grid infrastructure to achieve the triangle goal of security of supply, power quality and cost efficiency on the long run. This usually includes the need of new substations, high voltage connections. Besides that, there is a process to handle the Medium Voltage (MV) and Low Voltage (LV) networks in a strategic view as well, but currently these processes are less integrated. From an IT perspective, the tools for those are usually grid calculation software (such as Neplan, PSS-E or PowerFactory). However, as flexibility services are becoming available, DSOs must assess strategic decisions with the use of large amount of data. These datasets are available scattered through the separated IT systems. Reaching different modules could be a key factor in the future. Network planning and design is the process where the elements are technically and financially schemed, on a level where the construction is feasible. This usually means processing a lot of data, while also using planning software to create the plans. Legislative actions are also an important part in this process, where IT business capabilities offer valuable automation steps. These two business capabilities are directly connected to the investments of a DSO company, also through the 1.6 investment management, which covers the procedure of the financial part of building the distribution network infrastructure.

Meanwhile, the currently operating infrastructure needs proper management. On the one hand, it means a life cycle management in the long run. Modelling assets, registering information and conducting regular analysis could help to exploit the assets better. These business capabilities usually mean expert systems which are tailored to the DSO's needs. 1.4. inspection and maintenance is the operative part of the management of existing assets, as based on the information provided by the expert systems, the work of electricians and engineers can be planned carefully to keep the elements in operation. Meanwhile, data management and visualization serve as a basis for the performance indices, reports and provide valuable feedbacks and connection possibilities to other business capabilities as well. As digitalization provides more and more data, both from meters/sensors and processed information from the inspections, it also opens up possibilities to build up new functions. Soft computing methods, machine vision and complex indexes based on statistical or stochastic calculations now can effectively predict the future state of assets. The predictive maintenance is a promising area for DSOs to enhance the utilization of the operational resources (financial and human as well). Health index-based tools become more and more common in the development projects of DSOs nowadays.

The second business capability is Active Network Management (ANM). This part is highly integrated in the grid control, the Supervisory Control and Data Acquisition (SCADA) system. The key functionalities can be organized as monitoring and control (2.1), outage management (2.2.) and communications (2.3.) nowadays. SCADA also provides more advanced tools in the energy management (EMS) modules, such as grid calculation (state estimation, load flow, contingency analysis). The core of any SCADA is reliability.

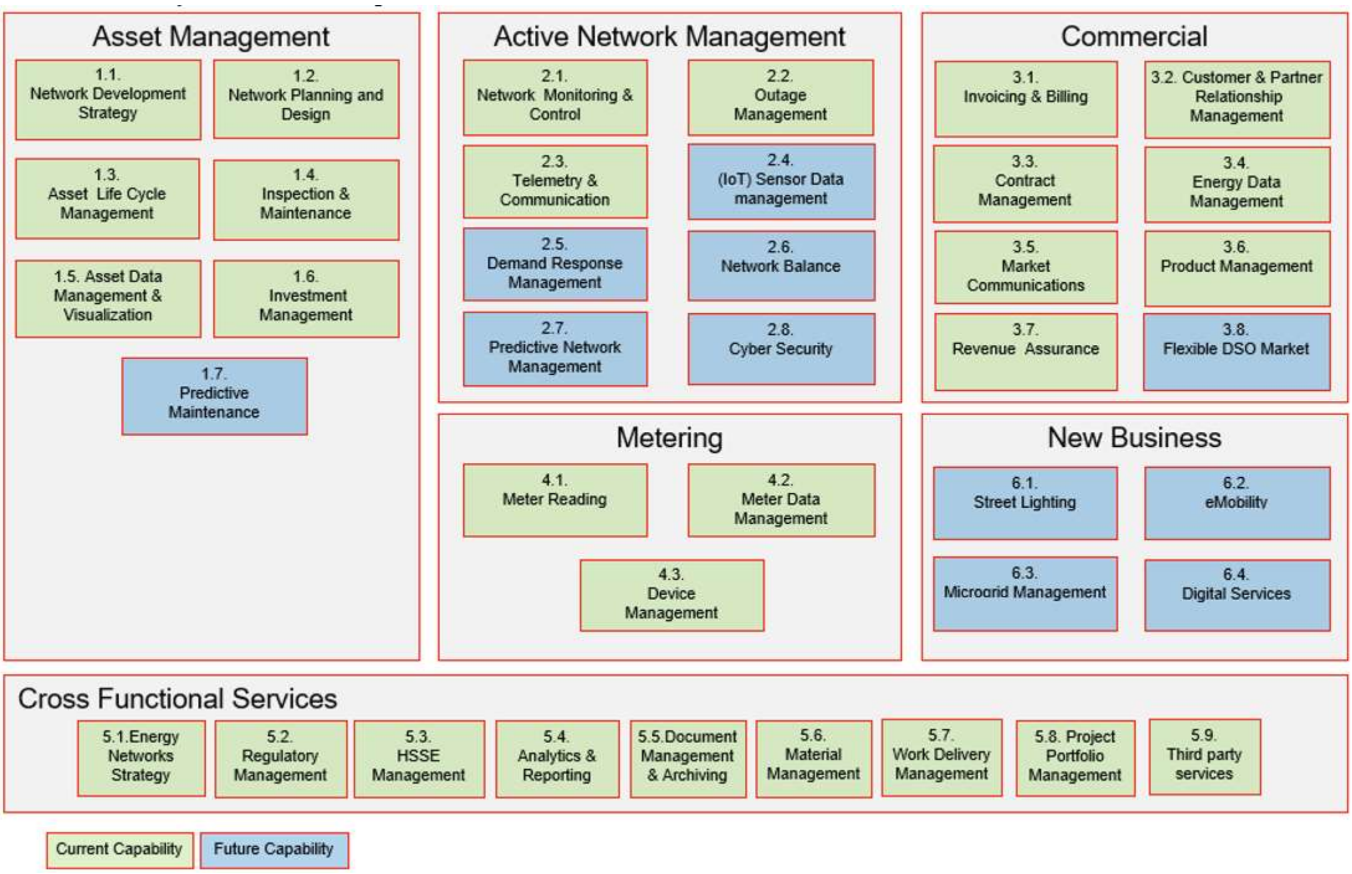

Fig. 1. Level 1 and 2 business capability map for DSOs

However, DSO SCADA is different from the transmission level. Information is only available from substations and isolated points of the radial MV grid (e.g. remote-controlled pole switches or fault indicators), and the switching options are also restricted to those elements. Below that, the LV is practically unseen for the operators nowadays. As Fig. 1. shows, the ANM part contains the newest business capabilities that are expected in the future. 2.4. shows the sensor data management. DSOs around the world deploy sensors to increase the observability, indicate faults directly to operators and support the strategic planning.

The number of distributed generators grows quickly, which highlights the importance of flexibility services and redispatch. The utilization of such requires IT business capabilities from the DSO. Either through direct control or building up a platform to attract aggregators, the DSO must be able to calculate the grid constraints and define services and products to effectively solve the overloading or voltage limit violations. Active participants such as energy communities, microgrids and aggregators appear on all voltage levels now, which results in a more complicated system operation. This needs sophisticated predictive tools, such as load and generation forecast, optimal flexibility provision tools etc. In the past, simple statistical approaches were sufficient for operation planning, and the distribution network was quite oversized. The appearance of these active participants changes the customer needs, and here the distribution infrastructure becomes a limiting factor. Distribution network state estimation is a promising calculation method to serve as the basic function of the ANM. Demand response management and balance calculations can help to utilize the infrastructure optimally and maximize social welfare.

Cybersecurity is a highly important topic around power systems. The implementation of EU-wide security initiatives enables the DSOs to plan the evolving systems in a protected framework. Power systems are critical infrastructure, and the resources spent on security is increasing for all the companies.

The commercial business capabilities of DSO cover many legislative steps. From the connection, through the use of the grid until getting the electricity bill, customers are connected to the DSO IT systems in many ways. SAP systems usually serve as a basis, while there’s other additional modules connected. Customers, or energy communities / aggregators are entitled to reach the meter data, which requires connections. The cooperation between the transmission system operator and DSOs also require the more frequent exchange of metering data. DSOs also try to be more customer-centric in their processes, the evolvement of these IT systems into more autonomous ones is inevitable. In addition, flexibility service providers try to reach DSOs through the new flexibility markets. The DSO here has to serve the flexibility needs. Also, during the development of the new market, some of the countries opted for the implementation of a DSO-operated marketplace, which means that a platform is needed which is similar to the ancillary service handling, but also has spatial attributes.

Regarding the metering data, there are already operating IT business capabilities at the DSO level. The roll-out of smart metering changes the landscape a bit. For residential customers, most of the DSOs still use synthetic load

profiles to estimate the temporality of the power needs. Smart meters provide time series measurements for active energy (and other parameters, such as reactive energy, power and voltage values), which can enhance the scheduling of the portfolio. The regular meter reading, data and device management tasks, the data sharing processes will be important as well.
Cross-functional services are already in an advanced phase regarding DSOs. The strategic departments usually process the external factors and try to oversee the operation of the company. As a natural monopoly, the most important external connection for the DSO is the national regulatory authority. Health and safety management, overseeing the processes from one end to the other, and connecting with third parties all require IT solutions that use several data sources. As the data management becomes more effective, the reporting – e.g. through dashboards – and the analysis of the performance become more clear and reflective.
DSOs also examine new business opportunities as their expertise in power and energy solutions become more and more valuable for different actors (municipalities, energy communities). Intelligent street lighting enables smart cities to reach energy efficiency goals. Operation and maintenance of e-mobility chargers is a viable product from the DSOs to the e-mobility service providers. Also, other power equipment, such as distributed generators, storage or demand side management equipment, needs electrical experts to operate. The energy transition provides an opportunity for DSOs to transform some of their activities from a legislated environment with obligations to a customer-centric, service-based approach.

B. The Smart Grid Architecture Model

DSOs need to implement a smart grid solution through the energy transition. The definition of the smart grid itself is complex [25–27]. The smart grid is a system, a complex entity, and most of the definitions use the *integrated* attribute. Besides the power infrastructure (generators, grid, storage, loads and other), smart grids contain communication technologies, metering/sensor and control, usually based on data analytics. The purpose of smart grids is not only technical, but the objectives usually include economic or social benefits as well. There is no geographical limitation, and the key motivation behind the implementation is the integration of renewables, being more customer-centric, while keeping the traditional goals, such as security, quality and cost-effectiveness. For the evaluation of smart grid solutions, the most common approach is to use the SGAM architecture (Fig. 2.). The European Commission assigned standard associations (CEN, CENELEC, ETSI) to propose a comprehensive model. This is practically a three-dimension approach. The connections can be defined on the vertical axis, as there are five different layers considered. Those layers consists of domains and zones. This approach helps to connect the physical elements (power infrastructure), data flow and connections on the communication (green) layer, data models on the information layer (orange), the use cases on the functional layer (blue), and business opportunities, regulatory and legal environment at the highest level (purple layer).

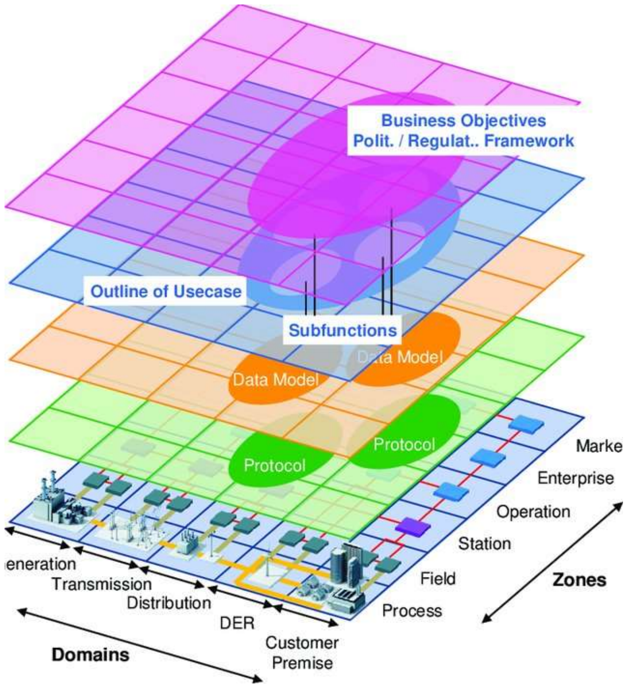

Fig. 2. The smart grid architecture model [28]

The different DSO business capabilities can be envisioned through this model. As an example, an ANM solution that uses the controllability of distributed generation covers the distribution domain and the field zone. It includes communication from the distributed generator to the DSO SCADA through remote terminal unit. The data model includes the control parameters, measurements (schedule, service, active and reactive power, voltage). The service part is a redispatch or flexibility service that the stakeholders agreed on. On the business level, the legislative (contracts) and the regulatory (grid codes) aspects and the business models (why the distributed generator chose to participate, effects on the social welfare) can be considered. This example shows how the SGAM works and establishes a framework for analysis.

3. Conclusion

Energy transition radically changes the role of DSOs in the value chain of electric power systems. The increasing number of active market participants, such as distributed generators, prosumers, energy communities, microgrids and aggregators increase the complexity of the DSO business. Furthermore, the data sources are increasing, which opens up many possibilities to improve the operation. From the IT viewpoint, this task could not be handled without a proper architecture strategy. This paper reviewed the most important processes and state-of-the-art solutions, then proposed and evaluated a complex IT architecture framework for a DSO which is oriented around business capabilities. The two-level classification mapped the key functions. The modular handling of such capabilities can improve the adaptiveness and agility of the DSO, which is key in a changing environment. The proposed architecture pointed out new capabilities with practical examples, such as predictive maintenance and network management, operation of flexibility platform, integrating sensor data and forecast through distribution network state estimation. The SGAM layer approach can help to identify and evaluate the connection between different capabilities.

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