A set of roles for the evolving business of electricity distribution

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Abstract

This paper proposes a set of roles that organizations could play to support the evolution of the electricity distribution business. Role theory is used to describe responsibilities and collaboration patterns for the proposed role set. The study also covers a framework outlining the adoption of roles by third parties and the timeframe for their adoption. Our research shows that the role set responds to the challenges faced by stakeholders in electricity distribution systems. Results from the assessment suggest that most of these roles are expected to emerge by 2020.

Keywords: Role model, Electricity distribution, Active system management

1. Introduction

Power systems are evolving from a centralized structure to a distributed one. This shift has been driven largely by the increased use of distributed energy resources (DER) for electricity generation. Decreasing investment costs combined with renewable energy sources (RES) support schemes are two of the factors that have led to an improved adoption and deployment of such technologies for electricity generation. The introduction and implementation of microgrids [1, 2], virtual power plants (VPPs) [3, 4, 5], and new aggregation models will accentuate this trend.

The proliferation of variable renewable energy sources (VRE) is not the only factor that will bring new business challenges and opportunities to the power system. Take, for example, urban mobility where subsidies, increasing vehicle range and decreasing prices

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have encouraged electric vehicles (EV) take up, which by 2020 is expected to reach 20 million units globally [6]. A similar example is load management. Historically, electricity consumers were considered inflexible in the short term. However, developments in the acquisition, management and communication of data (e.g., advanced metering and control systems) allow loads to become more responsive to market signals [7]. Today, load flexibility is used across European power systems [8, 9, 10, 11]. Storage is another example - where storage capacity within EVs [12] and the potential for flexibility EVs offer have been acknowledged by regulatory agencies [13].

Electricity markets are evolving. Among the factors driving this evolution are the introduction of new electricity market players (i.e., aggregators), which require advanced and comprehensive commercial and technical frameworks [14, 15]; and the work regulatory agencies carry out on the creation of a level playing field across all time-frames for all forms of generation and demand response [13]. As a result, operational principles to ensure system reliability and security leading to new approaches for real-time grid balance and voltage control will have to be evaluated [16]. Additionally, this evolution may require the introduction and assignation of a new set of responsibilities [17], in particular to stakeholders in the electricity distribution business; define and implement alternative market designs [18]; and put into practice novel coordination schemes between electricity transmission and distribution network operators [19, 20].

Stakeholders in the electricity distribution business will have to adapt and innovate their business strategies and tools continually. This is particularly relevant for the actors responsible for the development, maintenance and operation of the electricity distribution grid, i.e., the distribution system operator (DSO). DSOs are not only expected to serve electricity demand in a cost-efficient manner, but also to support the transmission system operator (TSO) in balancing the power system, assist the integration of technologies, and facilitate access to electricity markets. However, for DSOs to provide a cost-efficient solution to the complex task of supervising and managing the distribution grid without undermining the reliability and security of electricity supply to end-users, a shift towards an active distribution grid management approach is needed.

For this shift to take place, new roles are needed. The new roles should extend the responsibilities of electricity distributors across voltage levels and relevant activity areas, such as network planning and operation; facilitate access to electricity markets; enhance grid maintenance; and support system security. Also, these roles should enable stakeholders to implement active grid management approaches.

This paper describes a set of potential roles that support the evolution of the electricity distribution business by enabling the definition and exploitation of innovative services and management approaches using smart grid technologies. The structure of the paper is as follows: Section 2 provides a brief introduction to role theory and the notion of roles. Section 3 covers the methodology used to define the proposed set of roles. Section 4 describes each role. Section 5 discusses third-party assignation. Section 6 illustrates role interaction patterns with a role model. Section 7 shows potential adoption paths for the proposed set of roles in six European power systems. Section 8 provides recommendations and concludes.

2. Background

The use of roles to describe systems is not new. Francis Lodwick, a merchant in the seventeen century, used "appellative" nouns to refer to roles that had to be carried out by individuals, objects or venues [21, 22]. In his approach, roles served to label actors within a specific context. For instance, in the event of an assault there are two roles attacker and assaulted. Interest in the notion of roles has grown since [23, 24, 25]. To take a case in point, according to Biddle [26], the concept of role is popular in the social sciences, where at least 10% of all articles published in sociological journals use this term.

In general, role theory suggests that human beings or other entities have various roles during its existence. These roles have scripts for the behavior of the entity in a given context. The script delineates the responsibilities and interactions for the role. In a broad sense, roles can be seen as characteristic behavior patterns that change according to the situation at hand [26, 27].

The notion of roles has been extensively used in many areas, such as data models [28, 29], conceptual structures [30], object-oriented programming (OOP) and conceptual modeling [31], enterprise modeling [32]. This notion has also been used to support other frameworks such as coordination theory [33, 34].

Role theory and role modeling is relatively new to power systems and not extensively used in the electricity distribution business. However, just as the notion of roles was introduced in OOP to complement and overcome major problems in object modeling [35, 36, 37, 38, 39, 40, 41], it potentially has applications for delimiting responsibilities and interactions in an environment under constant evolution such as the power system and particularly the electricity distribution business. The extensive use of roles and role modeling across many areas shows that the concept is original and adaptable, even if its definition and representation is not standard.[1]

Despite the awareness of its relevance, within role theory, no consensus has been reached in respect to their representation or integration for established modeling frameworks [31]. In fact, according to Van der Horst [25] "role theory is not a unified theory, but a collection of them." Researchers in role theory constantly develop and add new concepts. The adoption of concepts by some researchers and not by others create many competing approaches. Consequently, there is no ideal way to define role the-

[1] Bögel [42] observes that the notion of role is founded but not semantically rigid.

ory. However, according to Biddle [26] role theorists agree on a ”triad of concepts”: characteristics behaviors, parts to be played, and expectations for behavior.[2]

3. Methodology

This paper defines a set of roles suitable to the evolving context of the electricity distribution business. The pragmatic approach used employs the notion of roles and role models. The characterization of roles is based on features currently identified in OOP, business modeling, and conceptual modeling literature.

Using [31] a subset of such features were selected, namely:

- A role comes with its own properties and behavior;
- Roles depend on relationships;
- An entity[3] may play different roles simultaneously;
- An entity may acquire and abandon roles dynamically;
- An entity and its roles share identity.

These features were used to characterize a set of roles and their patterns of interaction for the provision of services from/to the distribution grid within a smart grid

[2]For instance, Steimann [31] discusses three general views on how to represent a role, namely roles as named places of a relationship, roles as a form of generalization/specialization and, roles as separate instances joined to an object.

[3]In OOP, the notion of ’entity’ relates to the terms ’component’ and ’object.’ From a broad perspective, a ’component’ is a composition of entities, which collaborate to fulfill a specific function. An ’entity’ in a component can be an ’object’, a procedure or another component [40]. Sowa [43] further describes two subtypes of ’entity’: natural types and role types. Natural types are not founded and semantically rigid while role types are founded and not semantically rigid. Roles are a sub-type of natural types in some particular pattern of relationships. For instance, ’person’ (natural type) and ’father’ (role type) or ’dog’ (natural type) and ’gatekeeper’ (role type). In the examples, ’father’ is a sub-type of ’person’ in the role of parenting and ’gatekeeper’ is a sub-type of ’dog’ in the role of protector, respectively. In this paper we will use ’entity’ focusing primarily on role types.

context. Role theory is helpful in this sense because it allows the packaging of multiple heterogeneous procedures and makes abstractions of them. These procedures are then used to identify interactions and collaboration patterns between entities. For the provision of a service, entities need to be able to cooperate with one another. In this regard, interactions and collaborations are therefore of paramount importance. This study concentrates on subsets of interacting, collaborating entities which we believe are essential for the evolution of the distribution business.

We used the role model concept to support the characterization of collaboration patterns. A role model helps to identify and describe recurring interaction patterns of entities in terms of roles [44]. Moreover, role models are used to define role types [45]. A role type is a description of the functionality an entity assumes by 'playing' that role.

The notion of role and the use of role models are relevant to our approach because they provide the means for specifying the interfaces for (evolving and new) services within a smart grid context. Also, these concepts help to guide the development of standards to define services. The use of standards increases communication and collaboration among entities. Standards are particularly relevant for the electricity distribution business since expectations for different parties tend to show large variability [46].

The abstraction promoted by this pragmatic approach assumes that the DSO is the entity who would 'play' the role. However, the activities described for each role may be performed by any other party provided that it has the necessary capabilities and expertise to complete the task as cost efficient and with comparable warranties as the DSO would do.

The motivation for a high-level description of the roles is to illustrate their core functions with a level of detail that do not restrict potential evolutions. As a result, the proposed roles can be adapted based on functional [47] and non-functional requirements

[48] required for the provision of a service in a specific power system.[4]

We constructed the set of roles in three stages.

In the first stage, a thorough data collection exercise was carried out using a questionnaire. Responses from TSOs, DSOs, suppliers, technology providers, balance responsible parties[5] (BRP), balance service providers (BSP), aggregators, and research centers were used to describe the status quo of a wide-range of European electricity distribution systems. Also, these responses helped to identify practices for grid planning and operation [8].[6]

In the second stage, grid planning and operation practices were measured against possible requirements for future energy systems based on potential scenarios for generation electricity mix, demand flexibility and technological degrees of freedom (e.g., innovative and existing assets or technologies of the distribution system) [49]. Results from this assessment were used to identify, define and prioritize business processes (services) for the evolution of the distribution grid [46]. An expert group composed of network operators, electricity market players, research institutions and technology providers selected a subset of services based on its expected relevancy (concerning RES integration) [47]. This subset was further described employing the IEC 62559 Use Case methodology [50] and compared against core responsibilities of DSOs. The comparison highlighted the current limitations of the existent role model to ensure fulfillment of core responsibilities while facilitating the integration of RES. These limitations were used to reshape the boundaries of current roles giving birth to a new set of roles.

In the third stage, roles were fine-tuned and validated. To calibrate the theoretical

[4]Role theory in general, and role activity diagrams, in particular, can be used to address non-functional requirements such as reliability, security, and responsiveness of a business process [48].

[5]'party' is commonly used to refer to different entity types (i.e., natural types and sub-types also known as specialization) [31]. In this paper, 'party' and 'entity' will be used interchangeably.

[6]Stakeholders from the following 17 countries participated in this survey: Austria, Belgium, Germany, France, Ireland, Italy, Portugal, Spain, Greece, Czech Republic, Poland, Latvia, Netherlands, UK, Hungary, Slovenia, and Cyprus.

framework, we used the feedback provided by the Council of European Energy Regulators (CEER). The interaction with CEER served to validate potential benefits for stakeholders of the power system and, to highlight regulatory barriers to role implementation across selected power systems [51]. Finally, the robustness, relevance, and applicability of this framework were tested in research projects part of the FP7 "Smart Cities and Communities" call (i.e., DREAM, IDE4L, and INCREASE). Overall, the role set proved to be compatible with the concepts and solutions developed within these projects [52].

4. A new set of roles for a smart grid context

In this paper, a role defines an intended external behavior of a business party (actor) which cannot be shared, aiming at satisfying a specific service. A service can be defined as a business transaction between two parties [17]. Roles provide services by interacting with each other following a use case [53]. The use case describes the sequence of transactions between actors and systems.

There are eight roles for the proposed set (figure 1). Each role supports its activities by interacting with other roles. As depicted in figure 1, each role brings a different level of innovation to the distribution grid. The highest level refers to the definition of a completely new role for DSOs. New roles are defined when a new activity (and corresponding responsibility) is envisioned. While highly innovative, its adoption would require longer periods and a higher implementation complexity than other roles. The intermediate level refers to an existing role that needs re-definition. To cope with the challenges of the changing environment existing roles and responsibilities require to extend their current scope by defining and implementing new processes. The lowest level relates to existing roles and responsibilities that do not need re-definition. Roles that make use of new technologies to expand the reach of DSOs services and activities without the need of modifying current processes or responsibilities fall into this category.

4.1. Distribution Constraints Market Officer

Currently, network operators are in need of system services to increase their planning and operational flexibility. The Distribution Constraints Market Officer contracts system services, based on the needs of the Distribution System Optimizer (section 4.2). These services would be offered by flexibility operators (e.g., aggregators) and procured by network operators in the long- and short-term.[7]

From a power system perspective, flexibility characterizes the ability of a system to maintain the balance between generation and consumption under uncertainty [54]. Grid-connected units provide flexibility to the system by modifying generation injection or consumption patterns in reaction to an external signal (such as a price signal) [55] with the overall objective to maintain continuous service in the face of rapid swings in supply or demand [56].

Flexibility may be classified into two broad groups: technical and commercial. The former refers to the flexibility of grid assets directly controlled by network operators (i.e., TSO and DSO). The latter relates to the flexibility provided by market agents (such as aggregators) [51].

Flexibility has a wide variety of uses. Network operators could employ it for system purposes (e.g., load-frequency and voltage control, constraints management, and investment optimization), while BRPs could use it for portfolio optimization.

Flexibility is a scarce resource. Its allocation should, therefore, provide a social optimum, i.e., it should be allocated to the actor for whom the flexibility has the highest value (based on the willingness to pay of the actor and considering risk management

[7]Tenders may be used for the procurement of system services in the long-term. In the short-term, system services may be procured by participation (as any other market player) in flexibility market(s). Standardized contracts may be another option to procure flexibility.

aspects and uncertainty). Note that the value an actor can assign to flexibility at any given point in time might be influenced by the implemented market architecture and regulatory framework.

The role provides an additional lever to treat different system needs such as enhance distribution grid hosting capacity, solve congestions to maintain normal operation while respecting security boundaries, optimize network planning, and maintain voltage levels. By contracting (local) system services, DSOs promote their development and offering. Furthermore, the procurement of these services supports DER integration and provides further options for local constraints management and system support (if services are used to support the TSO).

4.2. Distribution System Optimizer

The advent of advanced monitoring and control technologies (smart grid technologies) has led to the transformation of distribution grids (e.g., grid management architecture[8]). To face challenges in a cost-efficient manner, DSOs require an architecture that provides options to manage the increasing operational complexity of the grid.

The Distribution System Optimizer enhances the development, operation, and maintenance of the distribution network. That is, it acts as a network developer, operational planner and network operator [46].

A cost-efficient network planning and management of grid constraints (including emergency events) allow cost-effective and non-discriminatory access to the grid. By handling centralized as well as distributed functions, the role optimizes the use of available levers (e.g., contracted system services).[9]

[8] With centralized, hierarchical, fully distributed and hybrid architectures currently under discussion.

[9] This will depend on the implemented architecture. For instance, the SuSTAINABLE project [57] proposed a hybrid architecture. This architecture includes centralized functions like RES forecasting or MV control and local/distributed functions such as droop for local voltage control.

In its optimization, the role considers (i) variable DG feed-in behavior (i.e., volatile in-feed patterns); (ii) expected dynamics of loads (including demand response); and (iii) impact of storage facilities (in planning and operation). As a result, the role optimizes network investments and system management at different time horizons. Note that, overall, the decision to procure flexibility would be evaluated against its opportunity cost, i.e., the cost of not using flexibility to relieve grid constraints but by expanding the grid.

To accomplish its tasks, the role uses specific grid technologies such as distributed control systems, network sensors, and fault indicators. Moreover, the role retrieves information from different systems and tools. For instance, the state estimator, the optimal power flow, and the distribution management system (DMS) including fault location/isolation/service restoration (FLISR).

The role innovates by allowing the development of new methods and processes for planning and operation of the grid that make use of new flexibility levers. Consequently, the adoption of this role leads to a more pro-active, adaptive and cost-efficient distribution system management approach.

4.3. Neutral Market Facilitator

In some European electricity distribution systems, DER generation capacity is expected to reach an annual growth rate of 5% to 10% by 2022 [49]. By means of aggregation, this capacity could participate in different markets and be used for different purposes, such as portfolio balancing, system support, and (local) congestion management. However, aggregation alone may not be sufficient. Fostering optimal DER participation in electricity markets also requires a critical assessment of grid constraints and resource location. This assessment should be supported by a strong collaboration among stakeholders. For example, a collaboration promoting the exchange of relevant information between eligible flexibility providers and grid operators.

The Neutral Market Facilitator role supports market participation of resources connected to the distribution grid.[10] This is done through pre-qualification of resources and by implementing a transparent instrument based on the traffic light concept to assess the grid status in combination with potential market actions. At its core, the role implements mechanisms for information exchange with market participants.[11] This exchange takes place at the different stages of the market, from resource characterization to bidding to settlement.

The characterization (pre-qualification process) gathers information on the flexibility of the market agent (e.g., location, amount, duration, response time, and grid impact). This process allows for an administrative validation in three stages; ex-ante (evaluating potential congestions triggered by the activation of flexibility), during activation (assessing real impact) and ex-post (calculating effective delivery).

The traffic light concept (TLC) provides a basic conceptual structure for identifying critical interactions between network and market operations [60]. The framework[12] has three different states: green (operation under normal conditions), yellow (imposition of some temporal limits to avoid jeopardizing the system) and red (implementation of pre-existing measures to avoid system collapse). These states provide information on the current and forecasted condition of the grid to stakeholders.

The Neutral Market Facilitator role innovates on the characterization of flexibilities and broadcasting system status to relevant parties (e.g., TSO). These new processes used in combination with operational planning and forecasting tools should facilitate

[10]This is a fundamental difference with the concept of Neutral Market Facilitator proposed by the smart grid task force (SGTF) in [58]. We differentiate between the role of Data Manager and the role of Neutral Market Facilitator. SGTF handles both roles as one. CEER has also acknowledged this in [59], stating that "DSOs should remain as Neutral Market Facilitators but this does not automatically confer the status of Data Management Coordinator."

[11]Information regarding system status can be broadcast to relevant parties such as the TSO. The role collaborates with the role of Contributor to System Security to broadcast this information.

[12]Developed by the German Association of Energy and Water Industries (BDEW).

market participation of DER.

4.4. Contributor to System Security

Collaboration between DSOs and the relevant TSO is needed to provide local solutions to system-wide problems. TSOs have to maintain the security and reliability of their system. DSOs operate their grid in a cost-efficient manner. However, the manner in which each operator accomplishes its tasks is presently being challenged. Network operators can face current challenges by defining and implementing action plans (e.g., cascading processes) that optimize operation in both networks. These action plans would have to be supported by an enhanced (bilateral) exchange of relevant information, especially for situations where resources located at distribution level are activated for reasons of system security, including reserves provision.

The Contributor to System Security exchanges network planning and operational data to coordinate actions with the TSO. The role also responds to planning, scheduling and security requests from the TSO.

For example, to respond to a TSO request, the role could potentially activate flexibility that has been contracted but is idle (in collaboration with the Distribution Constraints Market Officer and under the conditions stipulated by the regulatory framework). In emergency situations[13], the role may curtail resources connected at the distribution level to respond to load transfer requests made by the TSO.

By enhancing bilateral communication, network operators would be able to (i) efficiently use possible local solutions (flexibility levers) for system-wide challenges; (ii)

[13]The current definition of an emergency situation may vary from country to country. In this article, an emergency situation refers to an (extreme) event that requires the immediate intervention of the relevant system operator. The actions a system operator takes (to avoid a blackout) do not belong to normal operation or market procedures. The methods to tackle these events should be clearly described in the regulation. Note that in such situations, one cannot speak of 'real' flexibility levers, as an emergency situation usually implies drastic measures such as limiting the actions of stakeholders or actions with a direct unforeseen impact on grid users (e.g., switching off certain parts of the grid).

define and implement procedures for the collaborative assessment of impacts when activating resources at distribution system level; and (iii) define and implement cascading processes to maintain and improve system planning and operation.

4.5. Data Manager

The introduction of advanced monitoring and control technologies at electricity distribution system level will increase the amount of data available to stakeholders. Different types of data may serve distinct purposes for relevant actors (e.g., suppliers use meter data for billing energy consumption). Interested parties would have to comply with privacy and security regulations to gain access to this data. The eligibility of actors to have access to specific data should depend on what they intend to achieve with the data.

The Data Manager handles metered, contractual and network data.[14] Some of its functions are to collect, validate, analyze, archive, and provide data originating from meters, network monitoring and sensing devices, and contracts of eligible actors.

Cost-efficient management of data is critical for effective interaction among network operators and market agents. The exchange of relevant data allows the proposed set of roles to work together to accomplish the required tasks. The Data Manager supports the exchange of data in a coordinated, transparent and secure manner with eligible parties, for example, TSO, national regulatory agencies (NRAs), BRPs.

DSOs are key for the effective implementation of this role. DSOs use data to plan and operate their grid. Also, to serve different stakeholders, for instance, TSO and flexibility providers. Stakeholders recognize the importance of the DSO regarding data management. To take a case in point, according to Eurelectric [55], "DSOs should

[14]Metered data refers to data collected from metering infrastructure (incl. smart meters and EV charging stations). Contractual data comprise data gathered from connection and access contracts. Network data involves data assemble from grid components such as transformers [46].

manage operational data of distribution network users."

The role innovates in the way data is collected, handled and distributed. By being able to handle data in a timely and effective manner the role (i) supports grid management and planning optimization (in collaboration with the Distribution System Optimizer); (ii) facilitates access to current and new markets, e.g., ensuring technical availability of flexibilities (in collaboration with the Neutral Market Facilitator); (iii) enhances the quality of the settlement process by ensuring optimal remuneration of flexibility use and avoids disputes or free-rider behavior; (iv) improves traceability of market actions by adding the possibility to cross-check them with data on physical activations (in collaboration with the Smart Meter Operator); and (v) provides a standard and transparent mechanism for data sharing.

4.6. Smart Meter Operator

The Smart Meter Operator administers the smart metering infrastructure. The role takes care of physical meters from installation to maintenance to decommissioning.

Advanced metering infrastructure (AMI) and ICT unlocks new ways of bidirectional communication between utilities and customers. Such technologies open the door for data provision close to real-time.[15] Additionally, enhancing network observability supports the development of new grid management tools.[16] However, these technologies should be managed optimally and cost-effectively due to their shorter life-span (compared with legacy technologies). As such, they require an adapted management approach.

[15] Expected from developments on communication protocols, such as Power Line Communication PoweRline Intelligent Metering Evolution (PLC PRIME) (www.prime-alliance.org) or G3-PLC (www.g3-plc.com).

[16] This may also require further discussion on the definition of data types proposed by CEER [61] as expressed by the association of European Distribution System Operators (EDSO) in [62]. Active power measurements, for example, are used by suppliers to bill their customers but are also used by the DSO as essential data for technical grid management.

The Smart Meter Operator controls the information flow between components of the metering infrastructure (such as remote terminal units, concentrators, and metering points) and the database where data is stored (via the communication system).[17] Also, the role can perform actions on the infrastructure. For instance, adapt the smart meter parameters to set the maximum allowed power off-take.

Its novelty lies on extending the communication capabilities of the entity in charge of the metering infrastructure. This refers to the management of (more) advanced metering and data collection infrastructure and operations. Such infrastructure may also include the meter for EV charging stations.

The role could be seen as a qualitative shift from the meter operator role of DSOs. The implementation of advanced equipment allows for higher data resolution, which in turn supports the definition of new or adapted services such as remote adaptation of contracted power and demand response applications.

4.7. Customers Relationship Manager

An advanced metering infrastructure is capable of collecting data with higher frequency and resolution than with legacy technologies. A higher data resolution facilitates definition and provision of new database services that may be provided to different stakeholders. In general, these services may be of two types: basic and advanced. The former relates to current practices of DSOs. For instance, delivering raw data to the eligible requesting party. The latter aims to provide a higher understanding of the grid behavior. For example, data processing for eligible parties that do not have the experience or capability to do so.

The Customers Relationship Manager manages various types of contracts and requirements including grid users' connection and access. The role coordinates contrac-

[17] The role works in close collaboration with the Data Manager.

tual arrangements, sets requirements, and provides detailed data to eligible parties. The role also manages legal arrangements with the TSO, retailers/suppliers, grid users, and BRPs.

Regarding innovation, the role provides a qualitative shift in data services while complying with security and privacy regulations. Enhanced data services (both basic and advanced) can be used by stakeholders to develop flexibility services and smart grid solutions further.

4.8. Other Third-Party Relationship Manager

Each stakeholder of the power system has data needs. To supply these needs adapted services are required. These services have to comply with security and privacy legislation.

Similar to the Customers Relationship Manager, the Other Third-Party Relationship Manager provides basic and advances services. This role, however, focuses on another set of stakeholders.

The role manages the communication with regulators, conceding and local authorities, service providers, and other third parties. The data exchange process initiates with a request from the interested (and eligible) party. For instance, the role provides accurate network performance data in response to a request from the NRA for the valorization of quality of service (QoS) indicators. The role provides data required by national legislation that serves (i) to improve (urban or other) planning, (ii) avoid or reduce societal costs, (iii) facilitate the assessment of current and potential regulatory measures, and (iv) evaluate pilots as well as research projects.

Similar to the Customers Relationship Manager, the role's innovation is situated in the area of customer relationship, and specifically in the provision of enhanced (standard) data services to eligible parties. To recover the cost of providing these services, the regulated tariff could cover the costs of providing basic services. As for the advanced services, an extra remuneration per event may be foreseen.

5. Third-party assignation

Most of the proposed roles show no economic or regulatory justification for a third-party assignation. A reason for that is the closeness of roles' responsibilities to DSO obligations. However, a third party may also be entitled to adopt a given role. Although third-party assignation may seem trivial, it is, in fact, crucial regarding today's concern over market foreclosure and market distortions. Especially in discussions concerning the creation of a (local) flexibility market [18]. In this regard, roles like Smart Meter Operator (SMO) and Data Manager (DM) could hold concerns for regulators. For example, in the UK, retailers – who also own and manage smart meters – are responsible for the collection, aggregation, and processing of metering data [46]. Other examples could be found in Italy and Germany. In Italy, a third party, Integrated Informative System (IIS), will handle historical data from consumers making it available to interested parties (such as traders, regulatory agencies or a DSO) via a central platform [51]. In Germany, DSOs may not become full-fledged data managers. According to Gerard [52], by 2020 the TSO will become the settlement authority for intelligent metering systems relegating the DSO to a supportive role.

Among the reasons for the assignation of these roles to a third party are (i) to avoid potential neutrality issues concerning the management of data and (ii) to foster cost savings (e.g., by implementing a competitive supplier-led-roll-out with a central communication body).

The discussion concerning the SMO role seems to revolve around cost concepts related to implementation and operation of the infrastructure. It can be argued that implementing a smart metering infrastructure[18] may represent extra costs to some grid

[18]which could include -but is not limited to- advanced metering infrastructure (AMI) technologies,

users. This is particularly important if smart grid functionalities cannot be fully capitalized. While a commercial player (e.g., supplier) would have a higher incentive to provide a solution that is cost-efficient (since they are profit-driven), this cannot be the sole motivation for assigning the role to a third party. Consider the supplier-led-roll-out in the UK, where problems in technical communication, compatibility, delays, and lack of transparency raised serious considerations and led to several policy problems. In fact, authorities are considering whether to allow for more active participation of grid companies in an attempt to reduce costs to consumers.

Consequently, we believe that a sound assessment for the assignation of the role should focus not only on cost but also on the potential to achieve a timely and effective roll-out of an infrastructure that safeguards data privacy, integrity, and security. Additionally, the assessment should consider the potential limitations the assignation may impose on different stakeholders, e.g., devices with limited interoperability and scalability may slow down the definition of services. Therefore, we recommend applying a holistic approach to the decision-making process.

Arguably, the controversy surrounding the adoption of the DM role shares some features with the discussion on the SMO role. Historically, DSOs have been responsible for performing efficient, non-discriminatory and secure data handling (incl. data metering) [58]. Admittedly, the experience handling data from contracts, meters and network assets could be considered as an advantage over a third party. On the other hand, a third party may show higher flexibility to design and implement a reliable and scalable system for handling the ever-increasing amount of data. Additionally, a third party may bring benefits to DSOs that do not have the competence, experience or are too small to bear the cost of carrying out the activity under the new context. In coun-

remote terminal units (RTUs), intelligent electronic devices (IEDs) and meters for EVs' charging infrastructure.

tries with a fragmented network configuration, i.e., many DSOs, a central approach to data handling may be beneficial. Here, both a larger DSO or a third party could adopt the DM role.

From a regulatory perspective, any third party that assumes the DM role would have to be regulated. For the regulatory authority, this creates an extra burden since resources would have to be dedicated to monitor the behavior of the new regulated entity (incl. parties accessing the data and type of data accessed). Note that data collected by the AMI not only includes data from the meters but also from RTU and IED located across voltage levels. Naturally, DSOs would still require not only to have access to the data but also to be able to store it for a period of years. This situation may create inefficiencies in the form of data duplication (for example, increased transactions cost due to constant access requests) and data inconsistency (such as risks of outdated information).

When selecting the entity that will be handling smart grid data, we suggest considering the costs of data management and regulatory efforts. Also, the potential benefits the assignation might bring regarding non-discriminatory access, data privacy and security. Although it is true that, besides being a regulated entity, in most cases, DSOs would require an upgrade and not a complete lift-off of their infrastructure, it is not clear, however, which entity convey the most benefits to the end-consumer. Admittedly, this role is equally essential for a fully functional active grid management and the development of innovative business models. Consequently, further research on how the adoption of the role influence the activities of other stakeholders such as TSO, BRPs, and aggregators is recommended.

6. Roles and Collaboration Patterns

Flexibility-based services are at the core of the evolution of the electricity distribution business. These services respond to particular needs of a power system, which may differ from country to country.

A business process (i.e., service) is made of interactions (collaboration patterns) that can be generalized. In this regard, business process modeling aims to decrease the complexity and enhance the understanding of the process [63]. Making them independent (to some extent) from the design of electricity markets and regulatory frameworks highlights potential barriers a specific market design or regulatory framework may impose to the service. This is useful when designing a service since it allows the identification of the fundamental steps needed for its provision.

Role models are a powerful tool to analyze collaboration patterns in respect to a particular collaboration purpose. They are reusable, expandable, and allow sequencing and role transfer. Furthermore, role models can be generalized, specialized or aggregated.

The role model-based approach to represent collaboration patterns between role types is based on Riehle [45], De Moor [64], and Bögel [42].

De Moor [64] refers to patterns as ”solutions to recurring problems at the right level of abstraction” and to collaboration patterns as ”a particular class of patterns.” In preparation for the example, a set of collaboration patterns are presented below. In parenthesis the considered roles for each pattern are listed:

- Make request (requester, provider);
- Ask question (inquirer, respondent);
- Coordinate others (coordinator, co-worker);
- Share information (information provider, information receiver);

- Discuss and clarify (worker, worker);
- Save information (saver, knowledge base);
- Record information (recorder, protocol).

According to Riehle and Gross [45], for every pair of role types A and B, i.e., (A, B), from R (set of all role types) there is one constraint value. These constraint values could be:

- Role-indifferent: no restriction concerning role A and B;
- Role-implied: the entity playing role A also has to play role B;
- Role-equivalent: the entity playing role A also has to play role B and vice versa;
- Role-prohibited: the entity playing role A never plays role B and vice versa.

In the following, we show a complex communication pattern that illustrates the reaction to a smart grid service request. Figure 2 depicts a role model of collaboration patterns based on the service ”contracting non-firm grid access” [46, 47]. In role model notation, an oval represents a role type, with the natural type in parenthesis. A line with a forward slash at each end indicates a role-prohibited value. An arrow with a black arrowhead at both ends describes a bidirectional interaction. An arrow with a single black arrowhead indicates an interaction. An arrow with a white arrowhead at both ends depicts a role-equivalent value. An arrow with a single white arrowhead represents a role-implied value. Note that if no role constraint value is given, the default role-indifferent value is assumed.

The interaction starts with a grid user submitting a grid connection request to the DSO web platform (pattern ”make request”). The Customers Relationship Manager verifies the data and transfers the task to the Distribution System Optimizer (pattern "coordinate others"). The Distribution System Optimizer creates a grid connection study (pattern "record information"). The study includes load flow calculations considering long-term forecasts of generation and load. Following the study, the Distribution System Optimizer elaborates a connection offer stipulating the potential power limitation of the connection (pattern "record information"). The study and the connection proposal are sent to the Data Manager by the Distribution System Optimizer (pattern "share information"). The Data Manager stores the documents (pattern "save information"). The Distribution System Optimizer sends the connection proposal to the Customers Relationship Manager (pattern "share information"). The Customers Relationship Manager discusses the proposal with the grid user (pattern "discuss and clarify"). If signed, the Customers Relationship Manager creates a contract (pattern "record information"). The Customers Relationship Manager then sends the contract to the Data Manager (pattern "share information"). The Data Manager stores the contract (pattern "save information"). The Customers Relationship Manager request the Smart Meter Operator to manage the metering infrastructure of the grid user (pattern "make request"). The Smart Meter Operator, according to his objectives/goals, decides the date for the installation.

7. Expectations for role adoption

In general, the adoption of the role set will depend on the prevailing regulatory framework, the state of the technology and the interest level of stakeholders. Particular aspects that will also influence their adoption are the evolution of ancillary services, the status of demand response, developments in system management (i.e., approaches towards planning and operation) and data management and, the status of smart metering infrastructure. Note that these aspects differ across countries. It follows then that the tempo at which the role set is deployed would also vary from country to country.

7.1. Case studies

To indicate the potential adoption path of the role set we assessed the current context of six European countries[19] through surveys and interviews with experts. Each case study considers regulatory highlights, the evolution of ancillary services, the status of demand response, developments towards system operation and data management, and the status of smart meter implementations. The time-wise expectation (potential adoption path) is based on the existence (or lack of) of clear indications on ongoing regulatory discussions, adaptations to the regulatory framework in preparation, ICT infrastructure in place (or planned to be in place), and a clear view on market design appropriate for role adoption. This qualitative analysis is illustrated by country-specific pictures where horizontal arrows point to the expected time horizon (today, short-term, long-term) for each role.

The empirical data resulting from the assessment shows that, among the aspects mentioned above, the national regulatory framework determines, in large part, the feasibility and timing for a role to be adopted. That is, a faster adoption pace, i.e., by 2020 (short-term), is expected for roles requiring few modifications to the regulatory framework. Roles that require substantial changes to the existing regulatory framework are expected to be adopted in the long-term (i.e., by 2030 or later). Note that the magnitude of changes is linked to the level of innovation required by the role.

These findings are relevant because they illustrate key drivers for a role to materialize in a liberalized power system. For instance, the expected interactions among stakeholders, the target level of transparency and neutrality, and the objectives of the regulatory framework.

Figure 3 depicts an overview of the expected adoption pace of the surveyed countries along with examples of enablers and barriers for each role. The presence of different ar-

[19]Belgium, France, Germany, Ireland, Italy, and Portugal.

rows highlights the existence of divergent opinions (characterized by national contexts) regarding the adoption of the role set. Figure 4 illustrates the expectation on a country basis.[20] Note that both illustrations assume the DSO as the entity that plays each role. However, this does not mean that all roles are or will necessarily be adopted by DSOs. For instance, German DSOs may not be able to fully adopt the DM role (see section 5).

As shown in figure 4, DSOs in some countries have already adopted a subset of roles (light blue). Not surprisingly, for each country the Distribution Constraints Market Officer (DCMO) role, an entirely new role, could be adopted only in the long term (dark blue). Other roles show some variation between countries. For instance, the Neutral Market Facilitator (NMF) and Contributor to System Security (CSS) are expected to be adopted in the short term (or in the longer term), depending on the country. The other five roles are either perceived as adopted by the DSO or expected to be adopted in the short-term (blue).

The list below takes a closer look at the expectations for each country:

- Belgium: currently only one role seems to be adopted by DSOs. However, it is expected that the majority of the role set is adopted in the short-term based on the regulatory recognition of roles and the willingness of regulators and network operators to discuss and propose solutions to overcome adoption barriers, e.g., cost recovery of flexibility options, and platform model to host data and exchange information among power system stakeholders;

- France: most roles may be realized in the short-term. Today, three roles are perceived as adopted by DSOs. This perception is based on observed direct assignation (DM and SMO) and regulatory facilitation of service provision (i.e., inno-

[20] In the figure, DSO refers to the Distribution System Optimizer role.

vative access contracts to grid users proposed and handled by CRM). Note that the expectation for the distribution system optimizer role is set for the short-term. This is mainly due to the current limitation to use smart meter data for network management. In the long-term, the realization of the full role set will depend on regulatory developments towards grid management actions, for instance, procurement and activation of distributed flexibility, and incentives to valorize alternatives to grid reinforcements;

- Germany: similar to France and Belgium, most of the roles are expected in the short-term. However, the German context appears to be favorable for the realization of most roles, i.e., only the DCMO role is expected in the long-term. Note that roles related to data management (DM) and collection (SMO) may be adopted to a certain extent. This expectation is based on the assignment of the TSO as settlement authority for intelligent metering systems; the progress in common processes, e.g., Energieinformationsnetz (energy information grid); the implementation of the new metering law; and the evolution of price regulation and technical implementation of smart meters;

- Ireland: in contrast to previous countries, a larger subset of roles is foreseen for the longer track, i.e., long-term. Additionally, the distribution system optimizer role, as described in this paper, is foreseen for the short-term. The prognosis is based on the current need for a regulatory approach that fosters valorization; procurement and utilization of distributed flexibility; and provides incentives for DSO-TSO cooperation concerning data management and exchange;

- Italy: a comparable picture with France is depicted. However, in respect to data management, the Italian regulatory framework introduces a data hub (Integrated Information System - SII) with the objective to centralize and make historical data available to traders, NRAs, customers or their delegated parties, and external stakeholders. Another difference is that in Italy offering "non-firm grid access" contracts is currently not possible;

- Portugal: analogous to Ireland, a larger share of roles is expected to materialize in the long-term. The assumption is based on the present approach towards valorization and use of distributed flexibility. The prevailing regulatory framework limits the procurement of flexibility by regulated entities for purposes other than system services (e.g., balancing services acquired by the TSO). It is worth to mention that even though the DSO currently adopts the Data Manager role, there is still the possibility that the role is assigned to a third party in the future.

8. Recommendations and Conclusions

The definition and adoption of the proposed role set is not a static but rather, a continuous process. It starts when the core feature of a role can be performed by an entity but has no defined endpoint since more features may be added within the limits of the relevant context. In this regard, NRAs are well positioned to judge the relevance and applicability of a role at any given point in time.

8.1. Recommendations

Facilitating the transition of the power system requires regulatory frameworks that promote interoperability and efficiency from a holistic system perspective. Regulatory frameworks should provide a sound environment for testing new approaches (both for planning and grid operation), technologies and flexibility-based solutions. To this end, we recommend the following features to advance the adequacy of the regulatory framework.

- Enable innovation by allowing for new operational solutions to be tested and implemented;
- Encourage the assessment of new flexibility levers for optimal network planning and operation;
- Set clear rules and guidelines for the recognition of capital and operating costs (CAPEX and OPEX). These rules and guidelines should assess, over different timeframes, the benefits and costs of using flexibility for active grid management;
- Encourage the definition of mechanisms that make optimal use of system flexibility services for the sake of the entire power system and its users.

The last point touches upon the need of improved cooperation between DSOs and TSOs so that hierarchy and priority of actions are well defined in (cascading) processes for system support, operation and (bidirectional) information exchange.

The features listed above, when combined with clearly delimited responsibilities and role interactions have the potential to increase the capabilities of network operators to provide a timely response to network events and guard operational security and QoS.

8.2. Conclusions

In conclusion, power systems are in transition. DSOs that implement active approaches to optimize grid management, data handling, and cooperation among stakeholders are key players in this transition.

Our research uses role theory to frame responsibilities and analyze relationships needed to implement active grid management approaches and innovative services at electricity distribution system level. The set of roles proposed in this study provides options to handle the increasing complexity of smart power systems. These roles optimize flexibility use across timeframes; facilitate market participation of stakeholders in a neutral manner; promote the joint definition of coordination mechanisms between network operators; and, safeguard neutral, secure, cost-efficient and transparent data and information exchanges.

The technology readiness level and stakeholder interest are critical factors that impact the adoption of roles. However, findings from our case study suggest that the adoption of these roles largely depend on national regulatory objectives. The regulatory framework may enable (hinder) the provision of a service by promoting a favorable environment (posing substantial barriers) for organizations to undertake new activities. For instance, the regulatory framework could enable the adoption of roles by implementing an operation-oriented remuneration for system operators that recognizes the associated costs of using flexibility. These associated costs could target, among other activities, the test and deployment of efficient and innovative techno-economic solutions for the power system value chain.

Moreover, regulatory frameworks are bounded by the national context. As a result, regulatory approaches vary across countries. Accordingly, as illustrated by our case study, the timeframe for the adoption of the role set is country specific.

To summarize, the regulatory framework determines to a large extent the pace and conditions for the evolution and adoption of existing and new roles. Similarly, the adoption speed and conditions set for these roles will have a substantial impact on the advancement of the distribution business.

Acknowledgements

The research leading to this publication was supported by the evolvDSO project (grant agreement No 608732) funded by the 7th Framework Programme (FP7) for research and innovation of the European Union. The authors gratefully acknowledge the valuable input of the different experts from the evolvDSO consortium.

Figure 1: Set of roles for the electricity distribution business

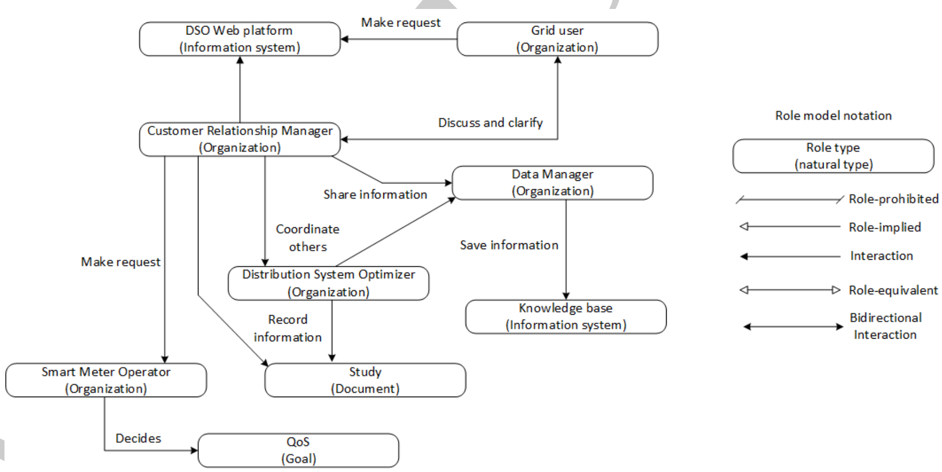

Figure 2: Role model "reaction to a request for non-firm grid access connection"

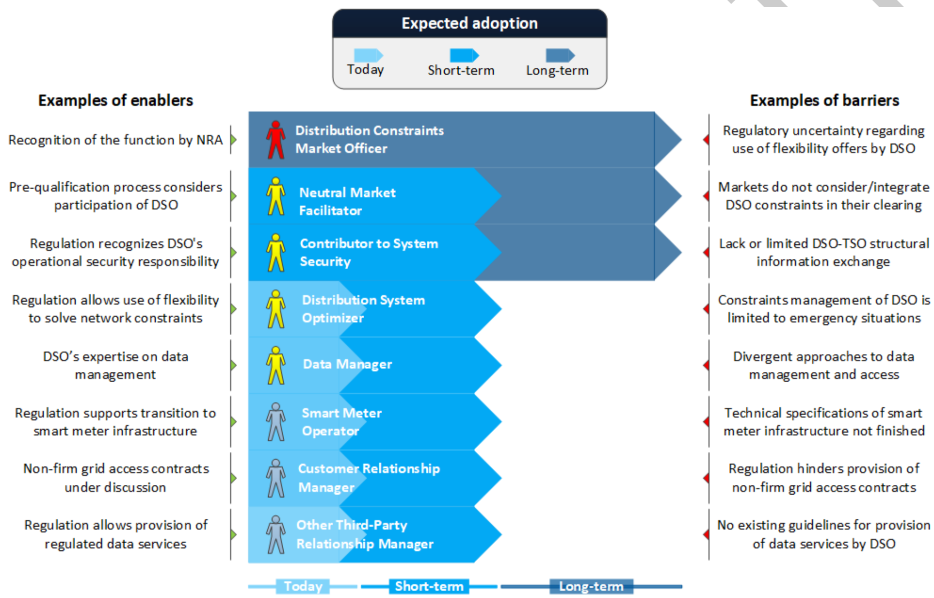

Figure 3: Time-wise expectation for the adoption of roles - European perspective

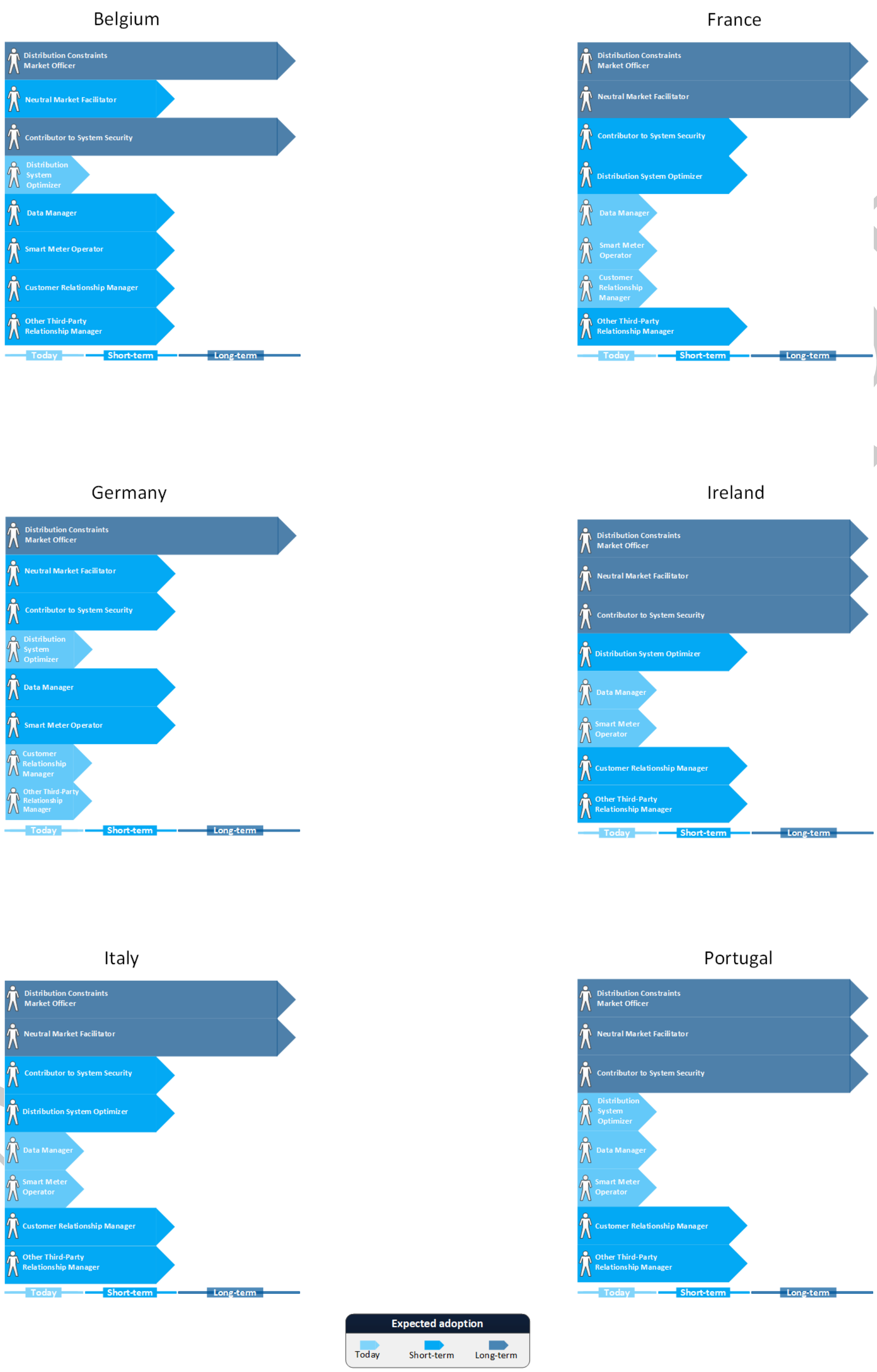

Figure 4: Time-wise expectation for the adoption of roles - Country perspective

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