REPORT

Modelling the DSO transition using the Smart Grid Architecture Model

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Executive summary

Introduction

The development of models to represent five possible future market frameworks (or 'worlds') that could materialise as part of the DSO transition has been commissioned by Energy Networks Association as part of its flagship, cross-industry Open Networks project. This work falls into work stream 3 of Open Networks and ran from September 2017 until June 2018.

The scope of the work was to develop a market-agnostic framework against which the five diverse worlds could be compared. This was informed by extensive stakeholder workshops considering detail of specific DSO functions and activities for each world. The outcomes of these workshops were collated to form a common modelling approach, and this resulted in outputs in the form of "processes and interactions" necessary to facilitate the world.

The developed models have captured the outputs of these workshops on the top three layers of the SGAM framework (business, function and information) with provision for further details to be added to the lower two layers (communication and component) as implementation plans are developed.

Top 5 takeaways

1. An in-depth approach to analysis of the different worlds is important as it uncovers hidden details that were previously not considered. This is evidenced by participant comments at the workshops.
2. This work is not seeking to identify the 'optimal' framework, however it recognises that some models are more complex to implement and present a larger step change from the status quo.
3. The level of commonality between the five worlds is considerable, meaning that there are a number of fewest regrets actions which could be progressed with minimal risk.
4. Different actors are attempting to achieve a range of local and national objectives and the alignment of these objectives can cause conflict and need to be carefully managed and considered as part of any framework.
5. The five SGAM models have been built in a visual modelling and design tool known as Enterprise Architect. This allows for the models to be development and extended in the future should this be required.

Outputs

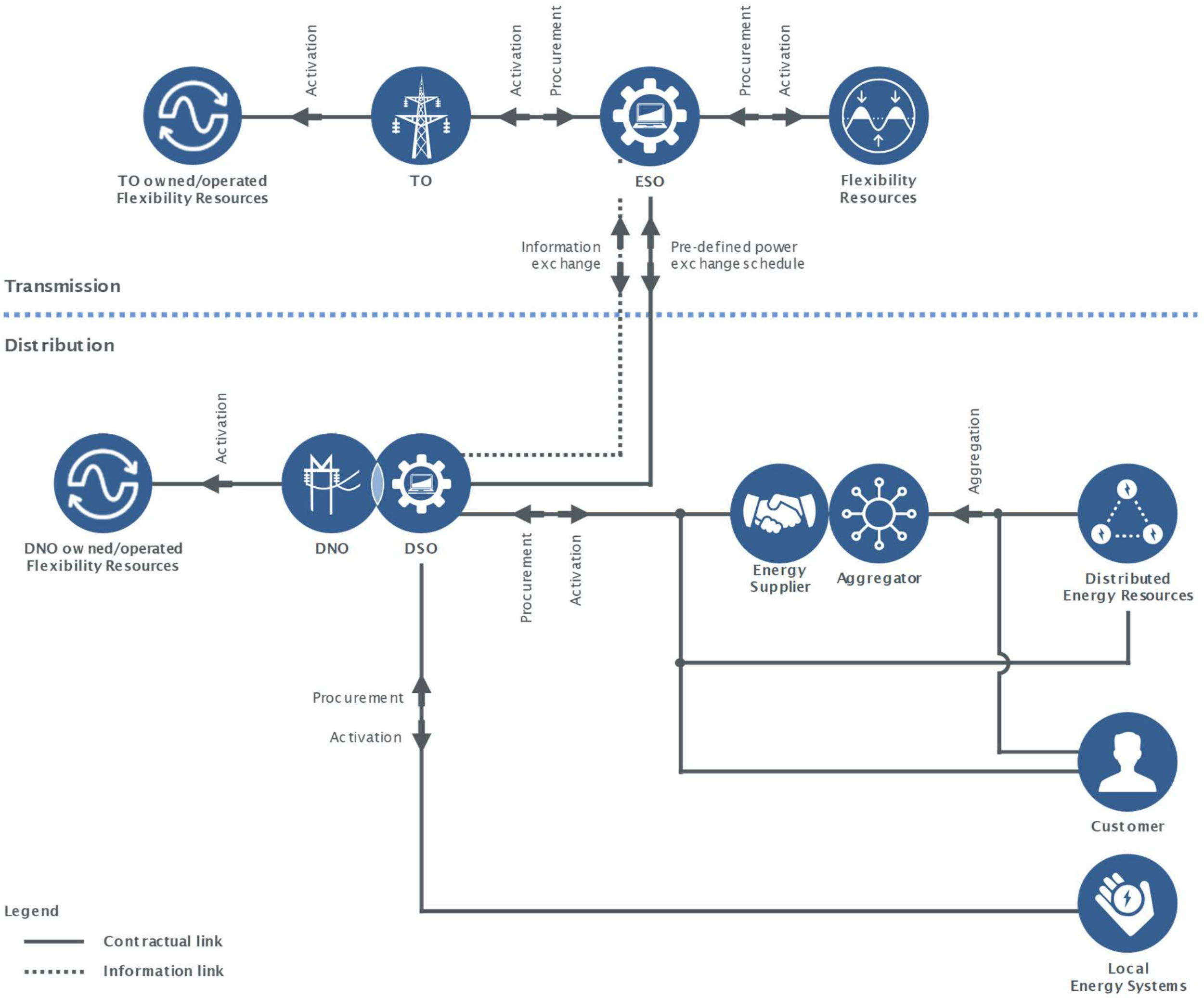
The outputs from this work are as follows:

- SGAM models in Enterprise Architect form to allow for ongoing review and refinement;
- A user guide accompanying the models;
- HTML versions of the SGAM models to facilitate dissemination and to support the stakeholder consultation;
- This report, which pulls out key findings gleaned through creation of these models.

Key findings

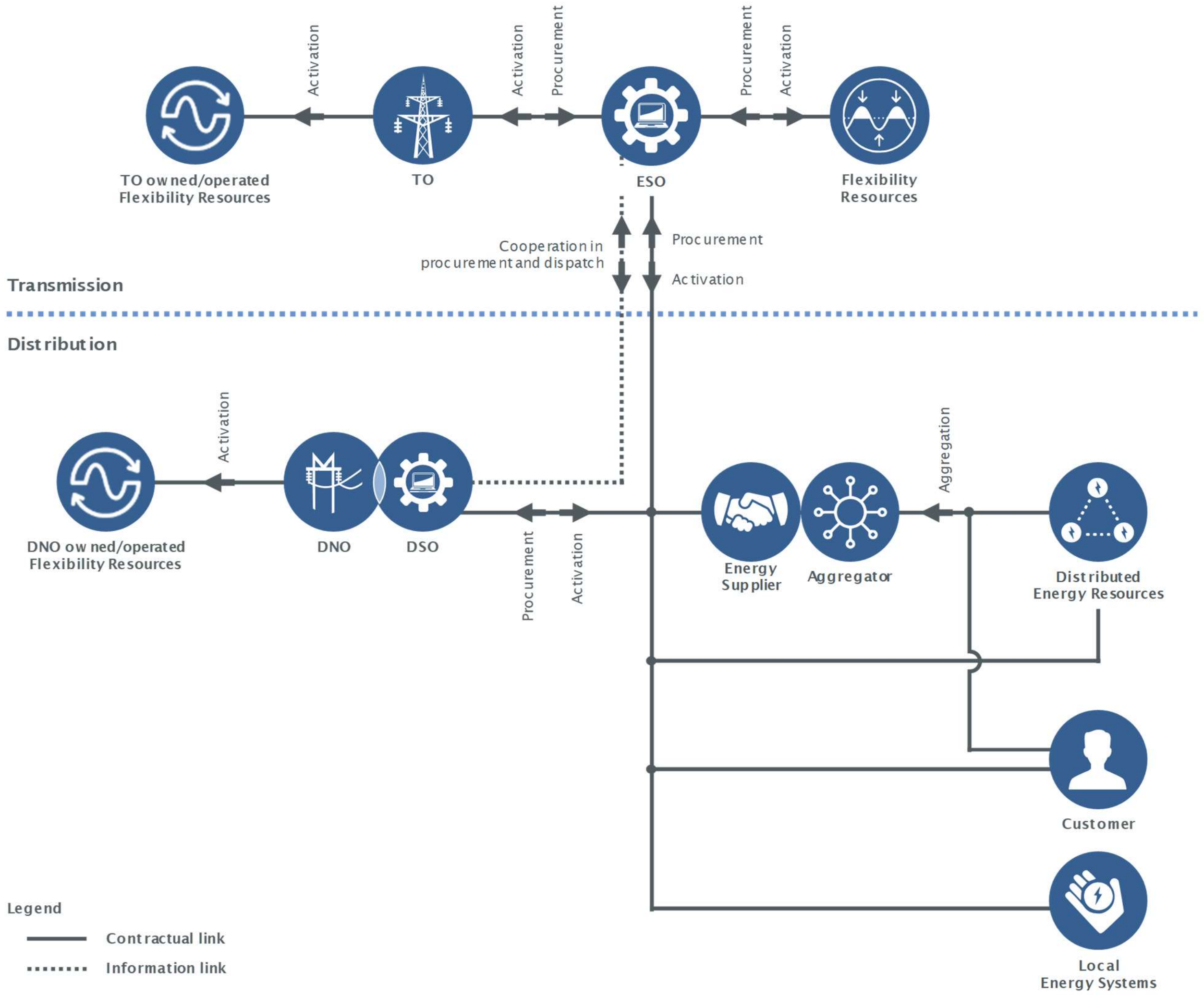
The following diagrams illustrate the five worlds considered and provide some commentary on their key characteristics.

World A: DSO Coordinates



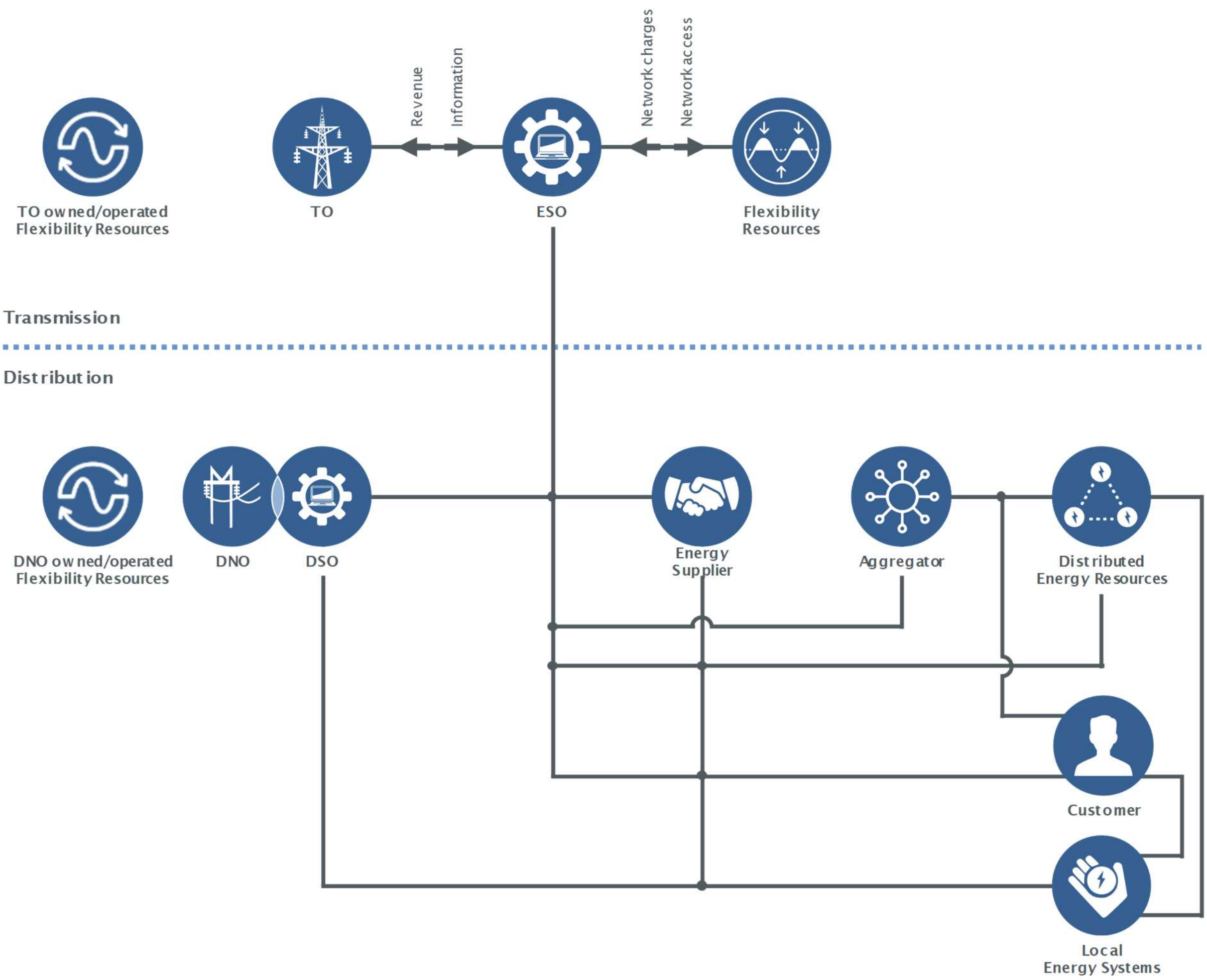
- The DSO is more likely to be in tune with local stakeholder needs and best placed to understand the limits of the local network.
- The DSO can act as a technical gatekeeper to ensure network performance remains as required.
- This world is highly effective at managing local constraints using local resources, however it is more difficult in this world to achieve national efficiencies
- A reasonable amount of interplay between the DSO and ESO is necessary as all contracts for service provision will run through the DSO.
- Regulatory oversight would be necessary to ensure transparency in decision-making; i.e. to demonstrate that the DSO does not merely take the actions that are easiest for it to implement.
- As the DSO is responsible for coordinating the services to resolve a ESO issue, there is a requirement for a team of people within the DSO charged with performing a function that is not necessarily aligned with the current drivers and objectives of the DSO.
- A variety of approaches is likely to manifest across different DSOs, which could lead to confusion for service providers operating across different portions of the country; regulation and standards may be required to manage this.

World B: Coordinated Procurement and Dispatch



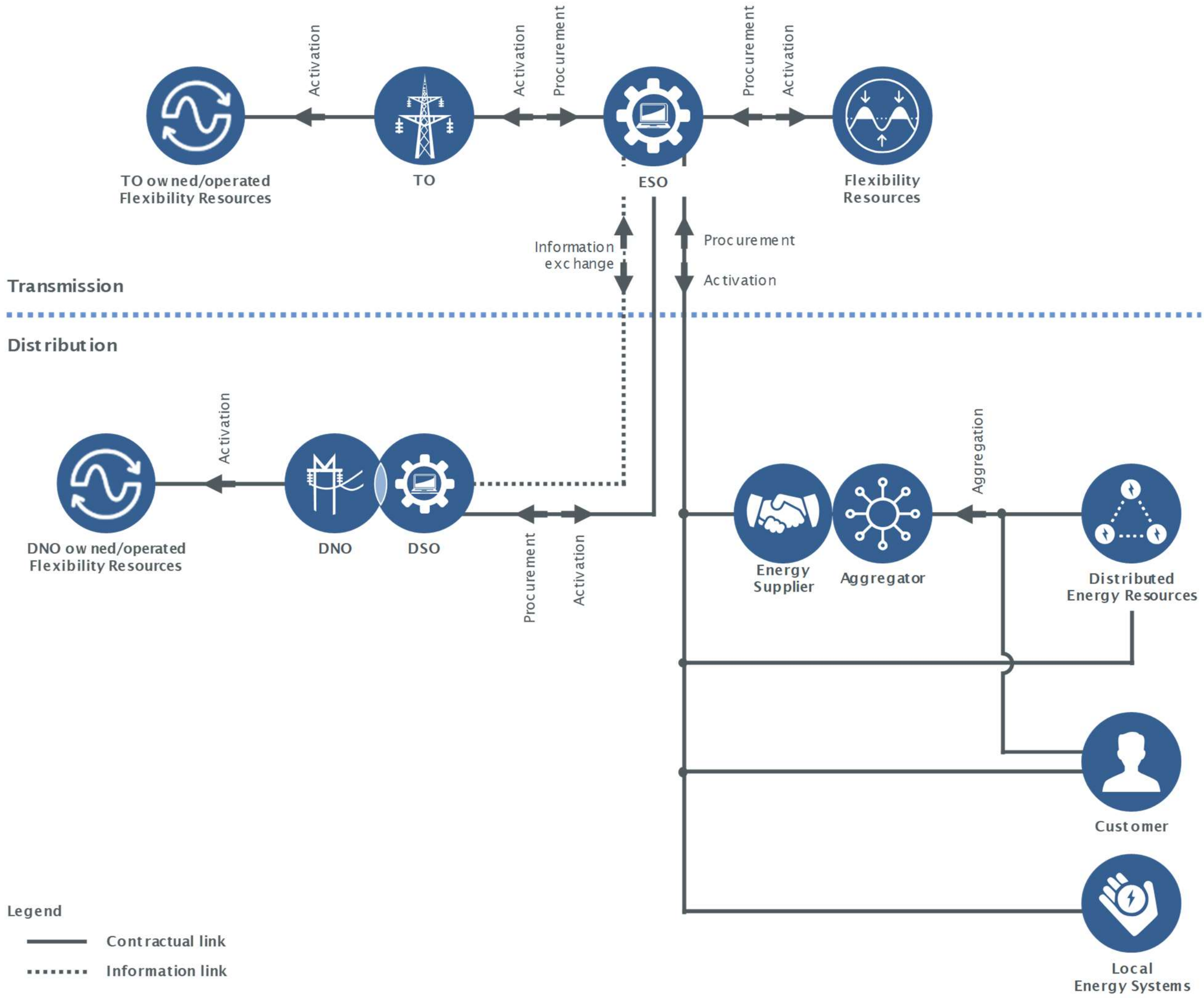
- This world has the potential to optimise solutions across both local and national objectives.
- However, this very advantage has the consequential effect that optimisation processes could be inserted into every business function, e.g. connections, markets operation, network operations, etc.
- Each of the parties (DSO and ESO) is setting up contracts to directly meet their requirements (so internally interests are aligned rather than in the DSO Coordinates model above; i.e. there is no need for a business function existing solely to serve the needs of another party).
- Market participants have more routes to market (they can sell to DSO and to ESO), potentially opening greater revenue opportunities.
- There is a need for careful management of conflicts and greater control measures to eliminate the possibility of the same actor being called upon by each party to resolve an opposing issue (such as charging a battery to increase demand or discharging a battery to resolve a local network constraint). Similarly, a process must be in place to avoid the duplication of payment to an actor for delivering the same service to both DSO and ESO as this would represent poor value for money for customers.
- No single party has ownership of the decision-making process; meaning that conflicts can arise, and their resolution could be complex.
- Conflict resolution requires near real time communication and decision making between the DSO, ESO and actors to ensure secure and reliable operation of network.

World C: Price driven flexibility – 'Network access and charging model'



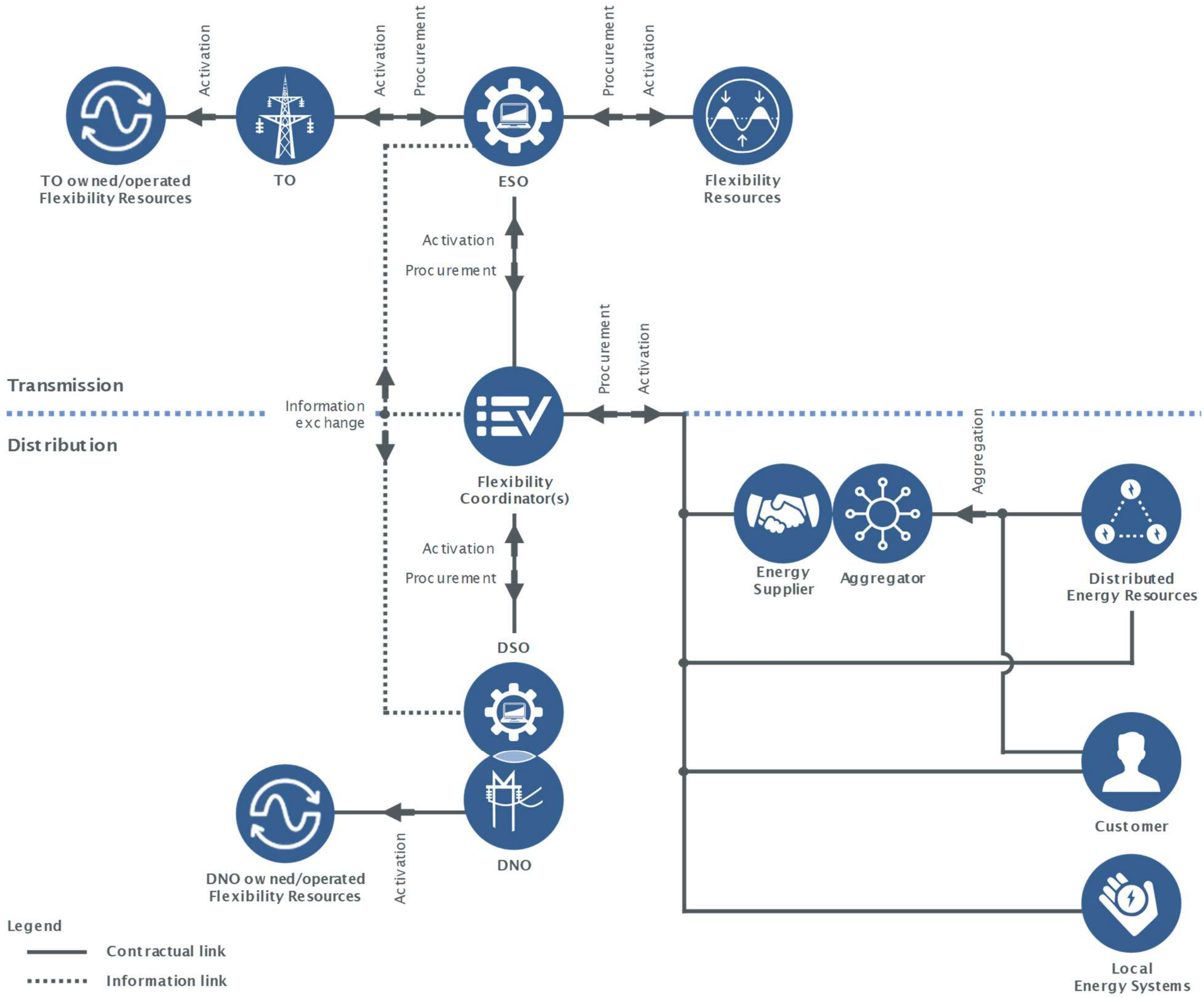
- This world is concerned with a truly market led approach, which should therefore deliver value.
- There is an assumption that participants will respond to price signals (which need to be sufficiently strong) to ensure efficient network operation. However, to ensure security of supply, there will remain a need for some contracted flexibility.
- There is some uncertainty regarding the real-time nature (or otherwise) of the price signals.
- If the signal is real-time (or near-real-time) then there are significant costs in establishing the infrastructure to facilitate this, but the market should deliver value.
- If the price signals are longer-term, then it may be more difficult to manage local constraints efficiently, either leading to 'false constraints' being imposed on participants through artificially high/low price signals, or excessive risk being taken.
- This model establishes potential conflicts of interest between the physics of the network and the requirements of the market, which would need to be resolved by the DSO.
- The variable nature of the price signals could be a complex idea to message to market participants regarding local constraints, the availability of services at different times of day/year, etc.
- Significant effort is required to establish this market framework and signal to actors, however once in place, it could deliver long term value.

World D: ESO Coordinates



- This model is best aligned to deliver national objectives.
- This would deliver significant benefits where the flexibility is large scale, however it can overlook smaller actors with highly distributed flexibility resources.
- As per the DSO Coordinates world, there is a reasonable amount of engagement between ESO and DSO.
- Regulatory oversight would be necessary to ensure transparency in decision-making; i.e. to demonstrate that the ESO does not merely take the actions that are easiest for it to implement.
- Engagement with very small participants is challenging in this model, one solution might be that ESO retains the decision-making authority, but the information regarding these small participants is aggregated by the DSO and passed on to ESO.
- As for DSO Coordinates, there is a risk that ESO is having to take decisions to benefit DSO; i.e. expend time and effort on something that is not directly aligned with its own business goals and drivers.
- Having ESO as the sole decision-maker would lead to greater levels of consistency for market participants rather than having a range of different decision-making entities across the country.

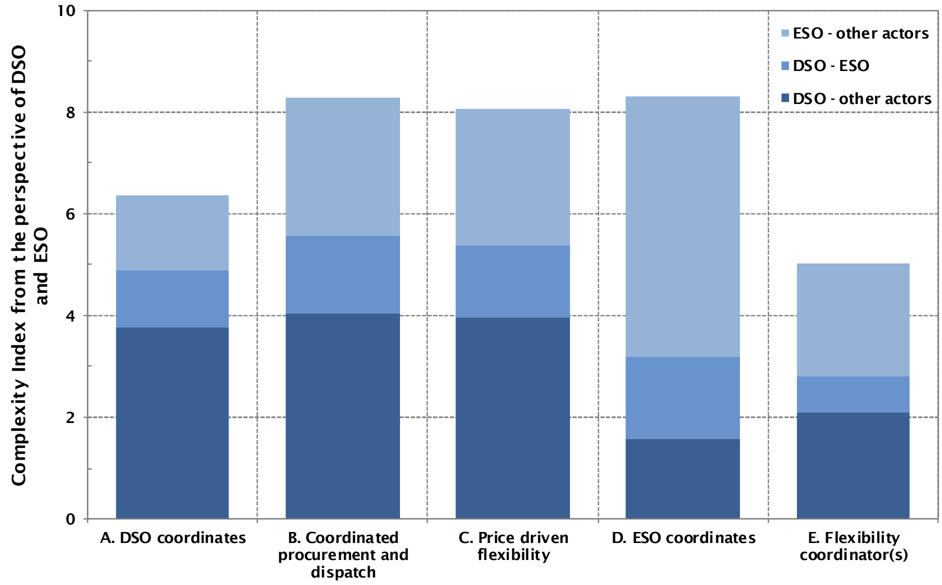
World E: Flexibility Coordinators



- This model seeks to address many of the conflict resolution issues identified in World B.
- Engagement with market participants via the Flexibility Coordinator is likely to result in simpler messaging, resulting in a more responsive market.
- The significant drawback in this world is the transfer of network risk and who takes responsibility for a network exceeding its limits: the question of whether this is the DSO/ESO, or the Flexibility Coordinator is a vital one and represents a potentially significant shift in the philosophy of network operation.
- Depending on how much network risk is transferred there may need to be a large amount of data processing in real time, to provide headroom and capacity limits to the Flexibility Coordinator.
- Regulatory frameworks will need to be adapted, and potentially applied to Flexibility Coordinators, to manage the transfer of network risk between parties.
- This results in clear delineation between market and network activities of ESO, DSO and Flexibility Coordinators.

Complexity of different worlds

The relative complexity of the 5 different worlds varies significantly in terms of both magnitude and composition. This is illustrated in the figure below which shows the complexity index of each world (see Section 5.3 for the derivation) broken down by the actors where the complexity resides as the different worlds naturally have more responsibility (and hence complexity) falling to one or the other of these actors. It should be noted that this complexity is only indicated from the perspective of the DSO and ESO and should not be regarded as 'whole system complexity'.



The relative complexity of Worlds B, C and D are very similar. However, the split indicating where the complexity lies is quite different for World D: ESO coordinates as the ESO take on far greater responsibility than the DSO in this instance.

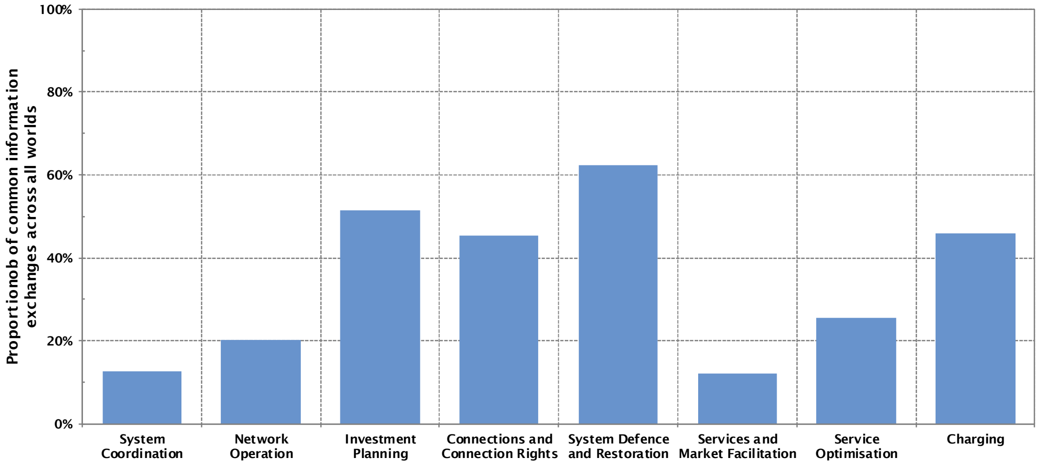
World A: DSO coordinates, shows the mirror of this to an extent (as one would expect), with the DSO taking the greater share of complexity. While it appears that overall this is a less complex world than some of the others, care should be taken with this particular world as it was the first to be considered by the stakeholders in the workshops. It is quite likely that as the stakeholders became more familiar with the process that they captured greater numbers of linkages for some of the latter worlds and hence there may be value in the future in reviewing this world and confirming whether there are more linkages to be added within it. Furthermore, as this work does not differentiate between DSO and DNO, it is likely that there is a reasonable degree of complexity and functionality that is essentially 'internalised' within the DSO actor here and is not captured.

World E: Flexibility Coordinators is an interesting case as the complexity is significantly lower than other worlds. This was one of the final worlds to be considered and hence the argument that that less information was captured due to unfamiliarity is not valid here. Instead, the reason for the lower score is that the Flexibility Coordinators take on a significant amount of the responsibility (and hence the complexity) in this world. Given that the workshop sought to capture the links between 'DSO – others' and 'ESO – others' then the level of complexity appears reduced for the DSO and ESO, but this is not a statement that the overall 'whole system' is necessarily less complex; rather that the complexity has been transferred to a third party, the Flexibility Coordinator(s).

Fewest Regrets Analysis

There are a considerable number of identical information exchanges that occur across all worlds. This is no surprise given that irrespective of which DSO world is realised the problems that the future electricity network will face – as identified today – are the same. Consequently, approximately 31% of information exchanges have been identified as common across all 5 worlds. However, it should be noted that the parties between whom these exchanges occur can vary by world. For example, the

DSO may be passing information to ESO in World D, but would pass the same information to the Flexibility Coordinators in World E. Therefore, these fewest regrets point at least to the necessary processes to gather the requisite data such that it can be provided to whichever party requires it within the given world. For analysis this has been broken down by Function and is presented in the figure below.



The most common actors present within the least regrets actions are DSO, ESO and Regulator; illustrating the fact that the areas of commonality tend to be aligned with ensuring the achievement of national (or whole-system) objectives and are largely concerned with the development of frameworks that underpin and support this. For example, they are concerned with processes to ensure efficient whole system planning and robust emergency response procedures (e.g. black start).

By its nature, network operation and more day-to-day issues vary more widely across the different worlds and hence there are fewer least regrets actions that occur within these business functions, clearly illustrating the bias towards longer-term actions (planning timescales rather than operational timescales).

If we consider a subset of worlds (e.g. B and C) more similarities drop out resulting in additional least regrets activities. However, to derive these least regrets there needs to be timely agreement of the likely worlds that will be taken forward in the longer term. We expect this to be informed by the Impact Assessment (Cost Benefit Analysis), innovation trials and industry stakeholders' feedback, which will assist in determining the feasibility of different frameworks.

Local vs national objectives

To understand the part that localised issues will play and the need for potentially different models in different regions, it is important to understand which actors are concerned with 'national' objectives and which with 'local' objectives.

Local energy systems (LES), for example, are, by their nature, highly localised and will be trying to achieve different objectives from each other. Their drivers might be non-rational (economically). For example, they might be looking to improve air quality, or minimise carbon footprint of a community. The achievement of such 'non-financial' goals can therefore be challenging when considering these actors providing flexibility services to the market and how the provision of such services may be weighted and judged by the market operator (e.g. the Flexibility Coordinator).

Other actors have more national interests and will be seeking consistency in approach. Examples of this include ESO and gas networks, but this is not to say that they will not also be concerned with the delivery of local objectives. Hence while some actors will retain a solely local focus, others will have a range of business drivers to ensure they meet both local and national objectives.

Regional drivers (from legislation etc) could lead to different behaviours and requirements, potentially even for the same company. As an example, different targets in Scotland to England and Wales would lead to different responses for SP Energy Networks in their SPD licence areas (in Scotland) in comparison with their SPM licence area (in England and Wales). Similarly, UKPN's approach in London where targets will be driven by mayoral ambitions is likely to differ significantly from the EPN region in East Anglia which has very different demographics, drivers and objectives.

It seems highly unlikely there will be fundamentally different market structures in different areas; much more likely is an overarching national market. Within this analysis we are considering different market structures, which are more incompatible with each other than the sorts of scenarios that are often considered for future strategy within the DSO sector. It is therefore far more likely that all DSOs will fit into some overall 'umbrella' market structure rather than have vastly differing approaches in this regard.

Clearly there will be local drivers that will be experienced (such as the metro-mayors point previously referenced) and there will always be edge-cases which may require special treatment. Through further trialling and research in innovation projects, it will be possible to explore the ways in which these various frameworks can support the successful delivery of the DSO transition and supporting the whole-system by examining specific trial areas and conditions.

Next steps

The next steps in this area of the Open Networks project are as follows:

- Stakeholder consultation scheduled for summer 2018.
- Impact assessment of the various worlds scheduled for Autumn 2018.
- There will then need to be a rationalisation exercise reducing the five worlds down to those that are deemed most feasible.
- Development of detailed models (communications and component) for this subset of worlds.
- This analysis can then be taken down to next level of granularity for company-specific issues which will be informed by trials and projects, such as SSEN's TRANSITION, SPEN's FUSION, and the Centrica / WPD / National Grid Cornwall Local Energy Market, etc.

Contents

Appendices

Acronyms and abbreviations

ANM	Active Network Management
BEIS	Department for Business, Energy & Industrial Strategy
BUC	Business Use Case
DER	Distributed Energy Resources
DG	Distributed Generation
DNO	Distribution Network Operator
DSO	Distribution System Operator
DSR	Demand Side Response
DUoS	Distribution Use of System Charges
ENA	Energy Networks Association
ESO	Electricity System Operator
FC	Flexibility coordinator
GB	Great Britain
GWAC	GridWise Architecture Council
HLUC	High Level Use Case
ICT	Information and Communications Technology
IDSO	Independent Distribution System Operator
NIST	National Institute of Standards and Technology
Ofgem	Office of Gas and Electricity Markets
ON-PRJ	Open Networks Project
PUC	Primary Use Case
SGAM	Smart Grid Architecture Reference Model
SG-CG/RA	Smart Grid Coordination Group/Reference Architecture Working Group
SSP	System Service Provider
TNUoS	Transmission Network Use of System Charges
TO	Transmission Owner

1. Introduction

1.1 Context

The power sector is witnessing considerable disruption arising from a combination of policy, technological and customer change. It is creating a transformation in how we think about, produce and use electricity. This change towards a decarbonised, decentralised and digitalised system is profound and Distribution Network Operators (DNOs) are right in the frontline of its consequential impacts. The extent of change in the sector dramatically alters future assumptions about business models and future roles for network companies. This means that DNOs need to revisit their current business model, roles, capabilities, skills and consider their evolution to that of a Distribution System Operator (DSO). This transition process will enable them to adapt to meet the disruption challenges and realise associated opportunities whilst maintaining low cost and reliable energy distribution for customers with high-quality network services.

In this context, the Open Networks Project[1] (ON-PRJ) established the 'Workstream 3 – DNO to DSO Transition' to "develop a more detailed view of the required transition from DNO to DSO including the impacts on existing organisation capability"[2]. Furthermore, Department for Business, Energy & Industrial Strategy (BEIS) and Office of Gas and Electricity Markets (Ofgem)[3] have emphasised the need for electricity network operators to make greater progress around the Transmission and Distribution interaction including the onus on network companies to map out the transition from a DNO to a DSO model. The ON-PRJ identified and defined key capabilities[4] required by a DNO to develop and operate the distribution network following an Active Distribution System Management approach and to progress towards a DSO business structure. It then developed five potential market model options for the future DSO that can support the definition and the capabilities of the DSO established in the project.

The Energy Networks Association (ENA) have sought specialist advisory support from EA Technology to develop and assess Smart Grid Architecture Model[5] (SGAM) representations of the five potential market model options for the future DSO.

1.2 Aims and objectives

This report aims to develop comprehensive SGAM representations of potential market model options for the future DSO. Specifically, this work can be divided into the following key objectives:

- To create high-level market model options for the future DSO: review and analyse the ON-PRJ's initial thinking on potential future DSO models; research DSO models and DSO transition programmes in other geographies; critique and enhance the initial DSO models based on the research undertaken and industry stakeholder engagement;
- To develop a market agnostic SGAM framework: methodology for the development of a market agnostic SGAM framework; assess the standard structure of the SGAM framework to ensure it is fit for purpose of the architectural representation of the future DSO market models; modify

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[1] "Open Networks Project," Energy Networks Association, London, United Kingdom, 2017. http://www.energynetworks.org/electricity/futures/open-networks-project/open-networks-project-overview/
[2] "Introduction to ENA Open Networks Project," Energy Networks Association, London, United Kingdom, Jun. 28, 2017. http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/CURRENT%20Open%20Networks%20Introductory%20slides%20v3.pdf
[3] A Smart, Flexible Energy System – A Call for Evidence," Department for Business, Energy & Industrial Strategy and Office of Gas and Electricity Markets, London, United Kingdom, Nov. 10, 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/576367/Smart_Flexibility_Energy_-_Call_for_Evidence1.pdf
[4] Workstream 3: Product 2 Functional and System Requirements," Energy Networks Association, London, United Kingdom, May 15, 2018. http://www.energynetworks.org/assets/files/ON-WS3-P2%20DSO%20Functional%20Requirements.pdf
[5] "Smart Grid Reference Architecture," CEN-CENELEC-ETSI Smart Grid Coordination Group, Nov., 2012. https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf

and enhance the standard structure of the SGAM framework as appropriate; deliver a market agnostic SGAM framework for implementation of market models for DSO;

- To develop SGAM representations of the market model options for the future DSO: select a subset of the high-level market model options for DSO for detailed analysis; facilitate and deliver industry workshops to comprehensively characterise the market models for DSO; develop a methodology for the design and implementation of the SGAM; develop SGAM representations of the market model options for the future DSO; and

- To assess the SGAM representations of the market model options for the future DSO: analyse the risks and benefits of the various model options; identify the areas and actions of 'least-regrets' across the various model options; draw out geographically dependent 'local' (either regional or business driven) factors that can influence the transition process to DSO.

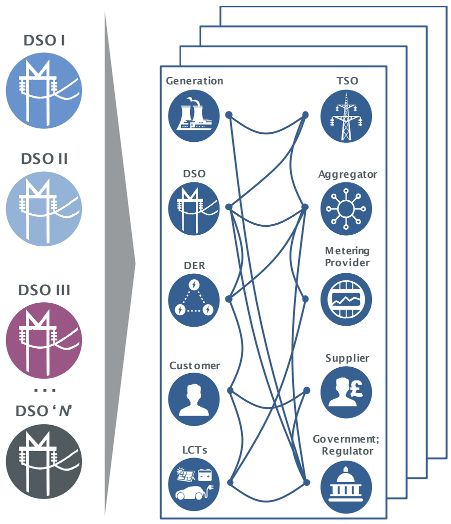
1.3 Scope of work

This report develops comprehensive SGAM representations of five potential market model options for the future DSO. It should be noted that this work does not intend to recommend market models but rather intends to: (i) develop these models so that they are well understood; (ii) to adapt these models to reflect improved learning; and (iii) to inform the cost-benefit analysis of these models that will be undertaken as future work.

The SGAM representation of a market model for the future DSO has proven to be extensive and complex. Therefore, attempting to present the SGAM of each of the five market model options in this report becomes an impractical task. Instead, the report extracts a single 'use case' from the SGAM developed in the Enterprise Architect software to demonstrate the application of the methodology developed to design and implement the SGAM. The detailed SGAM representation of each of the five market model options, developed in the Enterprise Architect software, are publicly available for industry stakeholders.

1.4 Approach to work

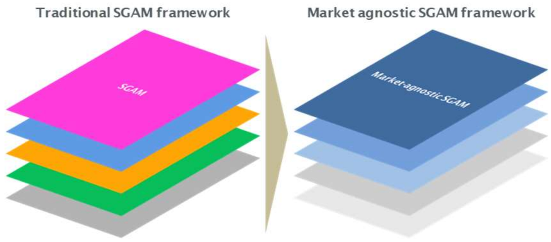
An overview of the approach followed by EA Technology to address the work plan specified in the project proposal is presented in Figure 1 below.



Stage I: Development of high-level market model options for the future DSO

- Review and analyse the ON-PRJ's initial thinking on potential future DSO models; research DSO models and DSO transition programmes in other geographies; critique and enhance the initial DSO models based on the research undertaken and industry stakeholder engagement

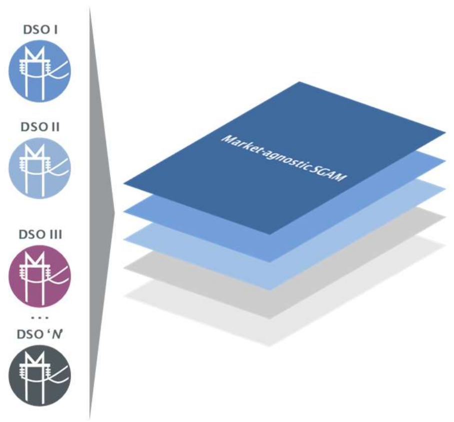
(a) Development of high-level market model options for the future DSO



Stage II: Development of a market agnostic SGAM framework

- Methodology for the development a market agnostic SGAM framework; assess the standard structure of the SGAM framework to ensure it is fit for purpose of the architectural representation of the future DSO market models; modify and enhance the standard structure of the SGAM framework as appropriate; deliver a market agnostic SGAM framework for implementation of market models for DSO

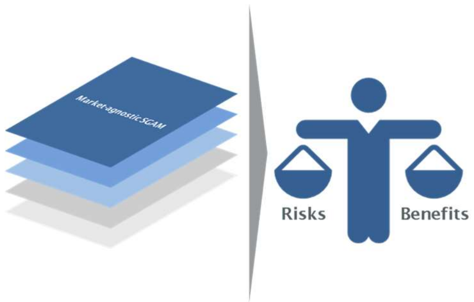
(b) Development of a market agnostic SGAM framework



Step III: Development of SGAM representations of the market model options for the future DSO

- Select a subset of the high-level market model options for the future DSO for detailed analysis; facilitate and deliver industry workshops to comprehensively characterise the market models for DSO; develop a methodology for the design and implementation of the SGAM; develop SGAM representations of the market model options for the future DSO

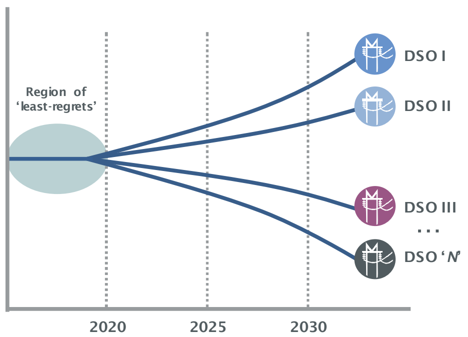
(c) Development of SGAM for market model options for the future DSO



Stage IV: Assess risk and benefits associated with the market model options for the future DSO

- Following the development of the SGAM models and the feedback gathered throughout the workshop process, a list of the overarching risks and benefits associated with each model is compiled.

(d) Overarching risks and benefits



Step V: Fewest regrets analysis

- By examining the processes and interactions necessary between actors to facilitate the delivery of each world, the areas of commonality and divergence can be identified. This permits those activities that are present across all worlds to be drawn out as fewest regrets.

(e) Fewest regrets analysis

Step VI: Localised issues analysis

- Different actors have different business objectives, leading them to behave in different ways. This can be analysed to determine how the risks and benefits and fewest regrets can be translated at a local level. It also allows the identification of key factors that can influence decisions that may be taken on an individual DSO basis.

(f) Localised issues

Figure 1 **Overview of the approach to work**

1.5 Structure of the report

This report details the research, analyses, conclusions and recommendations of the work undertaken by EA Technology to develop and assess SGAM representations of five potential market model options for the future DSO. This report is structured as follows:

- Section 2 sets out the principles, definition, roles and responsibilities of the future DSO and describes. It identifies and defines key capabilities required by a DNO to progress towards a DSO business structure. It then details five potential market model options for the future DSO that can support the definition and capabilities of the DSO.
- Section 3 introduces the fundamental conceptual principles that underpin the SGAM framework. It develops a methodology to create a market agnostic SGAM framework. It then assesses the standard structure of the SGAM framework to ensure that it is fit for purpose of representing the market models for DSO and provides a market agnostic representation of the SGAM framework.
- Section 4 presents the methodology developed the design and implementation of the SGAM for the market model options of the future DSO. It then extracts a 'use case' from the SGAM of a specific market model for DSO, to demonstrate the step-by-step application of the methodology.
- Section 5 describes some of the key characteristics of the worlds that have been derived through the conducting the workshops and developing the models. It then goes on to examine the relative complexity of the different models and identify whether this complexity resides with the DSO, ESO or at the interface between them.
- Section 6 examines the level to which the various worlds share commonality or are divergent and illustrates the types of actions that represent fewest regrets.
- Section 7 discusses the competing national and local objectives of different actors and explores potential drivers that could influence the adoption of different approaches both between, and within, DSOs in the future.
- Section 8 summarises the key conclusions and findings of the work.

2. Market model options

The section introduces the principles, definition, roles and responsibilities of the future DSO. It then identifies and defines key capabilities required by a DNO to develop and operate the distribution network following an Active Distribution System Management approach and to progress towards a DSO business structure. These key functional capabilities are described via eight DSO functions together with their own individual DSO activities. Subsequently, it details five potential market model options for the future DSO that can support the definition, functions and activities of the DSO. These model options can be generally categorised based on the extent to which the DSO accesses flexible DER, facilitates services and markets, provides own services to network customers, the extent of its relationship with other industry stakeholders and the associated market design. The five market model options are termed as: (i) DSO World A: DSO coordinates; (ii) DSO World B: Coordinated procurement and dispatch; (iii) DSO World C: Price driven flexibility; (iv) DSO World D: ESO coordinates; and (v) DSO World E: Flexibility coordinator(s). It should be stressed that this work does not intend to recommend market models but rather intends to develop these models so that they are well understood, to adapt these models to reflect improved learning and then to inform the cost-benefit analysis of these models that will be undertaken as future work.

2.1 Distribution System Operator

The ON-PRJ established the 'Workstream 3 – DNO to DSO Transition' to "develop a more detailed view of the required transition from DNO to DSO including the impacts on existing organisation capability"[6]. Whilst the high-level principle of the DSO transition is relatively well understood within the industry, there are a wide range of functional activities that could fall within its definition. Therefore, understanding the principles, definition, roles and responsibilities of the DSO is an important prerequisite to delivering this transition. The ON-PRJ definition of DSO forms a strong starting point for the development of the DSO transition process and it will evolve over time as the industry develops and more learning becomes available.

Definition[7]

"A Distribution System Operator (DSO) securely operates and develops an active distribution system comprising networks, demand, generation and other flexible distributed energy resources (DER). As a neutral facilitator of an open and accessible market it will enable competitive access to markets and the optimal use of DER on distribution networks to deliver security, sustainability and affordability in the support of whole system optimisation. A DSO enables customers to be both producers and consumers; enabling customer access to networks and markets, customer choice and great customer service."

It should be noted that in the definition above, the neutral market facilitator role is essential to ensuring that all potential providers of flexibility services can compete directly with more traditional network solutions, including as an alternative to network infrastructure reinforcement.

Roles and responsibilities[7]

This definition of DSO entails the following set of roles and responsibilities:

- Maintain distribution network resilience and security;
- Support whole system stability;

[6] "Introduction to ENA Open Networks Project," Energy Networks Association, London, United Kingdom, Jun. 28, 2017. http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/CURRENT%20Open%20Networks%20Introductory%20slides%20v3.pdf
[7] "Agreed in Principle & Updated 02/06/17 – DSO Definition and R&R," Energy Networks Association, London, United Kingdom, Jun. 02, 2017.
http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/DSO%20Definition%20and%20RR_v7.0.pdf

- Provide fair and cost-effective distribution network access;
- Provide capacity in an efficient, economic, coordinated and timely manner;
- Support whole system optimisation;
- Enabling and facilitating competition in energy markets; and
- Provide and maintain systems, processes and data to facilitate markets and services.

The practical execution of this DSO definition together with its roles and responsibilities involves the enhancement of existing and the creation of new functional activities in combination with people, processes, technology and organisational structures.

Principles[7]

This definition of DSO seeks to satisfy the following four key principles:

- Ensures non-discriminatory and technology neutral: favouring solutions that provide the most optimal solutions rather than particular technologies;
- Uses market mechanisms that are fair, transparent and competitive, providing a level playing-field for providers of network services and providers of energy products / services in order to deploy the most efficient and effective solutions;
- Supports flexible and innovative solutions in responding to customer future requirements and in developing the network services they require, including enabling and facilitating innovation by others; and
- Delivers value to customers and communities.

2.2 Functions and activities for Distribution System Operators

The ON-PRJ identified and defined key capabilities required by a DNO to develop and operate the distribution network following an Active Distribution System Management approach and to progress towards a DSO business structure. The ON-PRJ described these key functional capabilities via eight DSO functions together with their individual DSO activities[8]. Table 2 presents an overview of the eight DSO functions. These reflect the evolution of current DNO capabilities and the creation of new ones that enable the DNO to fulfil its enhanced requirements as a DSO. Table 3 broadly compares the eight functions across the DNO and DSO business structures. Subsequently, the DSO functions and associated DSO activities are introduced in greater detail.

[8] "Workstream 3: Product 2 Functional and System Requirements," Energy Networks Association, London, United Kingdom, May 15, 2018.
http://www.energynetworks.org/assets/files/ON-WS3-P2%20DSO%20Functional%20Requirements.pdf

Table 2 Overview of the DSO functions

Function	Description
System coordination	Operate local and regional areas and coordinate energy and power transfers with other networks and systems to enable whole system planning, operation and optimisation across different timescales. System coordination could include local actions to support thermal, voltage and frequency management across networks including actions to minimise losses, manage constraints and provide capability.
Network operation	Operate the electricity distribution network to maintain a safe and secure system. Ensure that network power flows remain within limits and that the network operates within acceptable voltage limits. Ensure that the network remains secure against credible evets such as circuit trips and generation loss. Identify and manage current and future risks. Coordinate and collaborate with the NETSO to manage potential conflicts to support whole system optimisation. Respond to customer needs.
Investment planning	Identify capacity requirements on the distribution network and secure the most efficient means of capacity provision to customers. Coordinate with the NETSO and TOs to identify whole system options. These would include commercial DER options as well as distribution network investment.
Connections an connection rights	Provide fair and cost effective distribution network access that includes a range of connection options that meet customer requirements and system needs efficiently.
System defence and restoration	Enhance whole system security through the provision of local and regional flexible services. Provide system resilience to very low probability but high consequence events using risk based approaches. Provide the means to re-establish the wider synchronous area in the event of widespread disruption.
Services / market facilitation	Interface with the GBSO and other network operators to enable the development of distribution capacity products, the creation and operation of local network service markets and to enable DER access/participation in wider services for whole system optimisation. Facilitate local and national markets to access and settle services through auctions and other market arrangements for whole system efficiency. Ensure these arrangements are fair and transparent. Provide information and control system infrastructure to facilitate local and national markets and service provision.
Service optimisation	Ensure system needs can be efficiently met across all timescales by identifying network requirements, understanding the limitations of network assets and providing network access for additional flexibility services from smart solutions and DER services. Ensure whole system optimisation and resilience through the optimal selection of flexibility services.
Charging	Sets Distribution Use of System prices for local network. Determines Point of Connection. Determines connections charges and informs of transmission reinforcement charges (if applicable). Consideration to exit charging (dependent on size, variations and apportionment).

Table 3 Overview of DSO functions within the present DNO and future DSO structures

Function	DNO	DSO
System coordination	Minimal at present.	Potential role: A DSO could operate local and regional balancing areas for whole system optimisation. This could include local actions to manage constraints, minimise losses and provide capability to contribute to maintaining the national energy balance
Network operation	Deliver safety and reliability through the maintenance and operation of distribution network assets. Respond to customer needs.	Operate the electricity distribution network to maintain a safe and secure system. Coordinate and collaborate with the NETSO to manage potential conflicts to support whole system optimisation. Respond to customer needs.
Investment planning	Deliver a network that securely operates through efficient, coordinated and Economical network assets.	Coordinate with the NETSO and TOs to identify whole system options. These would include commercial DER options as well as distribution network investment.
Connections an connection rights	Provide fair and cost effective distribution network access.	Provide fair and cost effective distribution network access that includes a range of connection options that meet customer requirements, and system needs efficiently.
System defence and restoration	Support local and whole system resilience and security.	Enhance whole system security through the provision of local and regional flexible services.
Services / market facilitation	Limited at present. For example, enable the flexible connection of DER to provide wider system services.	Interface with the NETSO (including information and control infrastructure) to enable development of distribution capacity products, creation of local network service markets and enable DER access/participation in wider balancing services for whole system optimisation. Facilitate local and national markets to access services through auctions and other market arrangements for whole system efficiency. Provide data / information to facilitate distribution markets and service provision.
Service optimisation	Minimal at present.	Potential role: A DSO could access services on behalf of others (e.g. NETSO or other DSOs), or provide services to others, where doing so is necessary to maximise whole system efficiency, and protects competition.
Charging	Adopts common methodologies and principles to set pricing for Distribution Use of System and Connections.	Sets Distribution Use of System prices for local network. Determines Point of Connection. Determines connections charges and informs connectees of transmission reinforcement charges (if applicable). Considers impact of Exit Charging (dependent on size, variations and apportionment)

System coordination

The 'system coordination' function comprises activities that the DSO would undertake to support whole system planning, operation and optimisation across the transmission and distribution networks. Power and energy transfers across local and regional areas would be managed to ensure adjacent networks or systems are balanced and operated efficiently.

Activities associated with 'system coordination' would include coordination with the National Electricity Transmission System Operator (ESO), with other DSOs, Independent Distribution System Operators (IDSOs) / Independent Distribution System Operators (IDSOs) and with local energy systems to ensure the overall system is operated within technical and commercial limits. In this respect, local energy systems could include community energy schemes, private networks, etc. Other activities falling under 'system coordination' could include cross vector energy exchanges, such as the large-scale transfer of electricity to heat. The coordination of services to support wider network operation (e.g. voltage management) is also included in this function. Table 4 presents an overview of the 'system coordination' function and its activities.

Table 4 'System coordination' function and activities

Function	Description	Activities	Description
System coordination	Operate local and regional areas and coordinate energy and power transfers with other networks and systems to enable whole system planning, operation and optimisation across different timescales. System Coordination could include local actions to support thermal, voltage and frequency management across networks including actions to minimise losses, manage constraints and provide capability.	Coordination with NETSO	Managing MW and Mvar demand and generation within a local network area and managing exchanges to and from the GB transmission system within agreed technical and commercial limits.
		Coordination with other DSOs and Distribution Networks (including IDSOs)	Managing MW and Mvar demand and generation within a local network area and managing exchanges to and from other distribution networks within agreed technical and commercial limits. These distribution networks will include networks operated by the same DSO, other DSOs, DNOs and Independent DNOs.
		Coordination with local energy systems including industrial networks, community schemes, smart cities etc.	Managing MW and Mvar demand and generation within a local network area and managing the interfaces to local energy systems and arrangements within agreed technical and commercial limits. These local energy systems and arrangements might include community energy arrangements, smart city arrangements as well as the private networks used to supply industrial complexes.
		Coordination of networks to enable cross vector energy exchanges	Managing the distribution network so that cross-vector energy exchanges are facilitated where these are acceptable technically and commercially.
		Coordination of local network services	Contributing to the management of other networks and wider systems (e.g. transmission voltage management, overall frequency management) through the facilitation and co-ordination of local network services provided by DER.

Network operation

The 'network operation' function covers activities that ensure the secure and efficient real-time operation of distribution networks. These include operating within acceptable thermal and voltage ratings and acting to ensure that the network and its connected resources remain stable. These activities are becoming more complex as levels of distribution connected generation, storage and responsive demand increase and as distribution networks become more active.

'Network operation' activities also include the configuration and operation of distribution networks to reduce losses and to enable the efficient use of connected resources. 'Network operation' will also require DSOs to take account of equipment outages and condition through operational planning and risk management activities.

It should be noted that the 'network operation' function covers technically based activities to ensure effective real-time operation whereas the 'system coordination' function focusses on interactions with other networks and systems. Table 5 presents an overview of the 'network operation' function and its activities.

Table 5 'Network operation' function and activities

Function	Description	Activities	Description
Network operation	Operate the electricity distribution network to maintain a safe and secure system. Ensure that network power flows remain within limits and that the network operates within acceptable voltage limits. Ensure that the network remains secure against credible evets such as circuit trips and generation loss. Identify and manage current and future risks. Coordinate and collaborate with Great Britain System Operator (GBSO) to manage potential conflicts to support whole system optimisation. Respond to customer needs.	Operate network within thermal ratings	Use network asset rating and power flow information and operate local distribution network assets within ratings.
		Operate network within voltage limits	Model network power flows and operate distribution network assets within secure voltage limits.
		Operate network to maintain dynamic stability	Operate distribution networks such that the network and its connected resources (e.g. generators) remain stable for secured faults.
		Operate network within fault level limits	Model network infeeds and contingencies to ensure that equipment and connected resources remain within short circuit ratings and within protection limits.
		Operate network to meet other power quality criteria	Review and monitor potential for other power quality problems including harmonics and unbalance and operate network to avoid these.
		Operate network taking account of ongoing asset condition	Monitor the condition of assets and adjust operation on the basis of latest condition.
		Operate network to minimise losses	Model network power flows to ensure that losses on distribution network are minimised.
		Enable network outages to provide access to assets and resources	Forward planning and ongoing operation to ensure that network security is maintained during network outages and outages of key DER.
		Optimised use of assets and dispatch of services	Utilise available resources in the most efficient way to operate within network limits.

Investment planning

'Investment planning' activities are becoming more complex as networks are developed with increasing levels of active resources. As well as the traditional investment solutions used by DNOs, alternative solutions are being developed to manage network capacity.

Alternative solutions include SMART network control-based solutions such as Active Network Management (ANM) and solutions that defer or avoid investment in new network assets by utilising network and connected Distributed Energy Resources (DER) flexibility.

Going forward, an increasing element of the 'investment planning' function could be to work with other network owners and operators to take forward efficient whole system solutions that address wider network limitations. Table 6 presents an overview of the 'investment planning' function and its activities.

Table 6 'Investment planning' function and activities

Function	Description	Activities	Description
Investment planning	Identify capacity requirements on the distribution network and secure the most efficient means of capacity provision to customers. Coordinate with the NETSO and TOs to identify whole system options. These would include commercial DER options as well as distribution network investment.	Traditional investment planning	Offering connections and upgrades for new customers and for load growth based on the provision of network asset based solutions.
		Whole system planning	Coordinate with the GB System Operator and Transmission Owners to determine the most efficient options for whole system optimisation.
		Non-traditional investment planning	Providing alternative solutions to traditional asset based investment including ANM systems to manage areas of constraint, DER contracts and despatch etc.
		Security of supply (D&G)	Ensuring security of supply and network resilience is maintained in accordance with regulatory planning and design codes.

Connections and connection rights

The ‘connections and connection rights’ function contains activities directly related to the provision of distribution network connections and to managing ongoing access to the distribution network. Such activities include the design of connections, putting in place connection agreements with clearly defined access rights and the ongoing management of these agreements.

Increasingly, the ‘connections and connection rights’ function is also covering how DSOs manage the increasing demand for connection to some areas of distribution networks. Activities here include how to manage access to limited network capacity including mechanisms such as queue management and commercial constraint payments. Table 7 presents an overview of the ‘connections and connection rights’ function and its activities.

Table 7 ‘Connections and connection rights’ function and activities

Function	Description	Activities	Description
Connections an connection rights	Provide fair and cost effective distribution network access that includes a range of connection options that meet customer requirements and system needs efficiently	Connection agreements	Providing connections for customers with defined terms and conditions for network access. Defining the roles and responsibilities for each party involved in the connection.
		Connection access rights / principles / information	Agreeing how capacity constraints on the transmission and distribution networks that affect all customers will be managed by network operators and how this information will be disseminated.
		Queue management / priorities	Managing clear, consistent and non-discriminatory arrangements for how customers waiting for new capacity will be treated.
		Commercial arrangements for constraints	The mechanisms for managing network constraints through commercial means.

System defence and restoration

The ‘system defence and restoration’ function recognises that distribution networks and resources can play an increasing role in the overall electricity system resilience and in the re-establishment of networks following a major system incident.

Activities part of the ‘system defence and restoration’ function are: contingency planning for extreme events (e.g. storms), the design and operation of resilience schemes that help managing extreme frequency deviations (e.g. Low Frequency Demand Disconnection), the design and operation of “islanding” arrangements and contributing to Black Start arrangements. DER resilience to system disturbances (e.g. Loss of Mains Protection, Fault Ride Through capability) and risk management of networks with high volumes of connected DER are also included in this function. Table 8 presents an overview of the ‘system defence and restoration’ function and its activities.

Table 8 ‘System defence and restoration’ function and activities

Function	Description	Activities	Description
System defence and restoration	Enhance whole system security through the provision of local and regional flexible services. Provide system resilience to very low probability but high consequence events using risk based approaches. Provide the means to re-establish the wider synchronous area in the event of widespread disruption.	Loss of mains and other protection arrangements	Ensuring the design and implementation of DER connection arrangements that have adequate resilience to network disturbances. This includes the specification of connection interface protection arrangements (including Loss of Mains) and compliance testing.
		Network contingency planning for High Impact Low Probability (HILP) events	Forward planning to ensure network has the capability to remain resilient against high consequence events such as extreme weather.
		Resilience (Voltage Reduction, LFDD, HFGD)	Providing whole system network resilience and defence through the design and implementation of mechanisms including Voltage Reduction, Low Frequency Demand Disconnection (LFDD) and High Frequency Generation Disconnection (HFGD).
		Resilience (islanding)	Providing local and whole system network resilience and defence through the design and implementation of islanding mechanisms to enable local areas of network to remain in service in the event of a wider system incident.
		Black start	Enabling whole system network re-establishment following a major system incident through the staged energisation of local networks. This could include the block loading of larger generators as part of wider Black Start plans.

Service / market facilitation

‘Service and market facilitation’ is a broad ranging function to define distribution network service requirements and support the market arrangements put in place to provide these and other services. Activities would include assessing the value of flexibility, the definition of new services and supporting the operation of the markets and systems needed to provide these services. DSO’s would also support the market participants through the provision of information.

Wider coordination aspects under the ‘service and market facilitation’ function include the mitigation of potential service conflicts and the design and implementation of service arrangements to provide efficient whole system outcomes. Table 9 presents an overview of the ‘service and market facilitation’ function and its activities.

Table 9 ‘Service and market facilitation’ function and activities

Function	Description	Activities	Description
Services / market facilitation	Interface with the GBSO and other network operators to enable the development of distribution capacity products, the creation and operation of local network service markets and to enable DER access/participation in wider services for whole system optimisation. Facilitate local and national markets to access and settle services through auctions and other market arrangements for whole system efficiency. Ensure these arrangements are fair and transparent. Provide information and control system infrastructure to facilitate local and national markets and service provision.	Define distribution network service requirements including scope, timescale and locational aspects	Establish the principles behind the planning, contracting and despatch of services to support distribution network operation. Sign post requirements for services through information provision. Define service requirements including scope, location, timescales and technology aspects.
		Assess value and facilitate services to utilise flexibility sources to support distribution network operation	Assess the value of flexibility for distribution network operation and sign post requirements. Facilitate services and markets to provide flexibility.
		Facilitate the operation of Distributed Energy Resource Management systems (DERMs) and Local Energy Markets (LEMs) that are transparent.	Put in place the infrastructure / platforms that enable network operators to access the technical capability of DER and to commercially optimise and settle payments for DER services.
		Interaction with aggregators and other non-traditional actors	Enable the operation of new market roles (e.g. aggregators) within the GB energy systems. This may include commercial and regulation requirements and the provision of information/data exchange.
		Support the implementation of non-traditional market models for local energy supply	Enable the operation of non-traditional business models within the GB energy systems (e.g. local energy markets, peer to peer trading). This may include commercial and regulation requirements and the provision of information/data exchange. Provide information to enable settlement of these markets.
		Service conflict mitigation/resolution	Identify, manage and mitigate service conflicts (e.g. GBSO and DSO use of resources). Enable sharing of services where feasible.
		T-D coordination for transparent and consistent whole system outcomes	Enable a more co-ordinated approach to the operation of services and markets and enable consistent whole system outcomes through enhanced Transmission and Distribution visibility, co-ordination and control.

Service optimisation

'Service optimisation' is a function to ensure that services are available to support networks and wider system operation. Activities include the procurement, selection and optimisation of services in line with capacity constraints and the facilitation of flexibility services through the smart use of networks. Activities might also include ensuring that last resort provisions are in place to support network operation in a situation where market operation has failed. Table 10 presents an overview of the 'service optimisation' function and its activities.

Table 10 'Service optimisation' function and activities

Function	Description	Activities	Description
Service optimisation	Ensure system needs can be efficiently met across all timescales by identifying network requirements, understanding the limitations of network assets and providing network access for additional flexibility services from smart solutions and DER services. Ensure whole system optimisation and resilience through the optimal selection of flexibility services	Smart grid network flexibility	Enable flexibility services through novel utilisation of existing network components.
		Service access management	How services will be selected and managed by network operators depending on capacity constraints. Includes prioritisation methodologies (e.g. LIFO, technical best, economic best).
		Service selection	Transparency of decisions and actions when choosing the optimal selection of flexibility services. May include a framework/rules/criteria.
		T-D coordination	How issues and solutions on both T&D are coordinated to enable efficient whole system outcomes.
		Conditions / process of market failure	Identifying when last resort provision should be enacted.
		Regulation and competition frameworks	Identifying the rules for managing and remunerating last resort service provision. Putting in place methodologies to ensure that these continue to be efficient against other solutions.

Charging

The 'charging' function recognises a potential DSO role in setting charges for the connection and use of distribution networks. Increasingly this will require a whole system view and close interaction between network owners and operators to design and operate efficient and equitable network charging arrangements. Table 11 presents an overview of the 'charging' function and its activities.

Table 11 'Charging' function and activities

Function	Description	Activities	Description
Charging	Sets Distribution Use of System prices for local network Determines Point of Connection Determines connections charges and informs of Transmission reinforcement charges (if applicable) Consideration to Exit Charging (dependent on size, variations and apportionment)	Distribution Use of System Charges	Sets Distribution Use of System prices for local network
		Determines Point of Connection	Designs incremental capacity increases on the network
		Determines Whole system reinforcement charges	Reflecting transmission charges and distribution costs in whole system charges
		Exit Charging (dependent on size, variations and apportionment)	Management of transmission costs at the Grid Supply Point (GSP)

2.3 Defining flexibility

The Great Britain (GB) energy regulator, (Ofgem), has defined flexibility[9] as "modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system". Flexibility has been a key feature of energy markets and it is used by several market participants across the energy value chain, to manage their operations efficiently. The energy industry has typically provided flexibility on the 'supply-side', with generation, historically, being the main source of flexibility. For instance, market participants such as suppliers, the ESO and generators would typically buy or sell electricity generated by power plants to meet demand and system needs. Furthermore, network operators have also built sufficiently enough network infrastructure to ensure electricity can always be transported to consumers.

The energy system is undergoing fundamental change as it moves towards a system where generation is distributed and more variable, where consumers can better monitor and manage their energy use, and where new technologies and business models are emerging. Thus, new sources of flexibility both on the supply and the demand side are necessary to help responding to the challenges whilst delivering a resilient, sustainable and affordable electricity system. For example, flexible distributed energy resources are new forms of flexibility connected at the distribution network and can be broadly categorised into flexible loads, distributed generation and energy storage.

[9] "Making the Electricity System More Flexible and Delivering the Benefits for Consumers," Office of Gas and Electricity Markets, London, United Kingdom, Sep. 30, 2015.
https://www.ofgem.gov.uk/ofgem-publications/96959/flexibilitypositionpaperfinal-pdf

BEIS and Ofgem have considered two broad types of flexibility[10][11]:

- **Price flexibility**: this occurs when any party varies their demand or generation in response to the price of energy and network use at a particular time and/or location; and
- **Contracted flexibility**: this is where parties trade and directly contract with one another to procure flexibility, and for which an agreed payment is made. Parties buying this currently include the ESO, DNOs and suppliers.

It should be noted that these two types of flexibility entail different actions and measures to achieve prices that reflect the value of the service to the wider system. The system should be making best use of the flexibility available to be cost-effective at any given moment. That means all users of flexibility (network and system operators, suppliers, generators and third parties) need to be using flexibility optimally, from all providers (generators, demand side response (DSR) providers, storage and interconnector flows). Hence, accessible markets and pricing which reflects the true system value of flexibility are critical to enable the delivery of a smart, flexible system. The following subsection explores different market model options that promote access to flexible distributed energy resources and are characterised by different ESO / DSO coordination schemes.

2.4 Market model options

The ON-PRJ consulted[12] on a range of issues associated with broadening the participation of distributed energy resources in the provision of flexibility services to network operators. The 'Commercial Principles' consultation sought to inform both the development of these services to ensure DER can participate in their provision; allowing them to optimise participation across markets and supporting efficient procurement by multiple entities; and the evolution of relationships between the entities (e.g. ESO, DSO, etc.) that are necessary to support that DER service provision. The consultation proposed six evolutionary market options that could enable this broader participation and presented ENA's initial views on how they compared against a range of assessment criteria. The ENA received thirty responses to the consultation, which has provided valuable insight into broader industry views on the characteristics of the models and on associated issues.

Following the 'Commercial Principles' consultation, the ENA, supported by EA Technology, undertook a wide-ranging review of the potential market models for ways in which third parties could provide flexibility services to the DSO, for the purposes of constraint management. This included a review of the models set out in the 'Commercial Principles' paper aforementioned, models from Ofgem, industry, academia and other countries. The ENA then selected a robust set of five potential market model options for DSO that can support the required definition and functions of the DSO (Sections 2.1 and 2.2) while delivering neutral market facilitation.

The five market model options (aka DSO Worlds) are termed as follows:

- DSO World A: DSO coordinates
- DSO World B: Coordinated procurement and dispatch
- DSO World C: Price driven flexibility

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[10] "A Smart, Flexible Energy System – A Call for Evidence," Department for Business, Energy & Industrial Strategy and Office of Gas and Electricity Markets, London, United Kingdom, Nov. 10, 2016. https://www.ofgem.gov.uk/system/files/docs/2016/12/smart_flexible_energy_system_a_call_for_evidence.pdf

[11] "Upgrading our Energy System – Smart Systems and Flexibility Plan," Department for Business, Energy & Industrial Strategy and Office of Gas and Electricity Markets, London, United Kingdom, Jul. 24, 2017. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633442/upgrading-our-energy-system-july-2017.pdf

[12] "Commercial Principles for Contracted Flexibility: Promoting Access to Markets for Distributed Energy Resources," Energy Networks Association, London, United Kingdom, Aug. 16, 2017. http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/ON-WS1-P4%20Commercial%20Paper%20(Final%20Draft)-170816-final.pdf

- DSO World D: ESO coordinates
- DSO World E: Flexibility coordinator(s)

These models can be generally categorised based on the extent to which the DSO accesses flexible DER, facilitates services and markets, provides own services to network customers, its relationship with the ESO and the associated market design.

Moreover, each model determines the operational processes and information exchanges between the ESO and the DSO relating to the pre-qualification, procurement, activation and settlement of distributed flexibility resources.

Each model is described in more detail over the following pages.

2.4.1 DSO World A: DSO coordinates

The DSO procures and activates distribution network connected flexibility resources for distribution network constraint management and transmission system management based on a pre-defined power exchange schedule agreed with the ESO. The DSO and the ESO actively exchange information to maximise synergies between transmission and distribution network service requirements and to minimise potential conflicts associated with the delivery of concurrent services. Figure 2 presents a schematic representation of the market design and key relationships between the ESO, the DSO and other network customers for the 'DSO World A: DSO coordinates'.

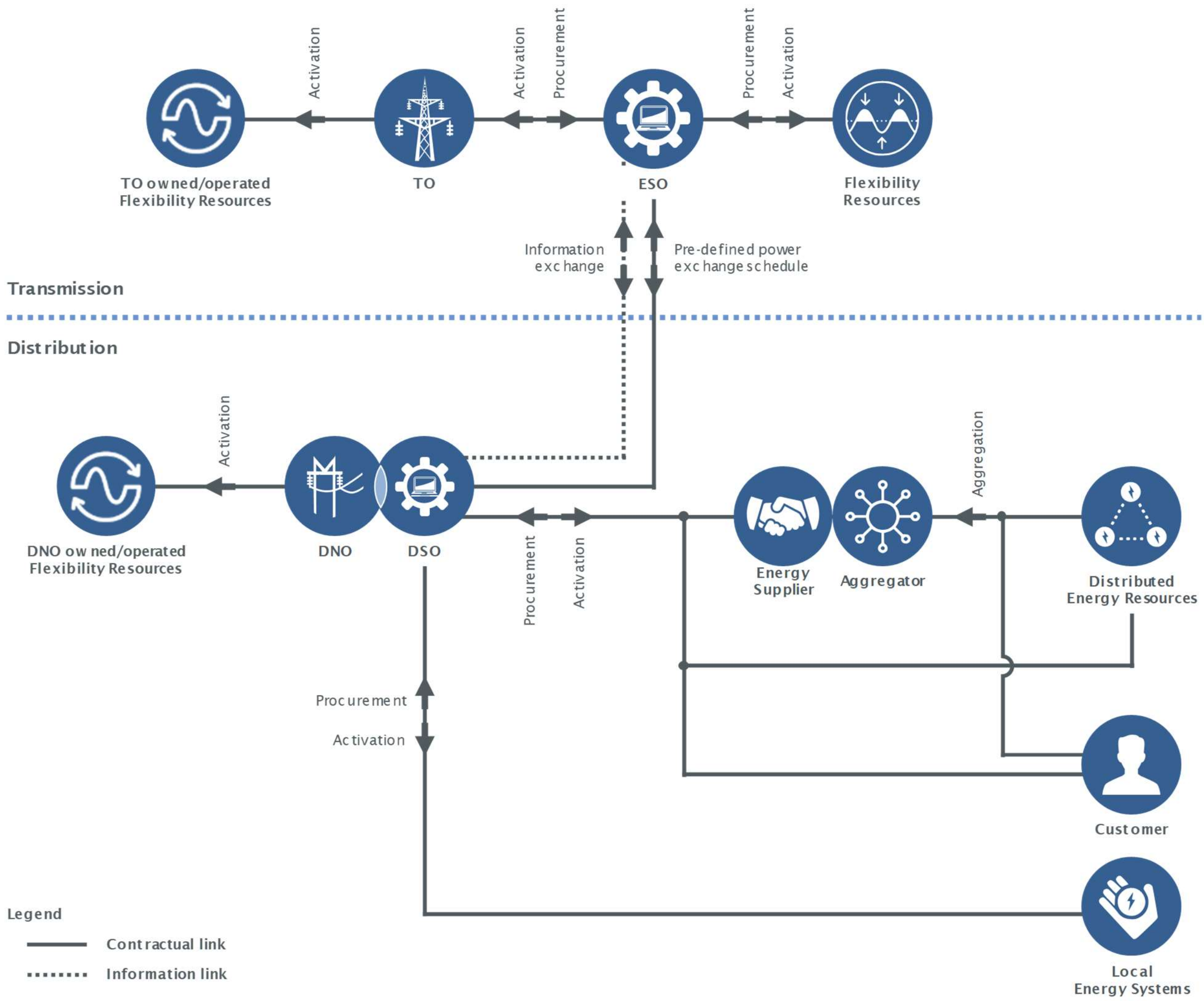


Figure 2 DSO World A: DSO coordinates

Market design

There is a central ancillary services market for flexibility resources connected at the transmission networks that is organised and operated by the ESO. There is a regional market for flexibility resources connected at the distribution network that is facilitated by the DSO of the respective geographical region. Distribution network constraints are included in the clearing process of the regional flexibility market. The ESO balances the electricity transmission system and the DSO balances the electricity distribution system according to a pre-defined power exchange schedule technically and commercially agreed with the ESO as a result of whole system balancing instructions.

ESO role

The ESO organises and operates the central market for ancillary services and is responsible for balancing the electricity transmission system. The ESO directly procures and activates flexibility resources connected to the transmission network (e.g. transmission connected generation and demand side services) for energy balancing and transmission system management purposes via the central market for ancillary services. The ESO has a commercial relationship with the DSO for the procurement of distribution connected flexibility resources on its behalf. Hence, the ESO indirectly procures and activates flexibility resources connected to the distribution network to support managing the electricity transmission system via the DSO. The ESO is involved in the procurement and activation of distributed flexibility resources led by the DSO through the active exchange of information to maximise of synergies between transmission and distribution network service requirements and minimise of potential conflicts associated with the delivery of concurrent flexibility services.

The ESO (i.e. via the TO) offers flexibility services to the DSO from its portfolio of smart grid network solutions (i.e. network asset-based solutions).

DSO role

The DSO is responsible for the development and operation of the electricity distribution network following an active network management approach. The DSO facilitates a regional flexibility market for flexibility resources connected at the distribution network. Accordingly, the DSO directly procures and activates flexibility resources connected to the distribution network for transmission and distribution networks management via the regional market for flexibility resources. The DSO contributes to whole system balancing actions by actively managing the electricity distribution system according to a pre-defined power exchange schedule technically and commercially agreed with the ESO. Therefore, the DSO has a central role in coordinating how distributed flexibility resources are used by the system as a whole. The DSO has the commercial relationship directly with distributed flexibility resources.

The DSO actively liaises with the ESO to identify synergies between transmission and distribution network service requirements through a coordinated procurement process of flexibility resources to avoid the risk of inefficiency through separate procurement of the same service from the same flexibility resource or from a different flexibility resource where that resource could have solved both distribution and transmission issues.

The DSO is responsible for the pre-qualification process of distribution network connected resources providing flexibility services. The pre-qualification process can be divided into technical and system pre-qualifications. Technical pre-qualification validates the technical requirements of a flexibility resource against those of the flexibility service that it intends to provide. System pre-qualification validates the flexibility resource for provision of a flexibility service under the condition that its activation does not cause additional constraints to the transmission and / or distribution networks.

Hence, the system pre-qualification process, established by the DSO in coordination with the ESO, guarantees that the activation of distribution connected flexibility resources does not cause additional constraints at the transmission network and meets concurrent transmission and distribution network service requirements (i.e. transmission and distribution network constraints can be resolved under the same activation of a flexibility resource).

The DSO offers flexibility services to the ESO from its portfolio of smart grid network solutions (i.e. network asset-based solutions).

Distributed energy resources role

DER provide flexibility services directly to the DSO or indirectly via an Aggregator of choice.

Aggregator / supplier / local energy system role

The aggregator / supplier combines different flexibility resources connected at the distribution network and offer their aggregated output as a flexibility service to the DSO.

Customer role

Customers provide behind-the-meter flexibility resources that can be directly offered to the DSO or indirectly via an Aggregator of choice.

2.4.2 DSO World B: Coordinated procurement and dispatch

The ESO directly procures flexibility resources connected to the distribution network for electricity transmission system balancing purposes in active collaboration and coordination with the DSO. The DSO procures flexibility resources connected to the distribution network for distribution networks constraint management in active collaboration and coordination with the ESO. The DSO and ESO cooperate to perform a coordinated dispatch of the distributed flexibility resources, procured by the DSO and ESO during their respective procurement activities, ensuring that concurrent transmission and distribution network service requirements are met. Figure 3 introduces a schematic representation of the market design and key relationships between the ESO, the DSO and other network customers for the 'DSO World B: Coordinated procurement and dispatch'.

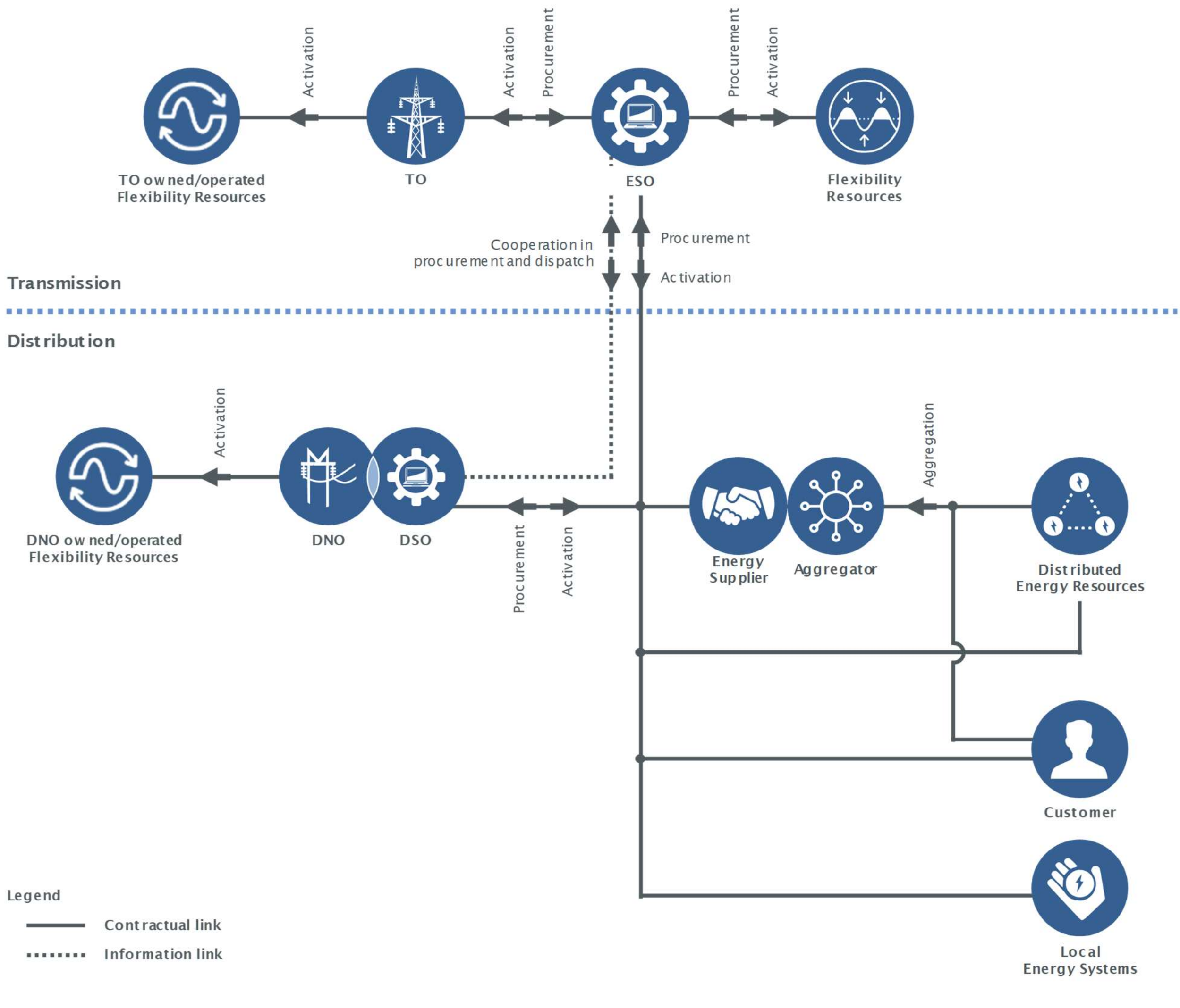


Figure 3 DSO World B: Coordinated procurement and dispatch

Market design

There is a central ancillary services market for flexibility resources connected at the transmission and distribution networks that is organised and operated by the ESO. There is a regional market for flexibility resources connected at the distribution network that is facilitated by the DSO of the respective geographical region. This market arrangement seeks to provide and coordinate parallel routes to market for distributed flexibility resources.

ESO role

The ESO organises and operates the central market for ancillary services and is responsible for balancing the electricity transmission system. Thus, the ESO directly procures and activates flexibility resources connected to the transmission network for balancing the electricity transmission system. The ESO directly procures flexibility resources connected to the distribution network for transmission system management and for energy balancing in collaboration and coordination with the DSO. The ESO actively collaborates with the DSO to facilitate a coordinated procurement and activation of distributed flexibility resources through the active exchange of information in order to maximise synergies between transmission and distribution network service requirements and minimise of potential conflicts associated with the delivery of concurrent flexibility services.

The ESO (i.e. via the TO) offers flexibility services to the DSO from its portfolio of smart grid network solutions (i.e. network asset-based solutions).

DSO role

The DSO is responsible for the development and operation of the electricity distribution network following an active network management approach. The DSO facilitates a regional flexibility services market for flexibility resources connected at the distribution network. The DSO directly procures flexibility resources connected to the distribution network for distribution network management, in active collaboration and coordination with the ESO, via the regional market for flexibility resources. The DSO cooperates with the ESO to perform a coordinated dispatch of the distributed flexibility resources that have been procured by the ESO and DSO during their respective procurement activities. Hence, the DSO actively collaborates with the ESO to deliver a coordinated procurement and activation process of distributed flexibility resources that identifies synergies between transmission and distribution network service requirements and meets concurrent transmission and distribution network service needs, respectively.

The DSO offers flexibility services to the ESO from its portfolio of smart grid network solutions (i.e. network asset-based solutions).

Distributed energy resources role

DER provide flexibility services directly to the ESO and the DSO or indirectly via an Aggregator of choice.

Aggregator / supplier / local energy system role

The aggregator / supplier combines different flexibility resources connected at the distribution network and offer their aggregated output as a flexibility service to the ESO and the DSO.

Customer role

Customers provide behind-the-meter flexibility resources that can be directly offered to the ESO and the DSO or indirectly via an Aggregator of choice.

2.4.3 DSO World C: Price driven flexibility

Ofgem has set out two broad types of flexibility (refer to Section 2.3 for further information); price flexibility (occurring when any party varies its demand or generation in response to the price of energy, and network use at a particular time and/or location); and contracted flexibility (where parties trade and directly contract with one another to procure flexibility). There are different actions / measures to achieve prices which reflect the value of the service to the wider system for different types of flexibility.

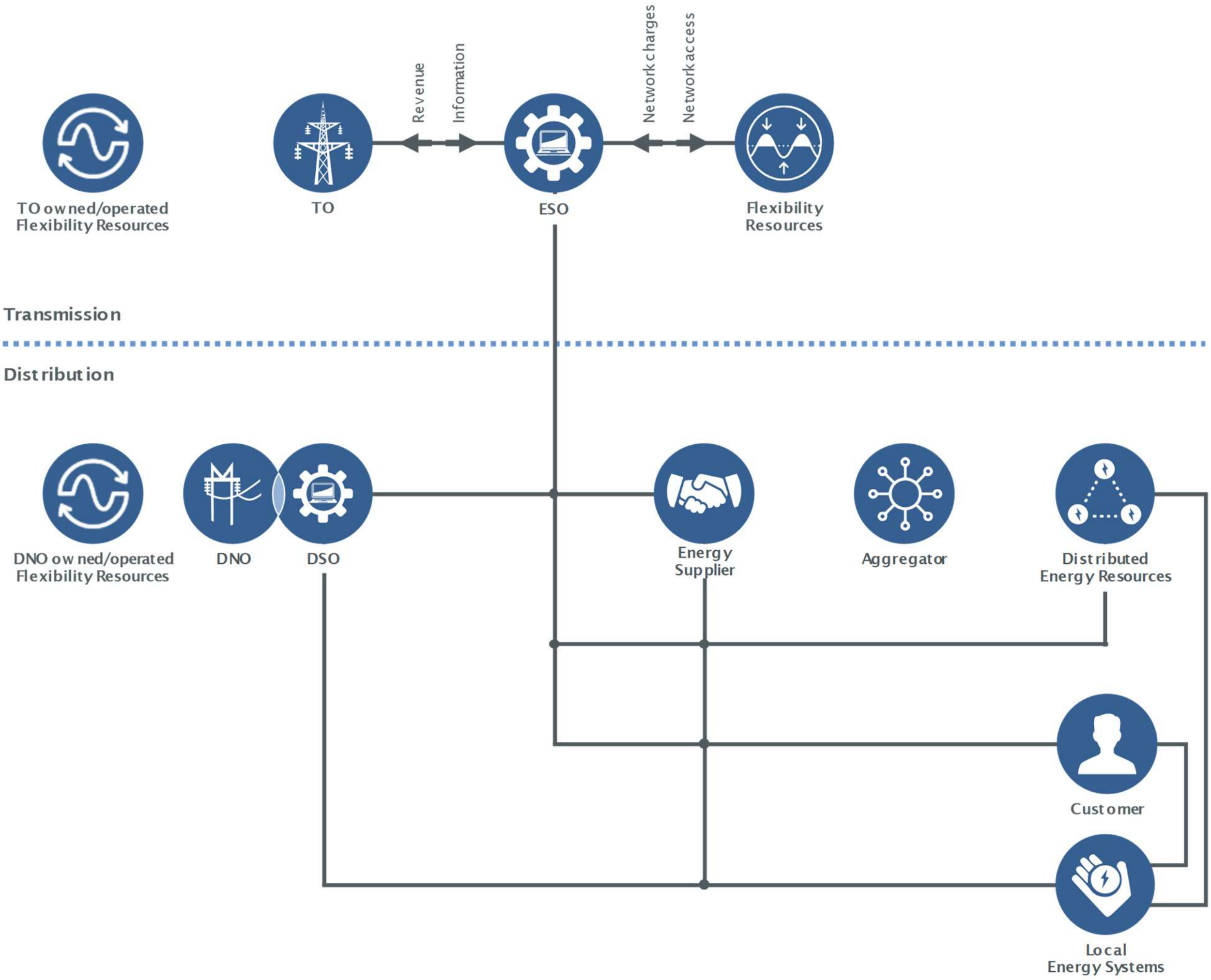
One component of price flexibility is ensuring that network tariffs appropriately signal the costs or benefits of using the network at different times and locations. Providing signals through network access and/or charging arrangements could offer the opportunity to allow the market to respond more dynamically to changing system needs thereby reducing the need for system operators (e.g. ESO, DSO) to actively procure flexibility to manage the system[13]. This could benefit consumers as a whole by providing better value by bringing forward flexibility more cost-effectively rather than principally relying on procurement by system operators and by helping to ensure that investment occurs where needed, underpinned by a good understanding of market value. Nonetheless, Ofgem also notes that these alternative means of providing signals are unlikely to be able to provide all of the flexibility that the system operators need and therefore it is likely that there will always be some need for them to procure some flexibility directly.

To this end, Ofgem[14] together with industry[15] are reforming the electricity network access and charging arrangements, in general, and improving the forward-looking signals for network usage (i.e. Use of System Charges – Transmission Network Use of System Charges (TNUoS) and Distribution Use of System Charges (DUoS)), in particular. The forward-looking element of Use of System Charges looks to provide signals to users about how their behaviours can increase or reduce future costs on the network therefore aiming to reflect network users' incremental impact on network costs, including current and future investment and reinforcement.

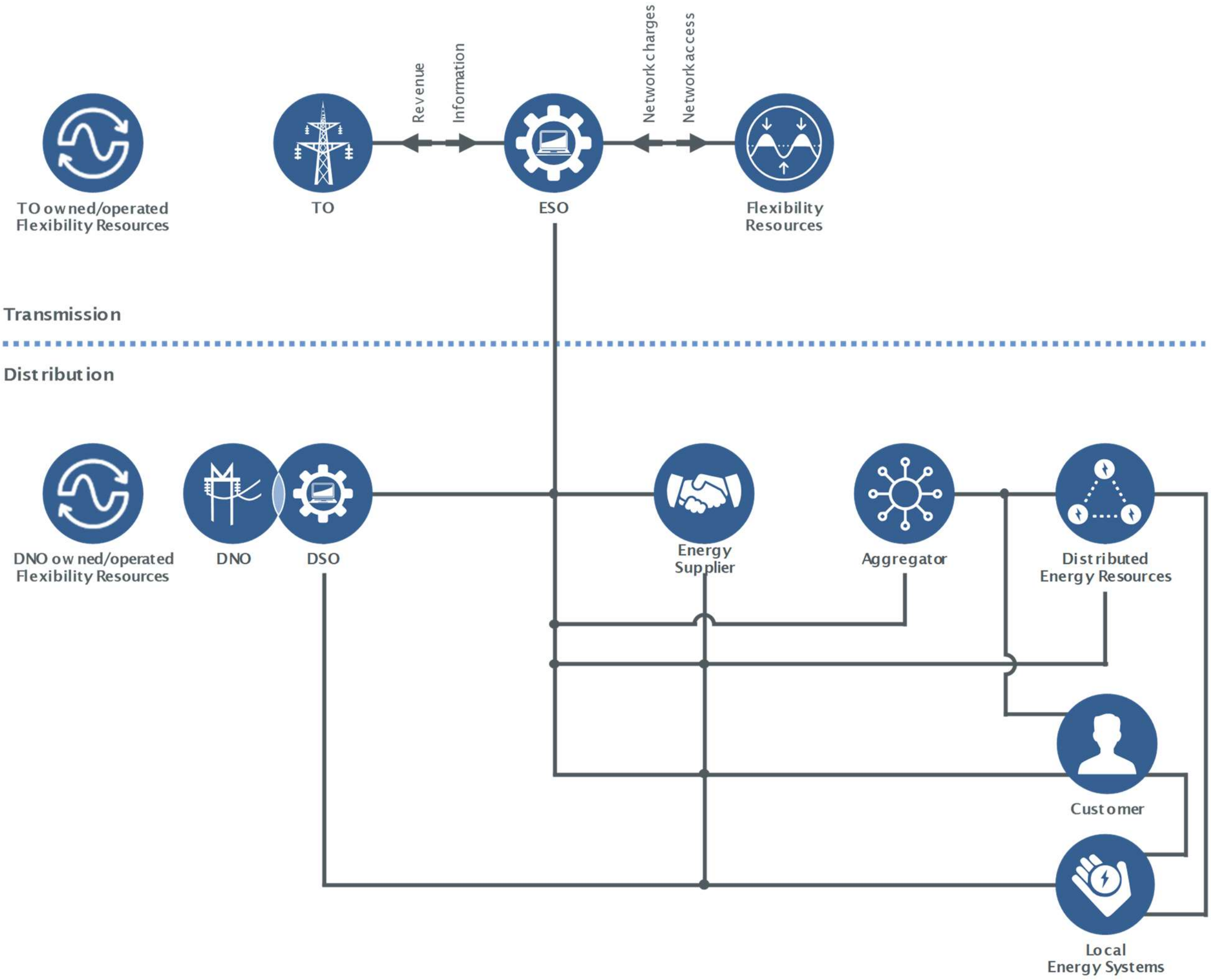
In summary, network access and forward-looking charging reform could reduce the amount of flexibility that system operators need to procure directly, however, it is likely that there will always be the need for them to take some residual actions. It is important that reforms in both access and forward-looking charges (i.e. price flexibility) consider compatibility with procurement by the system operators (i.e. contracted flexibility).

The 'DSO World C: Price driven flexibility' uses two distinct models, i.e. 'commercial services model' and 'network access and charging model', that coexist to represent contracted and price flexibilities, respectively. The 'commercial services model' to facilitate contracted flexibility is identical to that of 'DSO World B. Coordinated procurement and dispatch' (refer to Section 2.3 for further information). Figure 4 shows a schematic representation of the market design and key relationships between the ESO, the DSO and other network customers for the 'network access and charging model' to facilitate price flexibility.

[13] "Our Strategy for Regulating the Future Energy System," Office of Gas and Electricity Markets, London, United Kingdom, Aug. 04, 2017.
https://www.ofgem.gov.uk/system/files/docs/2017/08/our_strategy_for_regulating_the_future_energy_system.pdf
[14] "Reform of Electricity Network Access and Forward-Looking Charges: A Working Paper," Office of Gas and Electricity Markets, London, United Kingdom, Nov. 06, 2017.
https://www.ofgem.gov.uk/system/files/docs/2017/11/reform_of_electricity_network_access_and_forward-looking_charges_-_a_working_paper.pdf
[15] Charging Futures – Reforming Electricity Charging Together. http://www.chargingfutures.com/



(a) Present network access and charges



(b) Future network access and charges

Figure 4 DSO World C: Price driven flexibility – 'Network access and charging model'

Market design

There is a central wholesale electricity market supported by: (i) strengthened locational and time of use pricing signals (e.g. via network charging arrangements); and (ii) consistent access arrangements whereby those parties who wish to trade locally can be exempt from national costs.

ESO role

The ESO administers recovery of the costs of national infrastructure (i.e. TO assets) and therefore access rights to national products and markets.

DSO role

The DSO sends appropriate signals through DUoS charges to signal efficient use of distribution networks and appropriate local access. The DSO retains responsibility for cost of connection to transmission network at Grid Supply Points but passes appropriate signals for future infrastructure investment back to connected parties.

Supplier role

Suppliers continue to administer charges for the bulk of customers connected to distribution networks.

Aggregator role

Aggregators will not be liable for network costs unless directly involved in wholesale market. However, there will be a liability for operational cost recovery.

Local energy system role

LES facilitate local peer to peer energy trading between customers via local market platform with the net energy balance being traded out in the wholesale market. LES have the option to sell / buy access power or services nationally but will then be liable for a level of national costs.

Distributed energy resources role

DER pay a fair amount for their network requirements and in return receive commensurate access to those networks.

Customer role

Customers have choice whether to be registered through a supplier or individually registered. If individually registered, then may have direct communication path with network organisations.

2.4.4 DSO World D: ESO coordinates

The ESO procures and activates flexibility resources connected to the distribution network for transmission and distribution networks management and energy balancing. The DSO indirectly procures distribution connected flexibility resources for constraint management of the distribution network via the ESO. The ESO and the DSO actively exchange information to maximise synergies between transmission and distribution network service requirements and to minimise potential conflicts associated with the delivery of concurrent services. Figure 5 displays a schematic representation of the market design and key relationships between the ESO, the DSO and other network customers for the 'DSO World D: ESO coordinates'.

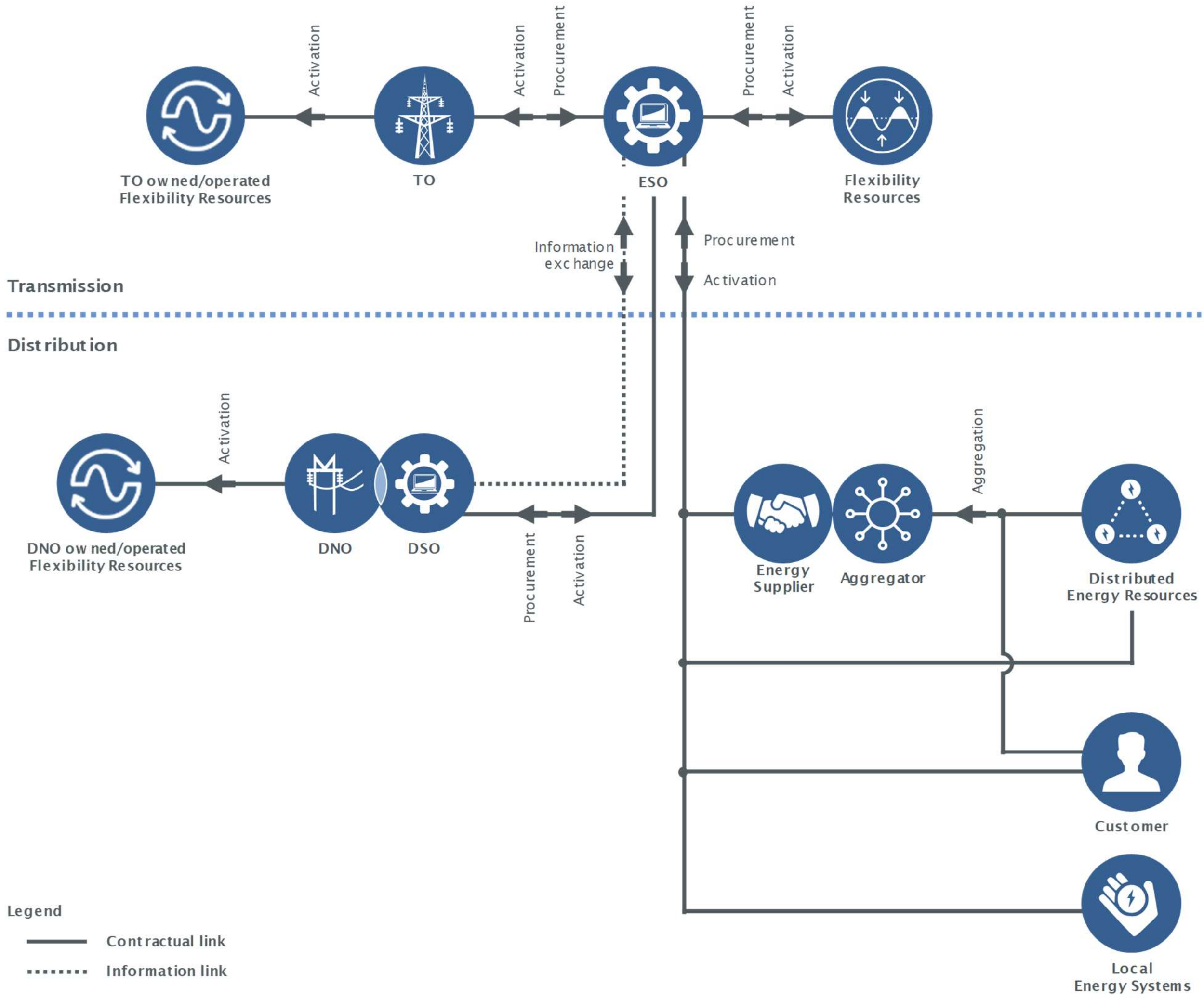


Figure 5 ESO coordinates model

Market design

There is a central ancillary services market for flexibility resources connected at the transmission and distribution networks that is organised and operated by the ESO.

ESO role

The ESO organises and operates the central market for ancillary services and is responsible for balancing the electricity transmission system. Thus, the ESO directly procures and activates flexibility resources connected to the transmission network for balancing the electricity transmission system. The ESO directly procures and activates flexibility resources connected to the distribution network for transmission and distribution networks management and for energy balancing via the central market for ancillary services. Therefore, the ESO has a central role in coordinating how distributed flexibility resources are used by the system as a whole. The ESO has the commercial relationship directly with distributed flexibility resources.

The responsibility of procuring distribution connected flexibility resources for both transmission and distribution networks management means that the ESO actively liaises with the DSO to identify synergies between transmission and distribution network service requirements through a coordinated procurement process. Furthermore, the system pre-qualification process, established by the ESO in coordination with the DSO, guarantees that the activation of distribution connected flexibility resources does not cause additional constraints at the distribution network and meets concurrent transmission and distribution network service requirements.

The ESO (i.e. via the TO) offers flexibility services to the DSO from its portfolio of smart grid network solutions (i.e. network asset-based solutions).

DSO role

The DSO is responsible for the development and the safe and secure operation of the distribution network following an active distribution network management approach. The DSO has a commercial relationship with the ESO for the procurement of distribution connected flexibility resources on its behalf. Therefore, the DSO indirectly procures distributed flexibility resources for distribution network constraint management via the ESO. The DSO is involved in the procurement and activation of distributed flexibility resources led by the ESO through the active exchange of information to maximise of synergies between transmission and distribution network service requirements and minimise of potential conflicts associated with the delivery of concurrent flexibility services.

The DSO offers flexibility services to the ESO from its portfolio of smart grid network solutions (i.e. network asset-based solutions).

Distributed energy resources role

DER provide flexibility services directly to the ESO or indirectly via an Aggregator of choice.

Aggregator / supplier / local energy system role

The aggregator / supplier combines different flexibility resources connected at the distribution network and offer their aggregated output as a flexibility service to the ESO.

Customer role

Customers provide behind-the-meter flexibility resources that can be directly offered to the ESO or indirectly via an Aggregator of choice.

2.4.5 DSO World E: Flexibility coordinator(s)

The flexibility coordinator(s) organises and operates the flexibility market for distributed flexibility resources in a neutral, independent and transparent way. The flexibility coordinator(s) procures and dispatches distributed flexibility resources for distribution network constraint management and electricity transmission system balancing purposes. The ESO and the DSO indirectly procure and activate distributed flexibility resources for network for transmission system management and energy balancing and for distribution network constraint management, respectively, via the flexibility coordinator(s). Figure 6 exhibits a schematic representation of the market design and key relationships between the ESO, the DSO and other network customers for the DSO World E: Flexibility coordinator(s)'.

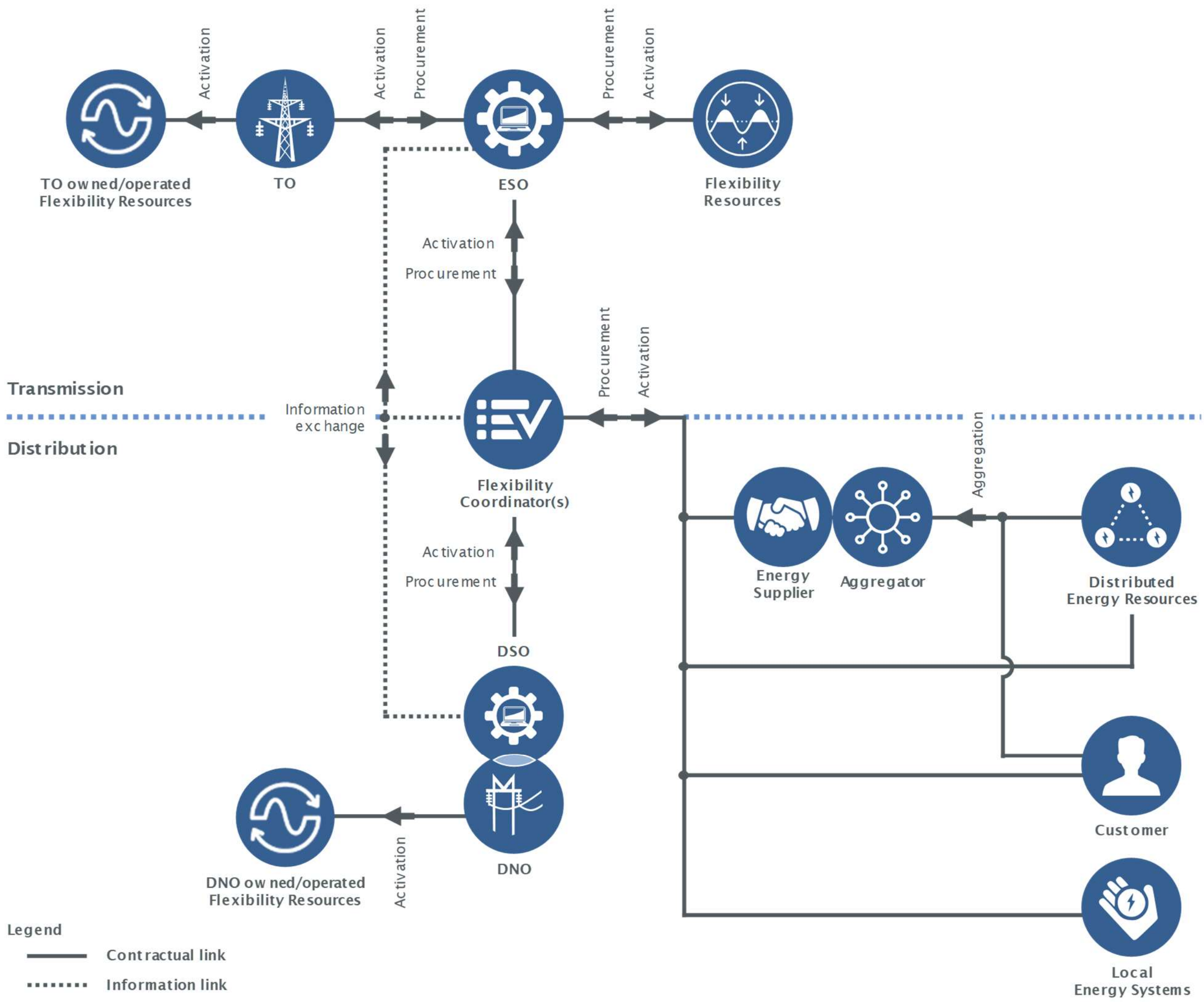


Figure 6 DSO World E: Flexibility coordinator(s)

Market design

There is a central ancillary services market for flexibility resources connected at the transmission networks that is organised and operated by the ESO. There is one (or more) flexibility market(s) for flexibility resources connected at the distribution network that is organised and operated by the flexibility coordinator(s). The ESO and DSO participate in the facilitation process of the market(s) through active exchange of information relating to the transmission and distribution systems.

Flexibility coordinator(s) role

The flexibility coordinator(s) organises and operates the flexibility market for distributed flexibility resources in a neutral, independent and transparent way. The flexibility coordinator(s) is responsible for the facilitation of the pre-qualification, contract, activation and settlement process of distributed flexibility resources in coordination with the ESO and the DSO. The flexibility coordinator(s) is responsible for the procurement and dispatch of distributed flexibility resources for distribution network constraint management and electricity transmission system balancing purposes through a whole system optimisation platform that includes both transmission and distribution network constraints. The whole system flexibility service optimisation ensures that: (i) synergies between transmission and distribution network requirements are identified; (ii) concurrent transmission and distribution network requirements are met by coordinated activation of flexibility resources; and (iii) additional constraints on the transmission and distribution networks are avoided. Thus, the flexibility coordinator has technical and commercial responsibilities. From the technical view point ensures the flexibility resources can meet the technical specification and requirements of the flexibility services and the transmission and distribution networks are capable of controlling network flows within technical limits. From the commercial view point conducts commercial transactions between market participants, ESO and DSO that utilise the technical capabilities of the flexibility resources.

ESO role

The ESO organises and operates the central market for ancillary services and is responsible for balancing the electricity transmission system. Thus, the ESO directly procures and activates flexibility resources connected to the transmission network for balancing the electricity transmission system. The ESO indirectly procures and activates flexibility resources connected to the distribution network for transmission system management and energy balancing via the flexibility coordinator(s). The ESO supports the facilitation of the flexibility market for distributed flexibility resources through the active exchange of information relating to present and future investment planning, operational planning and system operation states and requirements of the transmission network.

DSO role

The DSO indirectly procures and activates distributed flexibility resources for distribution network constraint management via the flexibility coordinator(s). The DSO supports the facilitation of the flexibility market for distributed flexibility resources through the active exchange of information relating to present and future investment planning, operational planning and system operation states and requirements of the transmission network.

Distributed energy resources role

DER provide flexibility services directly to the flexibility coordinator(s) or indirectly via an Aggregator of choice, which in turn offers them to the ESO and the DSO.

Aggregator / supplier / local energy system role

The aggregator / supplier combines different flexibility resources connected at the distribution network and offer their aggregated output as a flexibility service to the flexibility coordinator(s) which in turn offers them to the ESO and the DSO.

Customer role

Customers provide behind-the-meter flexibility resources that can be offered to the ESO and the DSO or indirectly via an Aggregator of choice.

3. The market agnostic framework

The ON-PRJ has chosen to use the SGAM to capture the definition of the different market model options for DSO. Thus, the section introduces the fundamental conceptual principles that underpin the SGAM framework and provide extensive references for further exploration. It describes the methodology developed to create a market agnostic SGAM framework. It then assesses the standard structure of the SGAM framework to ensure that it is fit for purpose of representing the market models for DSO and provides a market agnostic representation of the SGAM framework.

3.1 The Smart Grid Architecture Model

The SGAM was developed by the Smart Grid Coordination Group[16]/Reference Architecture Working Group (SG-CG/RA) as part of the European Commission Mandate M/490[17]. The SGAM[18][19] is a holistic framework for describing smart grid systems, from their functional specification right through to their architectural design. The SGAM is represented by a three-dimensional framework that subsumes concepts from the GridWise Architecture Council (GWAC) Interoperability Stack[20], the National Institute of Standards and Technology (NIST) Conceptual Model[21] and the Automation Pyramid. The structure and composition of this three-dimensional framework is illustrated in Figure 7.

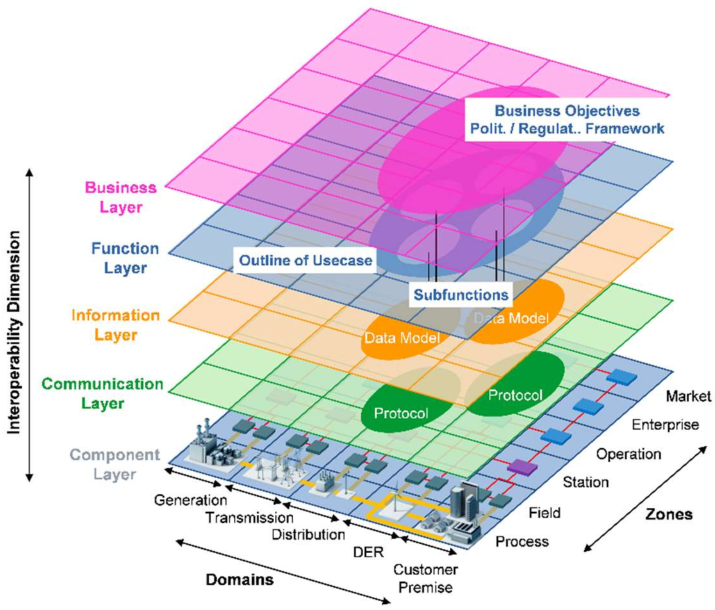


Figure 7 **Smart Grid Architecture Model[18] (SGAM)**

The SGAM framework is structured into five 'interoperability layers' derived from the GWAC Interoperability Stack. Each layer is represented by the 'smart grid plane' that is composed by

[16] Smart Grid Coordination Group:
https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx
[17] "Smart Grid Mandate, Standardization Mandate to European Standardisation Organisations (ESOs) to support European Smart Grid deployment," Mandate M/490 Smart Grids, European Commission, Brussels, Mar. 01, 2011.
https://ec.europa.eu/energy/sites/ener/files/documents/2011_03_01_mandate_m490_en.pdf
[18] "Smart Grid Reference Architecture," CEN-CENELEC-ETSI Smart Grid Coordination Group, Nov., 2012.
https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf
[19] "SG-CG/M490/F_Overview of SG-CG Methodologies," CEN-CENELEC-ETSI Smart Grid Coordination Group, Aug., 2014.
http://www.energynetworks.org/assets/files/electricity/engineering/Standards/SGCG%20Reports%20071014/SGCG_WGMethod_Sec0076_INF_ReportforComments(incl_annexes).pdf
[20] "GridWise Interoperability Context-Setting Framework," The GridWise Architecture Council, USA, Mar., 2008.
https://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf
[21] "NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0," NIST Special Publication 1108r3, National Institute of Standards and Technology (NIST), U.S. Department of Commerce, USA, Sep., 2014.
https://www.nist.gov/sites/default/files/documents/smartgrid/NIST-SP-1108r3.pdf

'domains' and 'zones' based on the NIST Domain Model and the Automation Pyramid, respectively. The five 'interoperability layers' represent business objectives and processes, functions, information exchange and models, communication protocols and components. The 'domains' reflect the electrical energy conversion chain. The 'zones' characterise the hierarchy of power system management. Thus, the SGAM framework allows the representation of smart grid systems and their relationships in the context of their spatial position within the electrical energy conversion chain, information management hierarchies and in consideration of interoperability aspects.

3.1.1 The interoperability layers[18]

The five 'interoperability layers' describe the smart grid system in terms of interoperability requirements between its constituting elements. These SGAM layers are defined as follows:

- **Business layer**: It represents the business-related aspects of the smart grid system such as business objectives, capabilities and processes, business models, business portfolios, organisational entities, policy and regulatory considerations.
- **Function layer**: It describes the functions and services, including their relationships, that are required to exist to realise the defined business aspects.
- **Information layer**: It describes the information exchanged between the functions and services that are realised by certain systems and components. The description the information exchanges adhere to information objects and derived data models.
- **Communication layer**: It consists of protocols and mechanisms for exchanging the information objects specified in the information layer.
- **Component layer**: It comprises the physical components, such as power system equipment, ICT devices, software, which allocate the functions and communicate among themselves using the specified information objects and communication protocols.

3.1.2 The smart grid plane[18]

Each layer is represented by the 'smart grid plane' that is composed by 'domains' and 'zones'. The 'domains' reflect the electrical energy conversion chain (i.e. generation, transmission, distribution, distributed energy resources and customer premise) physically relating to the electrical power grid. The 'zones' characterise the hierarchy of power system management (i.e. market, enterprise, operation, station, field, process) distinguishing between electrical process and information management viewpoints. Thus, every element on the 'smart grid plane' be aligned according to its position within the electrical power grid and its role within power system management. The 'smart grid plane' is depicted in Figure 8.

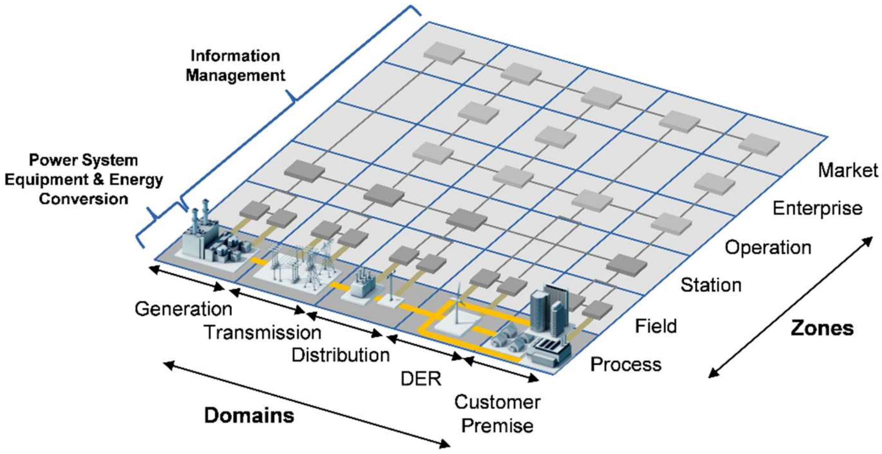


Figure 8 **Smart grid plane**[18]

3.1.3 Domains[18]

The 'domain-axis' of the 'smart grid plane' covers the electrical energy conversion chain as described in Table 12

Table 12 Domains

Domains	Description
Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale photovoltaic (PV) power – typically connected to the transmission system
Transmission	Representing the infrastructure and organization which transports electricity over long distances
Distribution	Representing the infrastructure and organization which distributes electricity to customers
DER	Representing distributed electrical resources, directly connected to the public distribution grid, applying small-scale power generation technologies (typically in the range of 3kW to 10,000kW). These distributed electrical resources can be directly controlled by DSO
Customer Premises	Hosting both - end users of electricity, also producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbours, shopping centres, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines, etc., are hosted

3.1.4 Zones[18]

The 'zone-axis' of the 'smart grid plane' covers the hierarchical levels of power system management, distinguishing between electrical process and information management viewpoints. These hierarchical levels are based on the concepts of aggregation and functional separation in power system management. The data aggregation process concentrates data from the field in the station zone. For example, data is typically aggregated at the station level to reduce the amount of data that is communicated and processed in the operation zone. The functional separation process assigns different functions to specific zones. For example, real-time functions are typically in the field and station zone (e.g. metering, protection) whereas functions that cover an area, multiple substations or plants, city districts are usually located in operation zone (e.g. wide area monitoring, generation scheduling). The 'zones' are described in Table 13.

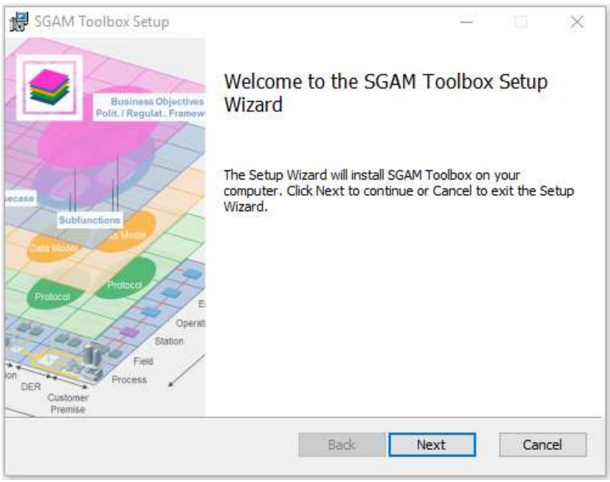
Table 13 Zones

Zones	Description
Process	Including both - primary equipment of the power system (e.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads, etc.) – as well as physical energy conversion (electricity, solar, heat, water, wind, etc.).
Field	Including equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system.
Station	Representing the aggregation level for fields, e.g. for data concentration, substation automation, etc.
Operation	Hosting power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.
Enterprise	Includes commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders, etc.), e.g. asset management, staff training, customer relation management, billing and procurement.
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market, etc.

3.1.5 Software tools

EA Technology used the Enterprise Architect[22] and the SGAM Toolbox[23] software tools for the design and implementation of the different market models for DSO as illustrated in Figure 9.

(a) Enterprise Architect (Corporate Edition)



(b) SGAM-Toolbox (Version 2.0)

Figure 9 Software tools for the design and implementation of the SGAM

[22] "Enterprise Architect," Sparx Systems. http://sparxsystems.com/
[23] "SGAM-Toolbox 2.0," Centre for Secure Energy Informatics, Salzburg University of Applied Sciences. https://sgam-toolbox.org/

The Enterprise Architect is a visual modelling and design tool covering all aspects of organisational architecture such as modelling of business process, re-engineering of business process, design and implementation of new systems or changing existing systems, documenting, etc. The SGAM-Toolbox is an add-in software utility that can be added to the Enterprise Architect to facilitate the usage of domain specific concepts, language and architecture relating to the SGAM domain.

3.2 The market agnostic framework

The ON-PRJ has chosen to use the SGAM to capture the definition of the different market models for DSO (refer to Section 2.4 for further information). It is, therefore, critically important that the SGAM framework is capable of accurately representing all the market model options for DSO defined in the ON-PRJ. This section assesses the standard structure of the SGAM framework (refer to Section 3.1 for further information) to ensure it is fit for purpose of the architectural representation of the five market models for DSO and modifies and enhances the framework, where appropriate.

3.2.1 Methodology

EA Technology developed a comprehensive methodology to assess the suitability of the standard structure of the SGAM framework to represent the five market model options for DSO, identify the existence of potential gaps on that structure and propose enhancements to that structure. Figure 10 depicts a schematic representation of the methodology for the development of the market agnostic SGAM framework.

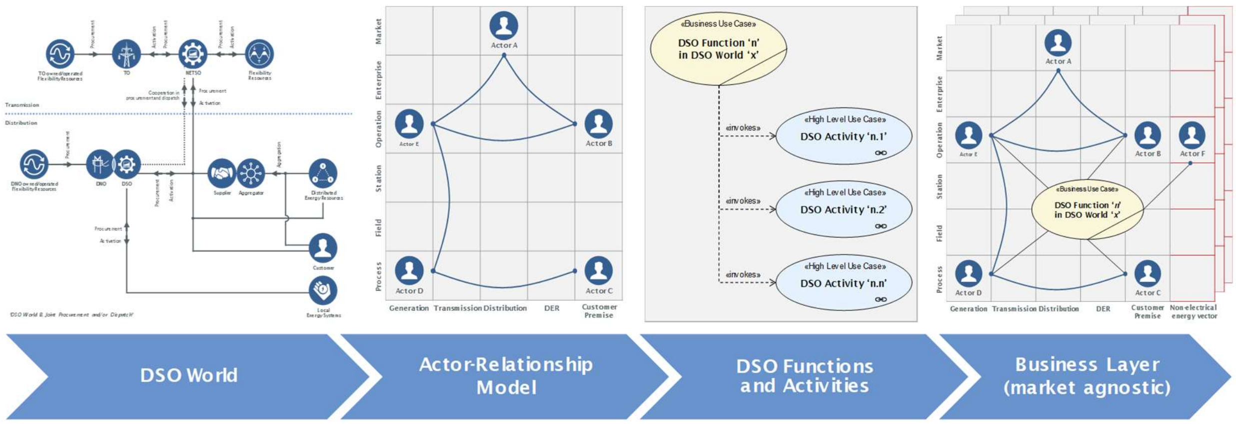
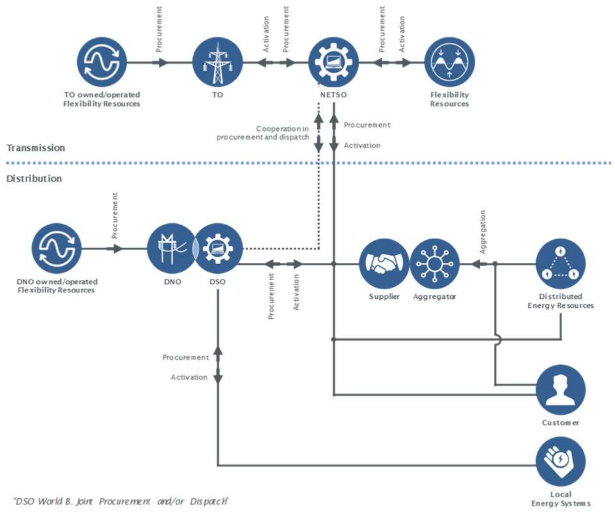


Figure 10 Methodology for a market agnostic SGAM framework

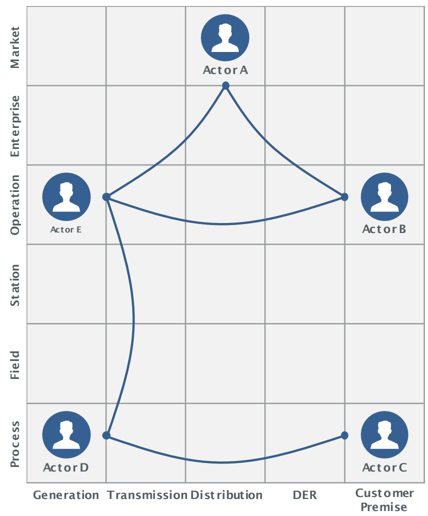
Specifically, the methodology develops a business layer grid for each DSO function of a particular DSO world; performs a gap analysis on the eight resultant business layer grids to assess the applicability of their 'domains' and 'zones' to the DSO functions, actors and relationships; updates the standard 'domains' and 'zones' of the business layer as appropriate; and selects the business layer grid that covers the most wide-ranging grid in terms of 'domains' and 'zones' to represent the DSO world. The methodology then analysis the five business layer grids of each DSO world to the one that covers the most wide-ranging grid in terms of 'domains' and 'zones' to represent the market agnostic structure of the SGAM framework for the ON-PRJ. Figure 11 in provides a step-by-step explanation of the methodology.



Step 1: Select a DSO world

- The ON-PRJ developed five potential market model options for DSO (or DSO Worlds):
  - DSO World A: DSO coordinates
  - DSO World B: Coordinated procurement and dispatch
  - DSO World C: Price driven flexibility
  - DSO World D: ESO coordinates
  - DSO World E: Flexibility coordinator(s)
- The worlds are broadly categorised based on the extent to which the DSO accesses flexible DER, facilitates services and markets, provides own services to network customers and the extent of its relationship with the ESO.

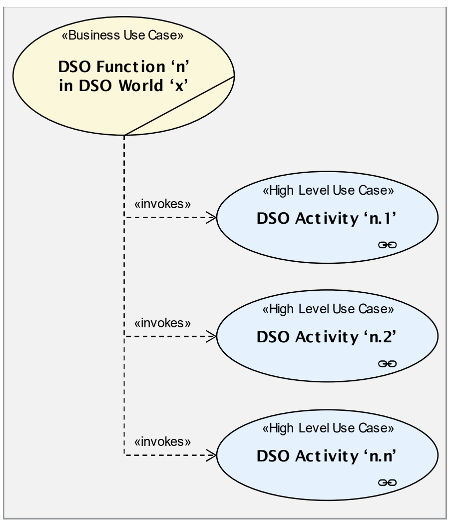
(a) Market model options for DSO



Step 2: Develop the ‘actor-relationship’ model

- Identify and define: business actors; business actor goals; and relationships between business actors
- Map business actors onto the business layer grid
- Perform gap analysis on the business layer grid to assess the applicability of its ‘domains’ and ‘zones’ to the business actors, goals and relationships
  - Gap analysis may result in the development of new ‘domains’ and ‘zones’ to accommodate all identified business actors
- Update the standard ‘domains’ and ‘zones’ of the business layer as appropriate

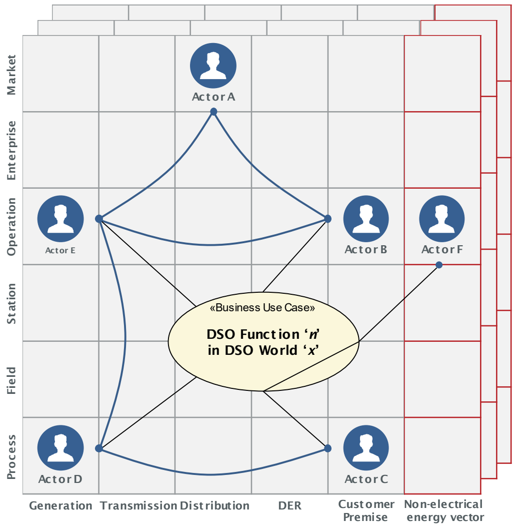
(b) Actor-relationship model



Step 3: Analyse the DSO functions and activities

- Analyse the DSO functions and their associated activities in the context of the defined business actors, goals and relationships
  - Identify the business actors, goals and relationships associated with each DSO function
  - The analysis may lead to the creation of new actors, goals and relationships that ought to exist to realise a specific DSO function
- Map each DSO function (i.e. ‘business use case’) together with its associated actors and relationships onto the business layer grid (i.e. a total of eight business layers for a DSO world)
  - There will be a total of eight business layers for each DSO world (i.e. one business layer grid per DSO function)

(c) DSO functions and activities



Step 4: Develop a market agnostic business layer grid

- Perform gap analysis on the business layer grid to assess the applicability of its 'domains' and 'zones' to the DSO function, business actors, goals and relationships
  - Gap analysis may result in the development of new 'domains' and 'zones' to accommodate the DSO function with all its related business actors and relationships
- Update the standard 'domains' and 'zones' of the business layer as appropriate
- Analyse simultaneously the business layer grid of all DSO functions and select the business layer grid that covers the most wide-ranging grid in terms of 'domains' and 'zones' to represent the DSO world
- Analyse simultaneously the business layer grid of all DSO worlds and select the business layer grid that covers the most wide-ranging grid in terms of 'domains' and 'zones' to represent the market agnostic structure of the SGAM framework for the ON-PRJ
  - Perform steps 1 to 4 for each of the five DSO words to develop the business layer grid representative of each DSO world

(d) Business layer grid

Figure 11 **Methodology walk-through: development of a market agnostic SGAM framework**

3.2.2 Market agnostic SGAM framework

The methodology for the development of the market agnostic SGAM framework has been applied to assess the fitness for purpose of the standard structure of the SGAM framework to represent the five market model options for DSO. As a result, the standard 'domains' of the 'smart grid plane' (refer to Sections 3.1.2 and 3.1.3 for further information) representing the electrical energy conversion chain have been extended to include non-electrical energy vectors. Figure 12 presents the market agnostic SGAM framework and Table 14 details the definition of the SGAM 'domains' used in the ON-PRJ.

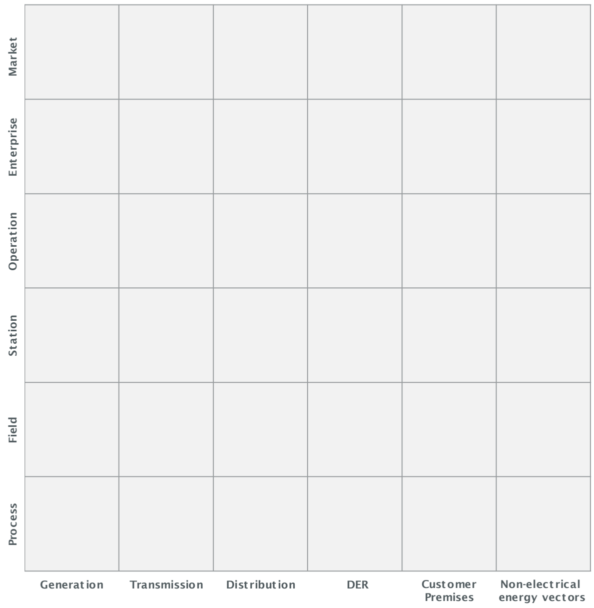


Figure 12 Market agnostic SGAM framework

Table 14 Domains

Domains	Description
Generation	Large scale power generation includes the infrastructure and technology used to provide electrical energy. Large scale power generation facilities are typically connected to the transmission system and may include fossil fuel-based technologies, such as coal and gas, nuclear power plants, hydro power plants, on- and off-shore wind farms, large scale solar photovoltaic farms, etc.
Transmission	Represents the network infrastructure and organisations which transport electricity over long distances
Distribution	Represents the network infrastructure and organisations which distribute electricity to customers
DER	Represents small-scale power generation technologies (typically in the range of 11kW to 10MW and including electric energy storage facilities) and larger end use electricity consumers (e.g. industrial and commercial) with the ability of flexing their demand as part of their business (i.e. demand side response) that are directly connected to the electricity distribution network.
Customer Premises	Represents end-user electricity consumers as well as producers. The premises include both domestic and smaller non-domestic facilities such as homes, shopping centres, hospitals, airports, etc.). Generation technologies includes solar photovoltaic, electric battery storage, electric vehicles storage, micro turbines, etc.
Non-electrical vectors	Represents a system that enables the transfer, in space and time, of a quantity of non-electrical energy. Thus, it may be a system that utilises, heat, natural gas, hydrogen or some other agent.

4. Practical application of the Smart Grid Architecture Model

The section presents the methodology developed the design and implementation of the SGAM for the market model options for the future DSO. It then extracts a 'use case' from the SGAM of a specific market model for DSO, to demonstrate the step-by-step application of the methodology.

4.1 Methodology

EA Technology developed a detailed methodology to represent the five market model options for DSO (refer to Section 2.4 for further information) in the SGAM framework. The methodology comprehensively describes the market models by capturing the interactions between different 'actors' from a high-level 'Business Layer' perspective down to the detail of what information is passed using what communications methods between equipment/components. This representation of the market models options provides a comprehensive understanding of how different models might practically work. Figure 13 presents a schematic representation of the methodology developed for the design and implementation of the SGAM.

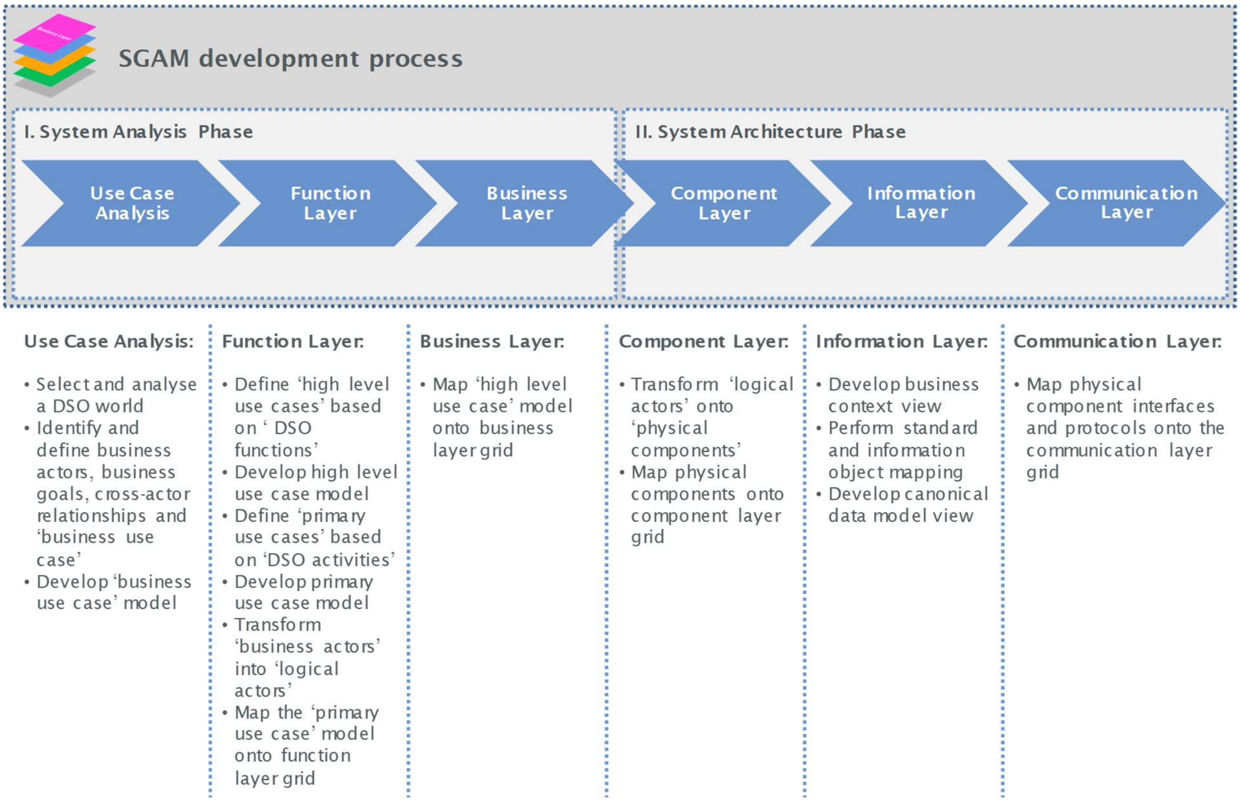


Figure 13 Methodology for the design and implementation of the SGAM

The design and implementation process of the SGAM is constituted by two distinct phases: system analysis; and system architecture. The system analysis phase aims at defining the system and its functional requirements. The focus is therefore on the required functional specification rather than on technical solutions. The system architecture phase aims at mapping the functional requirements of the system into a high-level architecture. This high-level architecture describes the main subsystems and their interactions without detailing their inner composition.

4.1.1 System analysis phase

The use case analysis explores a particular DSO world (refer to Section 2.4 for further information) in greater depth. It identifies and defines the business actors involved in the DSO world, their individual business goals, their relationship with other business actors and establishes the business use case(s) that needs to exist for business actors to realise their individual business goals. The function layer defines the functional specification of the DSO world that is required to deliver the business objectives that were set out during the use case analysis. The functional specification is described via 'high level' and 'primary' use cases. The high level use cases are defined from the DSO functions while the primary use cases are defined from the DSO activities. The primary use cases are mapped onto the function layer grid and the high level use cases are mapped onto the business layer grid.

4.1.2 System architecture phase

The system architecture phase maps the functional requirements of a particular DSO world into a high-level architecture. This high-level architecture describes the key functionality of the main subsystems / components and their interactions without detailing their inner composition. Thus, the system architecture can be interpreted as a black box model of all involved subsystems / components with the description of the interactions between them being the key difference and focus across the component, information and communication layers.

4.2 Use case

The SGAM representation of a market model for the future DSO has proven to be extensive and complex. For instance, the SGAM for the 'DSO World B: Coordinated procurement and dispatch' is constituted of around 155 'use cases'. Thus, attempting to present the SGAM of each of the five market model options in this report becomes an impractical task. Instead, the report extracts a single 'use case' from the SGAM developed in the Enterprise Architect software (refer to Section 3.1.5 for further information) for a specific DSO world. The 'use case' is then used to demonstrate the step-by-step application of the methodology developed to design and implement the SGAM.

The selected 'use case' is described by the following characteristics:

- DSO World: 'DSO World B: Coordinated procurement and dispatch';
- DSO Function: 'Network operation';
- DSO Activity: 'Operate network within thermal limits'; and
- DSO Process: Activation of distributed flexibility resources for 'distribution network thermal constraint management'.

Figure 14 defines the 'use case' to be modelled in the SGAM framework and establishes the relationship between the nomenclature used in the ON-PRJ and in the SGAM.

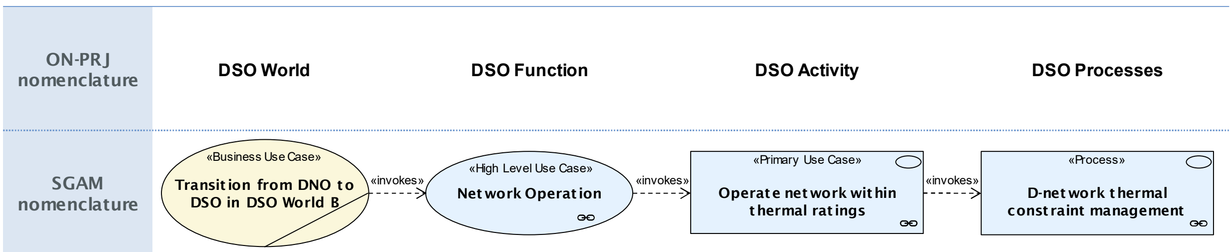


Figure 14 Use case

4.3 System analysis phase

4.3.1 Use Case analysis

The use case analysis develops the business use case model and identifies the high level use cases and the primary use cases describing the functional requirements necessary to fulfil the business use case.

Business use case model

The business use case model identifies and defines the business actors involved in the ‘use case’, their individual business goals and their relationship with other business actors. The use business case model then trades-off the objectives and constraints of business actors to derive the Business Use Case(s) (BUC) that needs to exist to realise the individual business goals of the business actors. Lastly, the business use case model identifies the High Level Use Cases (HLPUC) and the Primary Use Cases (PUC) that describe the functional requirements necessary to fulfil the BUC.

The business use case model for the ‘use case’ under analysis (refer to Section 4.2 for further information) is depicted in Figure 15. It includes the business actors, business goals, BUC, HLUC and PUC representative of the ‘use case’.

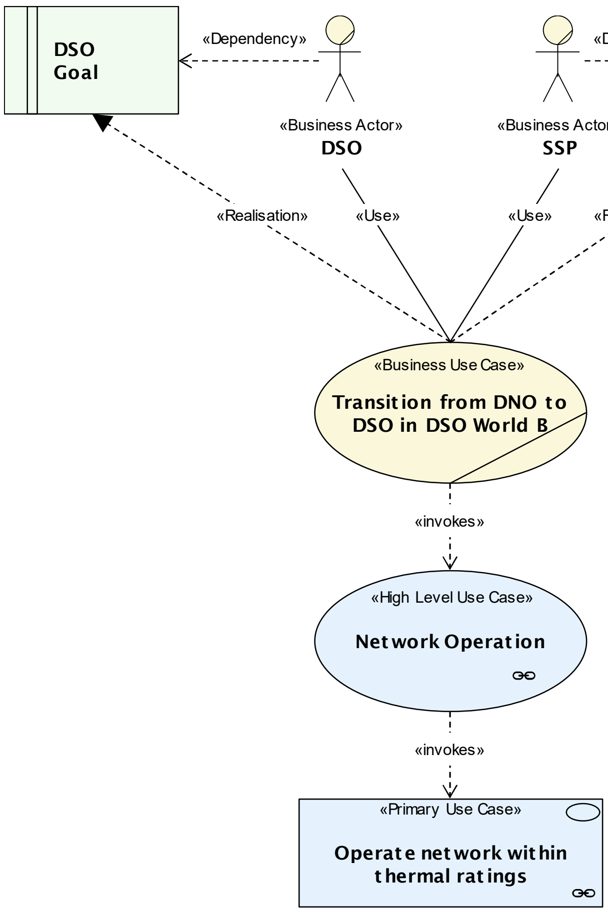
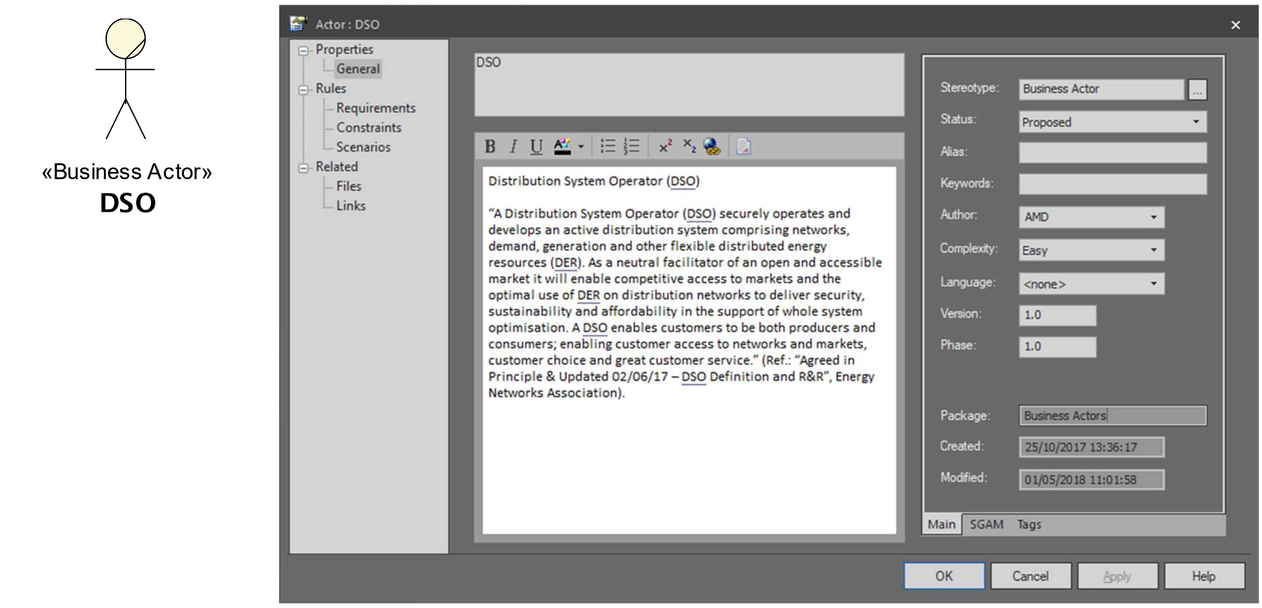
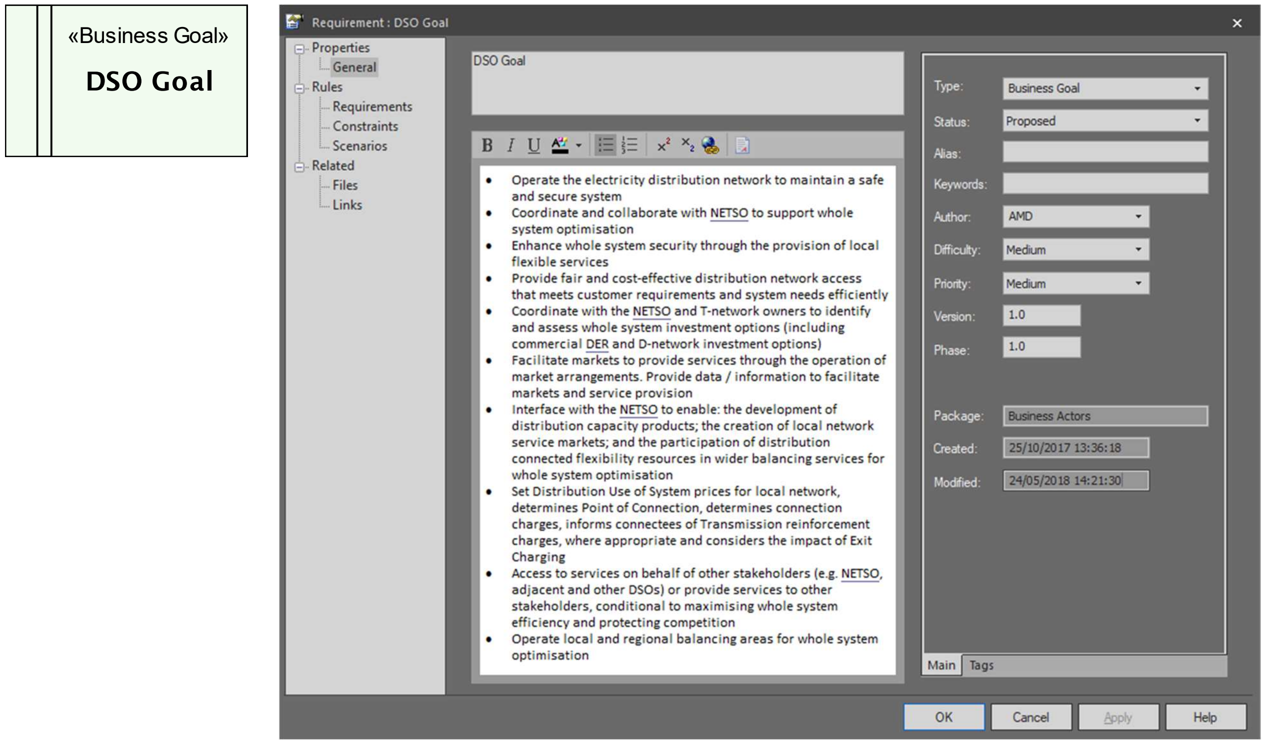


Figure 15 **Business use case model**

Figure 15 has been produced as part of the SGAM modelling work, developed in the Enterprise Architect software, for the representation of the ‘DSO World B: Coordinated procurement and dispatch’. Consequently, each Enterprise Architect element in Figure 15 is a placeholder of information that contains the detailed definition of its physical representation. For example, Figure 16 introduces the definitions of the business actor DSO and its associated business goal. The definition of other business actors and goals is presented in Appendix I.



(a) Business actor definition



b) Business goal definition

Figure 16 Business actor and goal: Distribution System Operator

Based on the aforementioned definition of the DSO business actor and its goals an overarching BUC can be derived to facilitate the DSO to physically realise its business goals. Accordingly, the BUC has been defined as the transition from the present DNO business structure to that of a future DSO in the 'DSO World B: Coordinated procurement and dispatch'. Figure 17 displays the definition of the BUC based on the Enterprise Architect elements in Figure 15.

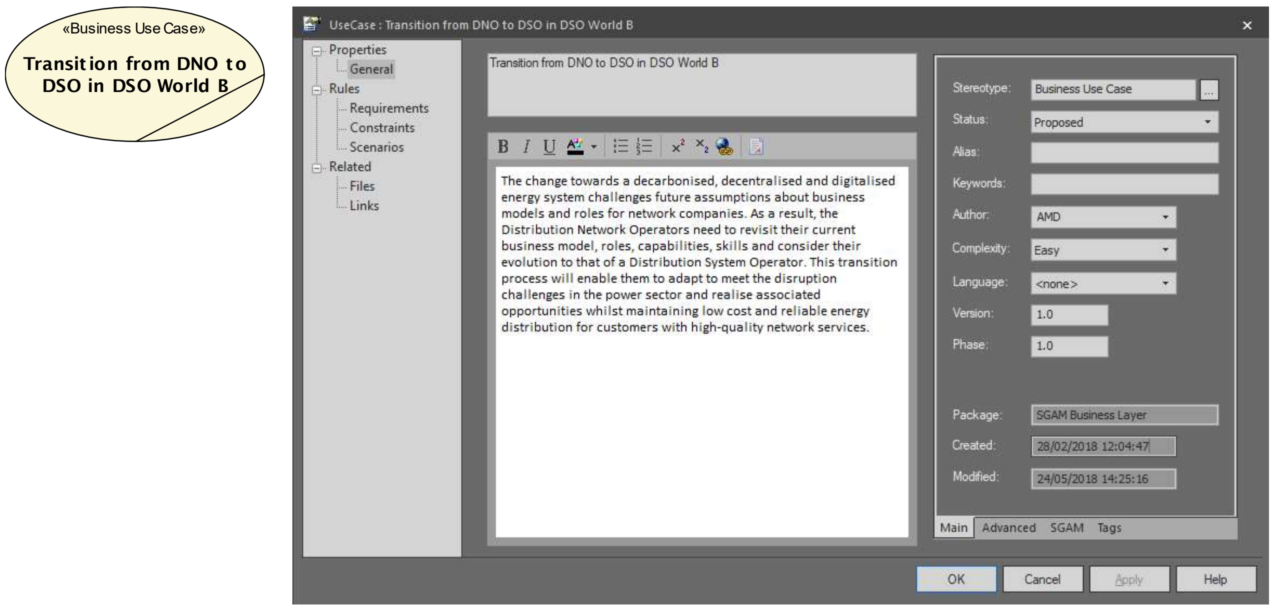


Figure 17 Business use case: Transition from DNO to DSO

The business use case model of Figure 15 also characterises the type of relationships between business actors, business goal and BUC. The DSO business actor has a 'dependency' relationship with its business goal as the physical specification and implementation of the DSO is dependent on the business goals that wants to achieve. The DSO business actor has a 'use' relationship with the BUC as the DSO uses the BUC to physically implement its goals. The BUC has a 'realisation' relationship with the DSO business goal as the physical implementation of BUC realises the DSO business goals.

Lastly, the business use case model in Figure 15 identifies the HLUC 'network operation' and the PUC 'operate network within thermal ratings' to describe a specific functional requirement necessary to realise the BUC 'transition from DNO to DSO in DSO World B'.

4.3.2 Function layer

The function layer defines the functional specification of the DSO world that is required to exist to deliver the business objectives that set out during the use case analysis. The high level use case model initiates the functional specification of the DSO world by decomposing the BUC into HLCUs and establishing the definition of these HLCUs. Next, the primary use case model decomposes the HLCU into more granular PUCs and describes them in greater detail to attain the full functional specification of the DSO world. Lastly, the PUCs cases are mapped onto the function layer grid.

High level use case model

The high level use case model initiates the functional specification of the system by decomposing the BUC into HLCUs and establishing the definition of these HLCUs. In this sense, the ON-PRJ identified and defined the functional capabilities required by a DNO to develop and operate the distribution network following an Active Distribution System Management approach and to progress towards a DSO business structure. The eight DSO functions and associated DSO activities (refer to Section 2.2 for further information) reflect the evolution of current DNO capabilities and the creation of new ones that enable the DNO to fulfil its enhanced requirements as a DSO. Figure 18 illustrates the high level use case model composed by the eight DSO functions.

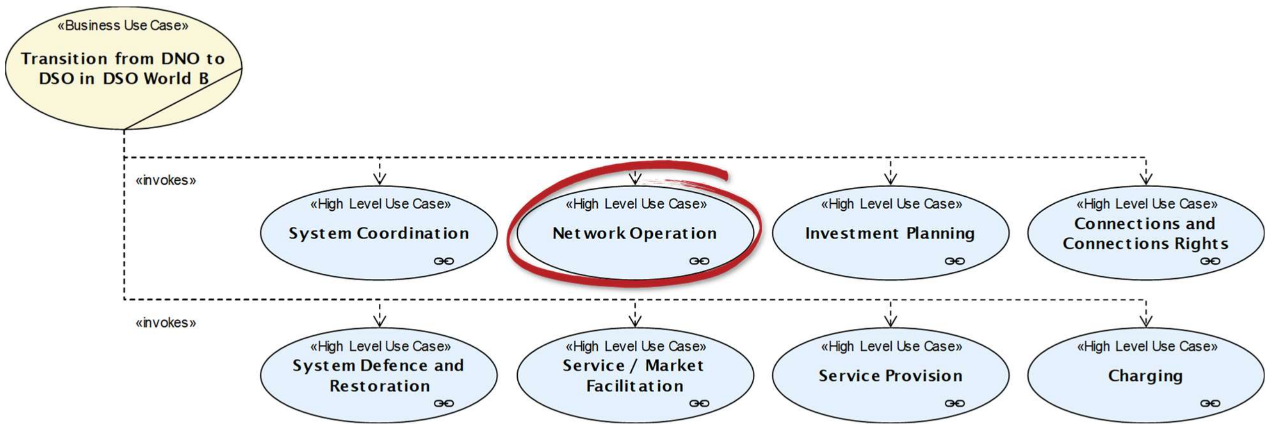


Figure 18 High level use case model

Finally, the high level use case model defines the HLUCs. Figure 19 details the definition of the HLUC 'network operation' as part of the 'use case' under analysis. It should be emphasised that the high level use case model together with the detailed definitions of the HLUCs is stored within the Enterprise Architect.

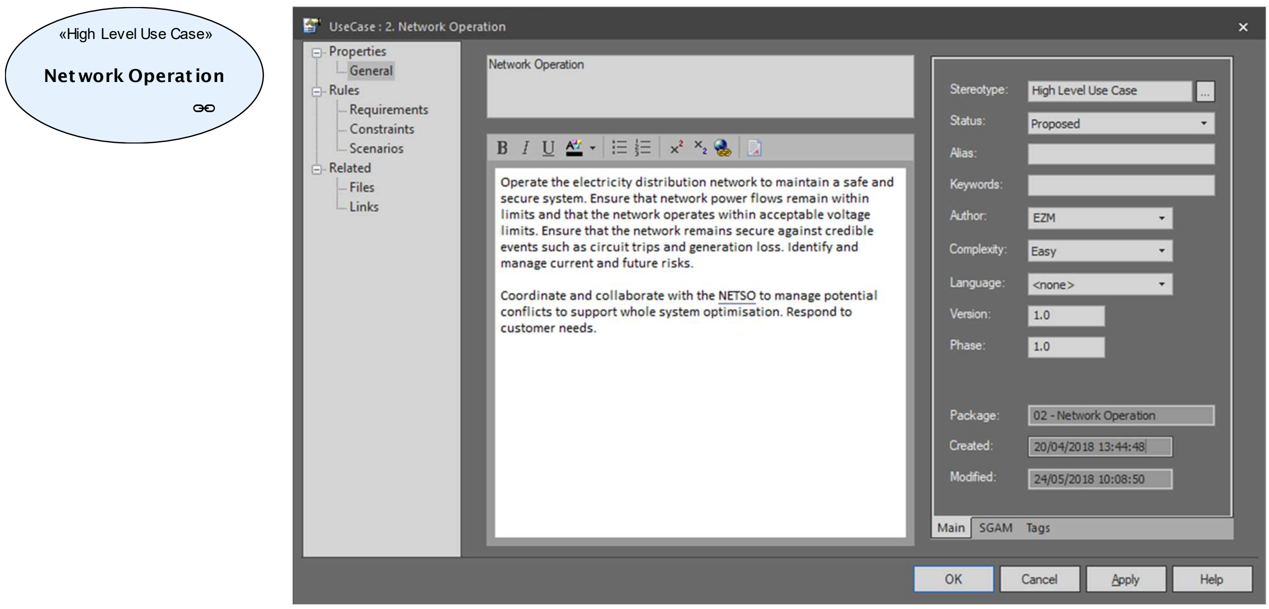


Figure 19 High level use case: Network operation

Primary use case model

The primary use case model decomposes the HLCU into more granular PUCs. The PUCs are then described in greater detail to attain the final functional specification of the system. Consequently, the ON-PRJ identified and defined a discrete set of activities that the DSO may be required to perform to deliver its business outputs within the remit of each DSO function (refer to Section 2.2 for further information). Figure 20 depicts of the primary use case model composed by the nine DSO activities.

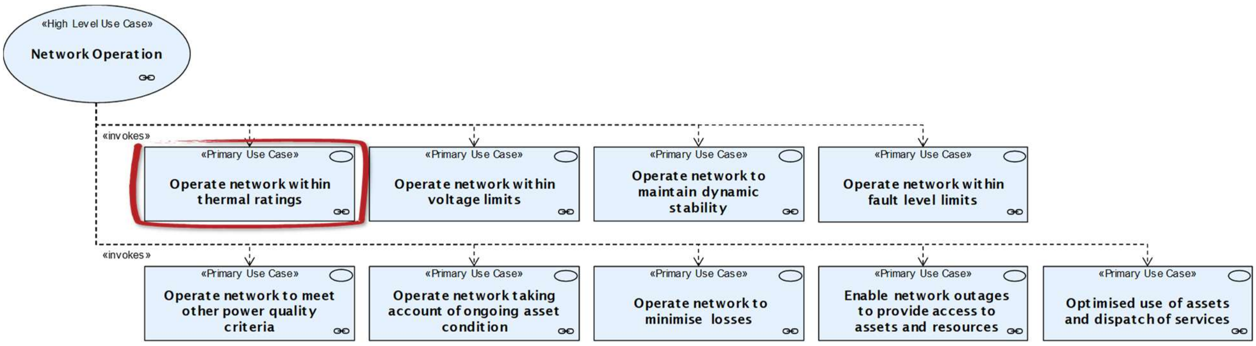


Figure 20 Primary use case model: defining the primary use cases

The primary use case model then defines the PUCs. Figure 21 provides the definition of the PUC 'operate network within thermal ratings' in accordance with the 'use case' under analysis. It should be stressed that the primary use case model together with the detailed definitions of the PUCs is stored within the Enterprise Architect.

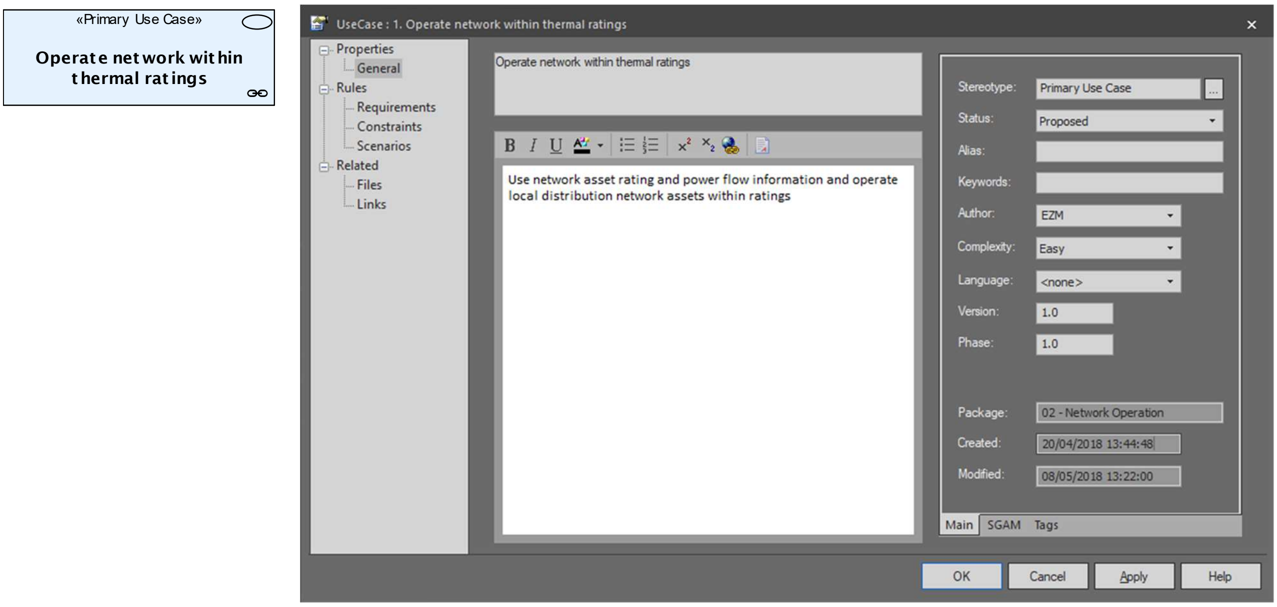


Figure 21 Primary use case: Operate network within thermal ratings

Whilst the PUCs have been identified and defined, they have not been developed to a sufficiently level of detail that allows for the full characterisation of the functional specification of the 'use case' under assessment. To this end, EA Technology has organised, facilitated and delivered five industry stakeholder workshops to develop the detailed functional specification of each DSO activity (i.e. PUC), DSO function (i.e. HLUC) and DSO world (i.e. BUC). In addition to the functional specification required for the development of the business and function layers, EA Technology also collected relevant information to support the development of the information, communication and component layers. Hence, for a particular DSO world, DSO function and DSO activity, workshop participants were asked three questions:

- **Q1.** Who is communicating with whom;
- **Q2.** What are they saying; and
- **Q3.** How are they communicating (and how often)?

Figure 22 provides an insight on the approach adopted by EA Technology to facilitate the workshops and capture the stakeholders' responses to the three questions expressed above.

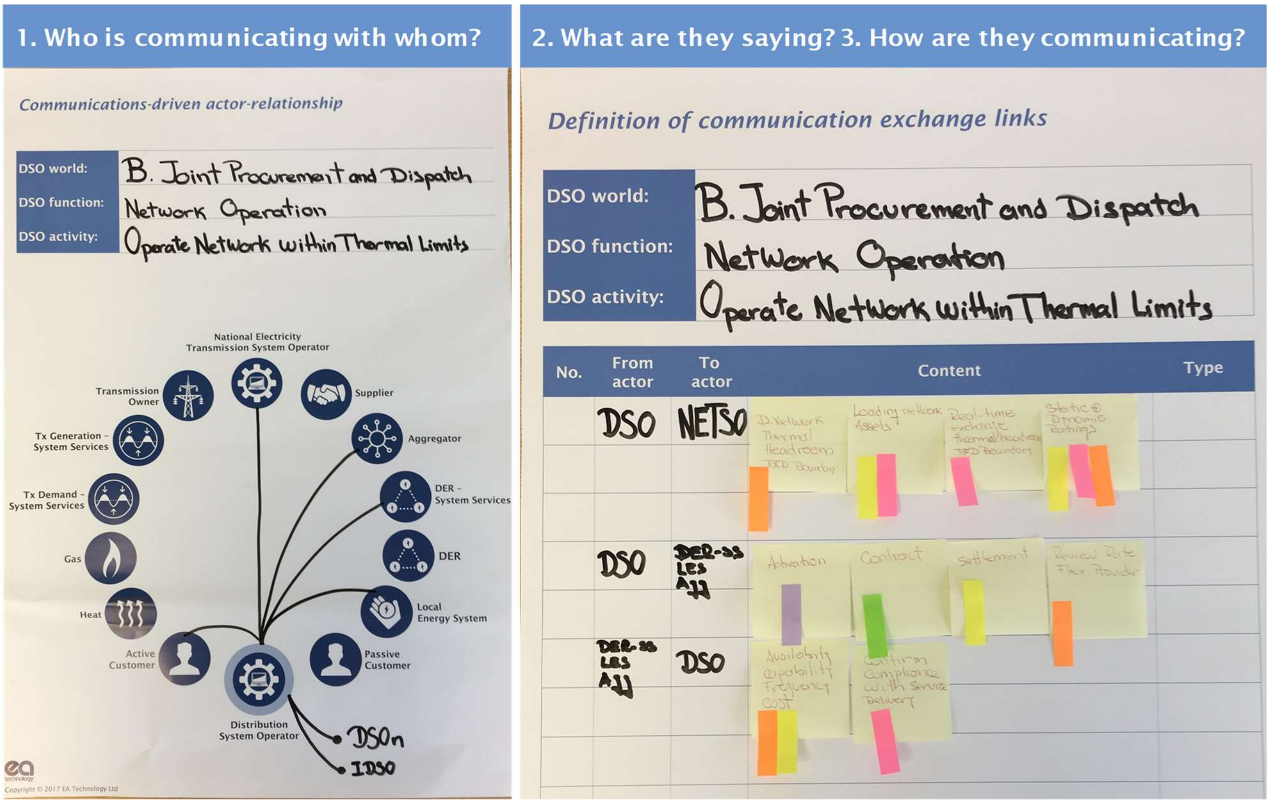
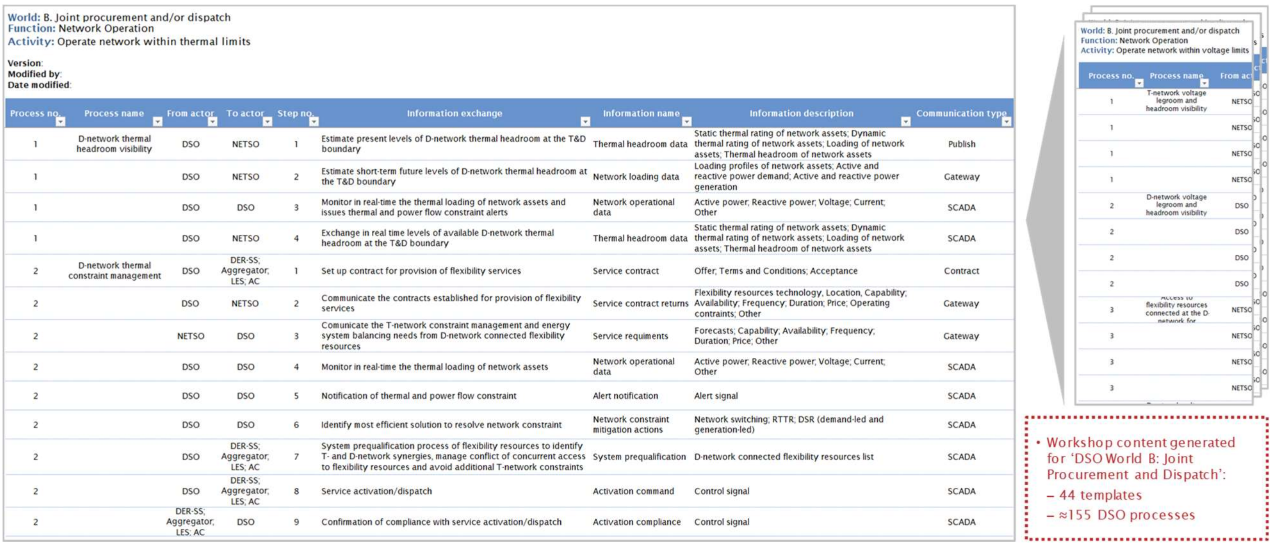


Figure 22 Example of content generated at industry workshops

Following each of the workshops, EA Technology processed the content generated by the industry stakeholders and translated it into bespoke templates for the Enterprise Architect software. Figure 23 depicts an example of the templates holding an extract of the content generated in the industry workshops for the ‘DSO world B. Coordinated procurement and dispatch’, ‘DSO function: network operation’ and ‘DSO activity: operate network within thermal limits’.



World: B. Joint procurement and/or dispatch
Function: Network Operation
Activity: Operate network within thermal limits

Version:
Modified by:
Date modified:

Process no.	Process name	From actor	To actor	Step no.	Information exchange	Information name	Information description	Communication type
1	D-network thermal headroom visibility	DSO	NETSO	1	Estimate present levels of D-network thermal headroom at the T&D boundary	Thermal headroom data	Static thermal rating of network assets; Dynamic thermal rating of network assets; Loading of network assets; Thermal headroom of network assets	Publish
1		DSO	NETSO	2	Estimate short-term future levels of D-network thermal headroom at the T&D boundary	Network loading data	Loading profiles of network assets; Active and reactive power demand; Active and reactive power generation	Gateway
1		DSO	DSO	3	Monitor in real-time the thermal loading of network assets and issues thermal and power flow constraint alerts	Network operational data	Active power; Reactive power; Voltage; Current; Other	SCADA
1		DSO	NETSO	4	Exchange in real time levels of available D-network thermal headroom at the T&D boundary	Thermal headroom data	Static thermal rating of network assets; Dynamic thermal rating of network assets; Loading of network assets; Thermal headroom of network assets	SCADA
2	D-network thermal constraint management	DSO	DER-SS; Aggregator; LES; AC	1	Set up contract for provision of flexibility services	Service contract	Offer; Terms and Conditions; Acceptance	Contract
2		DSO	NETSO	2	Communicate the contracts established for provision of flexibility services	Service contract returns	Flexibility resources technology, Location, Capability; Availability; Frequency; Duration; Price; Operating contraints; Other	Gateway
2		NETSO	DSO	3	Comunicate the T-network constraint management and energy system balancing needs from D-network connected flexibility resources	Service requiments	Forecasts; Capability; Availability; Frequency; Duration; Price; Other	Gateway
2		DSO	DSO	4	Monitor in real-time the thermal loading of network assets	Network operational data	Active power; Reactive power; Voltage; Current; Other	SCADA
2		DSO	DSO	5	Notification of thermal and power flow constraint	Alert notification	Alert signal	SCADA
2		DSO	DSO	6	Identify most efficient solution to resolve network constraint	Network constraint mitigation actions	Network switching; RTTR; DSR (demand-led and generation-led)	SCADA
2		DSO	DER-SS; Aggregator; LES; AC	7	System prequalification process of flexibility resources to identify T- and D-network synergies, manage conflict of concurrent access to flexibility resources and avoid additional T-network constraints	System prequalification	D-network connected flexibility resources list	SCADA
2		DSO	DER-SS; Aggregator; LES; AC	8	Service activation/dispatch	Activation command	Control signal	SCADA
2		DER-SS; Aggregator; LES; AC	DSO	9	Confirmation of compliance with service activation/dispatch	Activation compliance	Control signal	SCADA

Figure 23 Example of processed workshop content in bespoke templates

Figure 23 shows that this particular extract of the workshop content for the ‘DSO activity: operate network within thermal limits’ contains two DSO processes (i.e. ‘Process no.’ and ‘process name’ fields). Specifically, Figure 23 depicts 4 practical steps (i.e. ‘Step no.’ field) for the ‘DSO process: distribution network thermal headroom visibility’ and 9 practical steps for the ‘DSO process: distribution network thermal constraint management’. It should be noted that this is only a short extract of the workshop content for the 'DSO activity: operate network within thermal limits'. In fact, this DSO activity is characterised by a total of five distinct DSO processes. Overall, the industry workshop for the 'DSO world B. Coordinated procurement and dispatch' produced a total of 44 templates sharing around 155 DSO processes across them. The set of DSO processes present in each template represent the full functional specification of a particular DSO activity (i.e. PUC). In turn, the functional specification of a specific set of DSO activities forms the full functional specification of a particular DSO function. Moreover, the combination of the functional specification of the eight DSO functions results in the full functional specification of the entire DSO world.

As the industry stakeholder workshops were delivered on five different occasions and with a varied number of participants and backgrounds, different workshop groups derived content to dissimilar level of detail across the DSO processes, activities, functions and worlds. As a result, during the processing stage of the workshop content leading to the development of the templates of Figure 23, EA Technology used a common modelling language to help achieve consistency in the language used and to benchmark the definition of processes, activities, functions and worlds to a similar level of detail and standard. Figure 24 displays an example of the common modelling language used to process the workshop content and produce the templates shown in Figure 23.

Common Modelling Language

Project: 119560 - Open Networks
Version:
Modified by:
Date modified:

Process no.	Process name	Step no.	Information exchange	Information description	Communication type
1	Development of whole system flexibility services (wrt procurement / activation of D-network connected flexibility resources)	1	Indentify and specify the characteristics and requirements of flexibility services for T-and D-networks constraint management and energy system balancing	Thermal headroom; Voltage legroom and headroom; Rate of Change of Frequency; Fault Level; Power Quality; Other	Publish
		2	Define the high-level specification of balancing services for T-and D-networks constraint management and energy system balancing	Flexibility service provider id; Capability; Availability; Frequency; Duration; Price; Other	Publish
		3	Industry stakeholder consultation on balancing service specifications	Technical, commercial and regulatory specifications of flexibility services	Publish
		4	Define the principles, processes and standards that guarantee high performance of delivery of flexibility services across different providers	Performance of service guaranteed standards	Publish
		5	Review, update and submit flexibility service specifications	Capability; Availability; Frequency; Duration; Price; Other	Publish
		6	Approve flexibility service specifications		
		7	Publish flexibility service specifications	Capability; Availability; Frequency; Duration; Price; Other	Publish
		8	Contract for provision of flexibility services for T-and D-networks constraint management and energy system balancing	Offer; Terms and Conditions; Acceptance	Contract
2	Contract of D-network connected flexibility resources (wrt T-and D-networks constraint management and energy system balancing)	1	Publish flexibility service specifications for D-network constraint management	Capability; Availability; Frequency; Duration; Price; Other	Publish
3	Procurement of D-network connected flexibility resources	1	Submit long-term future D-network constraint management needs and requirements	Capability; Availability; Frequency; Duration; Price; Other	Gateway
4	Activation of D-network connected flexibility resources (wrt T-network constraint management and energy system balancing)	1	Submit short-term future D-network constraint management needs and requirements	Capability; Availability; Frequency; Duration; Price; Other	Gateway
5	Activation of D-network connected flexibility resources (wrt D-network constraint	1	Enact instruction for flexibility service activation/dispatch	Control signal	Gateway

Figure 24 Example of the common modelling language

Following an initial analysis of the workshop content, EA Technology identified commonalities between the DSO processes across the different DSO worlds and established a standard structure for each common process. Figure 24 shows an example common modelling language used for the development of DSO processes based on the workshop content. It should be stressed that the common modelling language only provides the basic structure for the DSO process as the structure is likely to change, via the addition or removal of steps, as it is used in different DSO activities, functions and worlds.

In particular, the industry workshops allowed for the characterisation of the functional specification of the 'use case' under analysis by inferring the DSO processes that need to exist to deliver the practical realisation of the 'DSO activity: operate network within thermal ratings' (i.e. PUC in Figure 21). Figure 25 displays the primary use case model constituted of five practical DSO process.

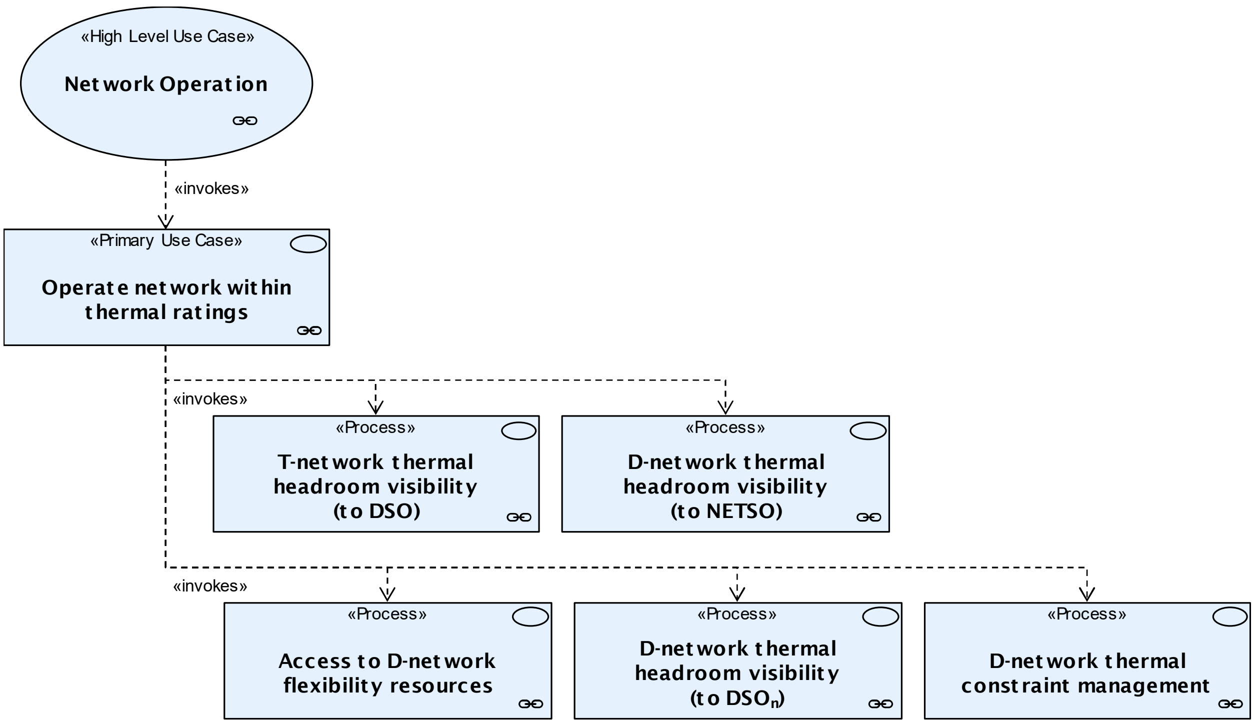


Figure 25 Primary use case model: defining the processes

Out of the five DSO processes identified in Figure 25, the 'use case' being analysed focusses on developing the functional specification of the 'DSO process: distribution network thermal constraint management' based on the information provided by industry stakeholders at the workshops. Precisely, this DSO process and the business actors involved are exemplified in Figure 26.

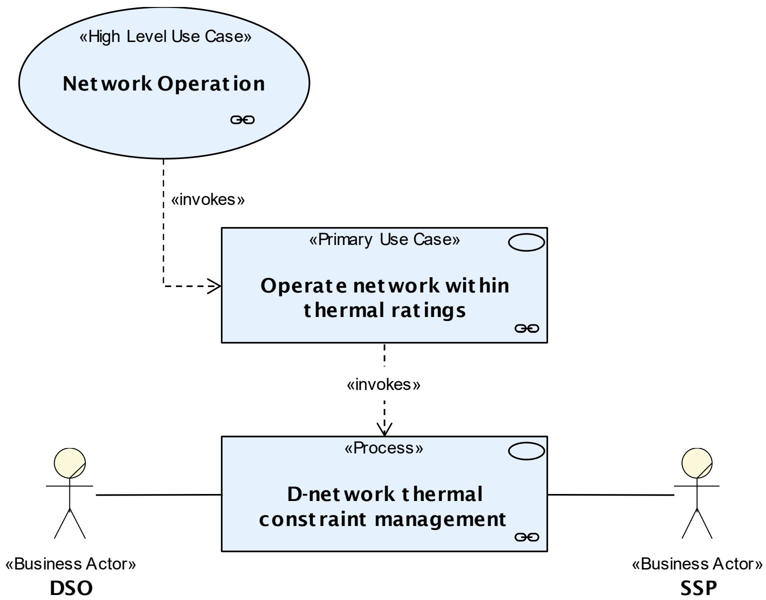


Figure 26 DSO process: distribution network thermal constraint management

It should be emphasised that Figure 26 holds two implicit assumptions described as follows:

- **A1.** A distribution network thermal constraint is resolved through the activation of distributed flexibility resources; and

- **A2.** The flexibility service is provided by an SSP (refer to Appendix I for further information) that owns and operates a DER.

These assumptions have only been made in the specific demonstration of this 'use case' for simplicity and clarity purposes. Therefore, these assumptions are not part of the final SGAM developed in the Enterprise Architect and published to industry as the SGAM recognises that:

- The DSO have an extensive set of mitigation tools available to resolve network thermal constrains that span from conventional solutions (e.g. network switching/reconfiguration) to smart solutions (e.g. Real Time Thermal Ratings); and

- There are other business actors providing flexibility services for distribution network thermal constraint management, such as aggregators, local energy systems, etc.

The functional specification of the PUC 'operate network within thermal limits' with respect to the process of activation of DER for 'distribution network thermal constraint management' was captured in the industry workshops and is displayed in Figure 27.

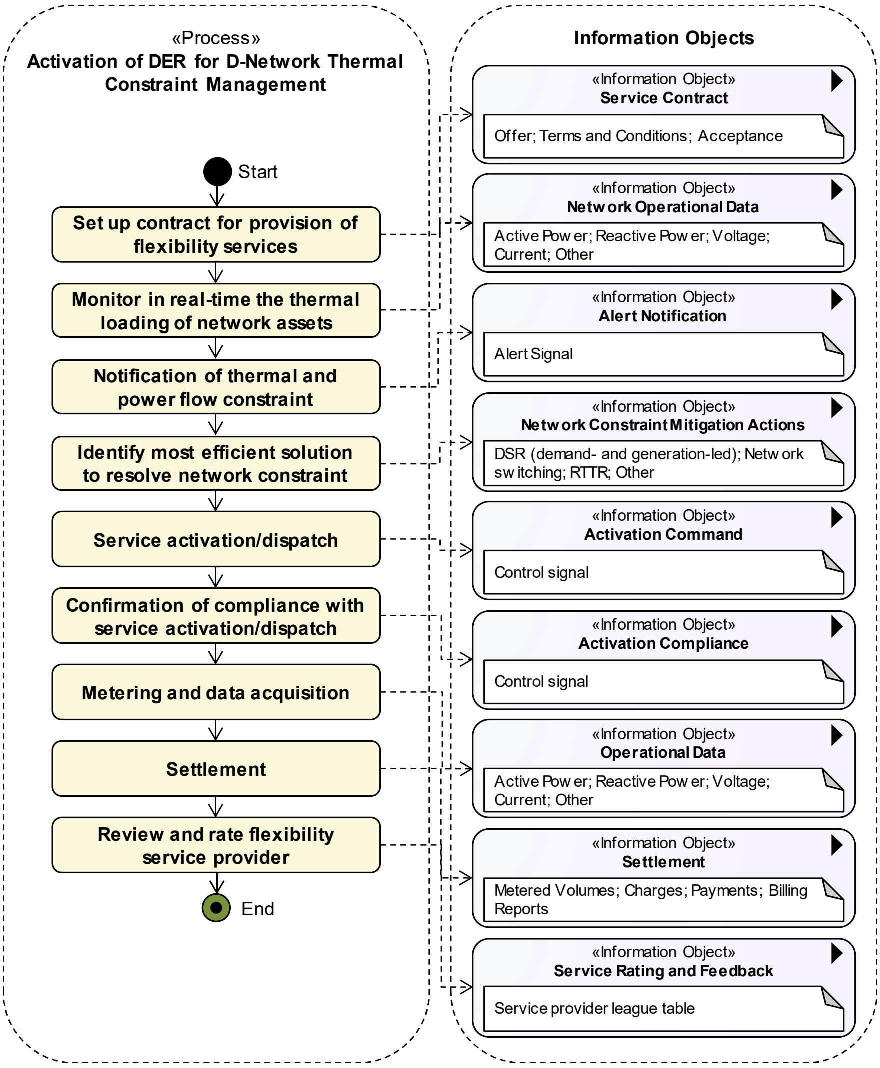


Figure 27 Activity diagram for 'distribution network thermal constraint management'

Figure 27 uses the so-called 'activity diagram' to describe the functional steps required to realise the PUC. It also assigns 'information objects' to the functional steps to characterise the information that is being exchanged. The 'activity diagram' is then complemented with a 'sequence diagram' detailing who is communicating with whom (i.e. business actors), what they are saying and in what sequence the activities and information are being realised. The 'sequence diagram' is introduced in Figure 28.

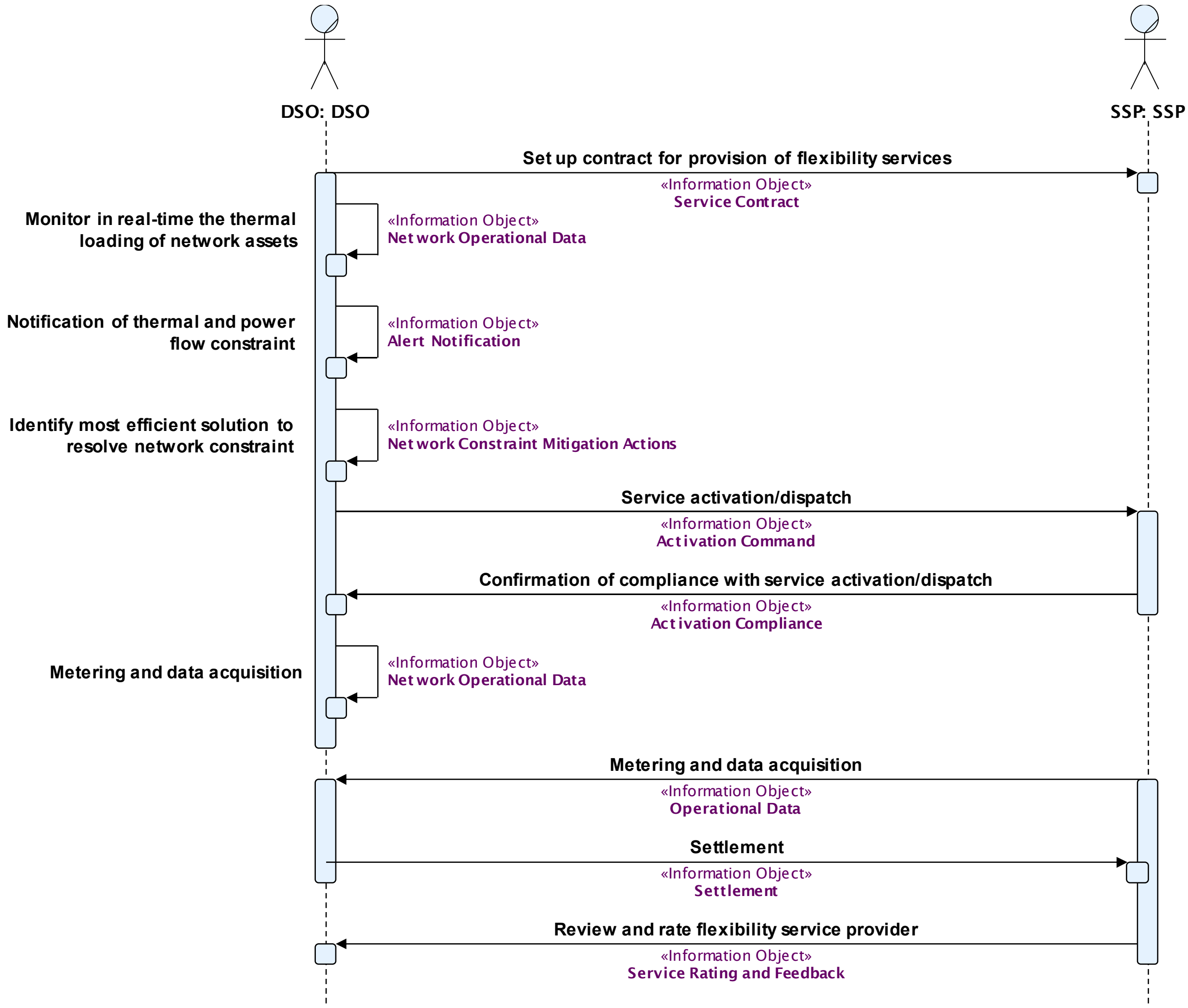


Figure 28 **Sequence diagram for 'distribution network thermal constraint management'**

Logical actors

The functional specification of HLUCs and PUCs has been represented at a 'logical level' as their physical realisation involves logical decisions and evaluations, processing commands, performing calculations, etc. Thus, business actors are converted into logical actors to realise the 'logical level' activities of the functional specification and to maintain independence from the 'business level' activities. Figure 29 illustrates the transformation of business actors into logical actors. This is a model transformation of type 1:*n* as a business actor can have various logical actors while any logical actor can only originate from a single business actor.

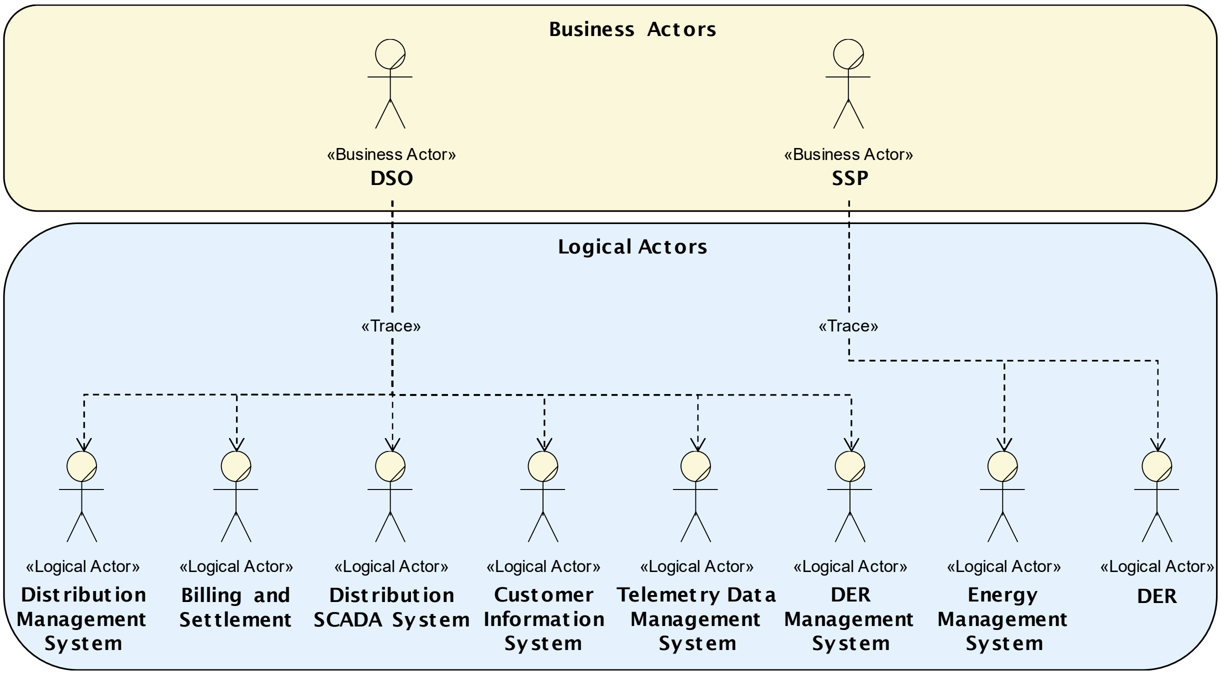
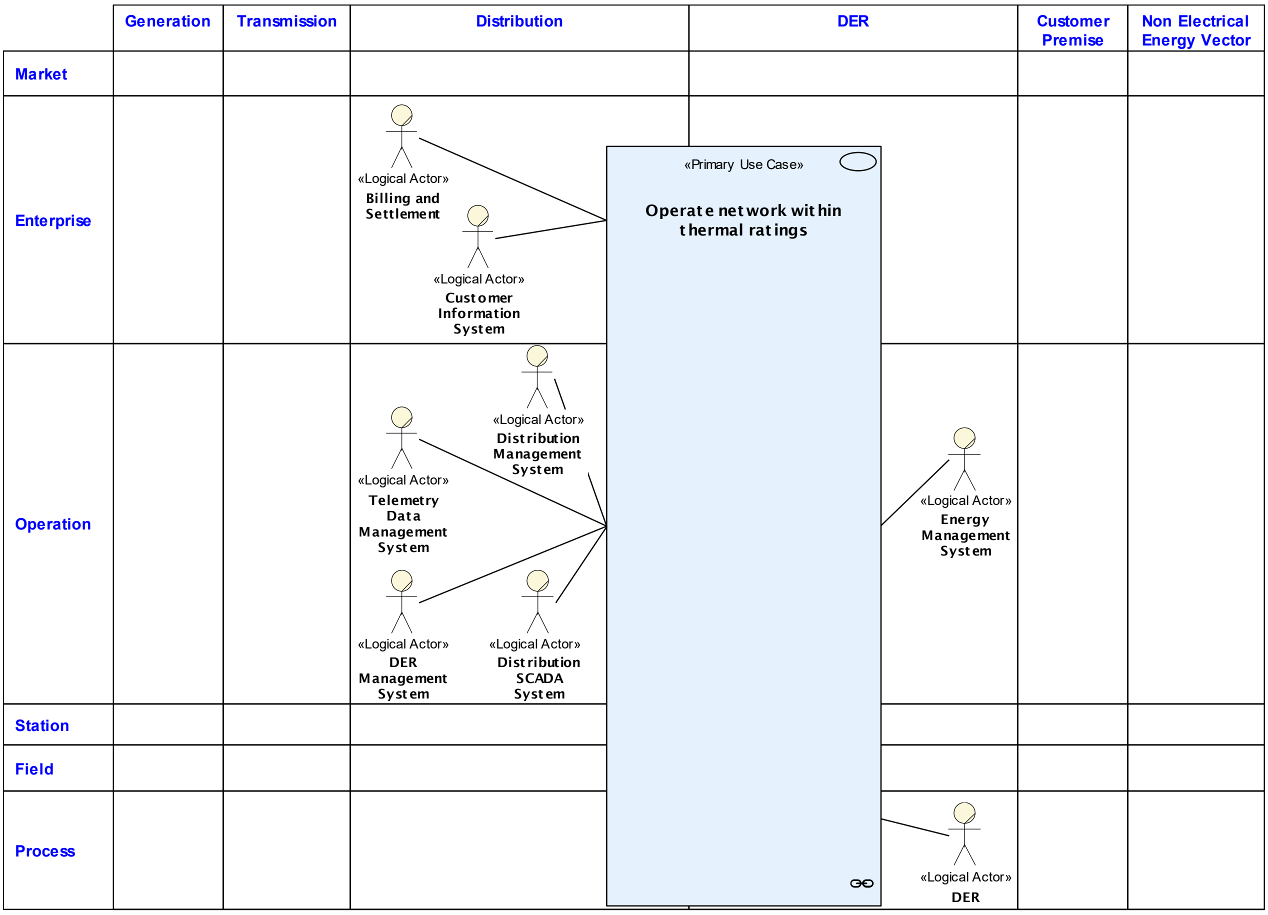


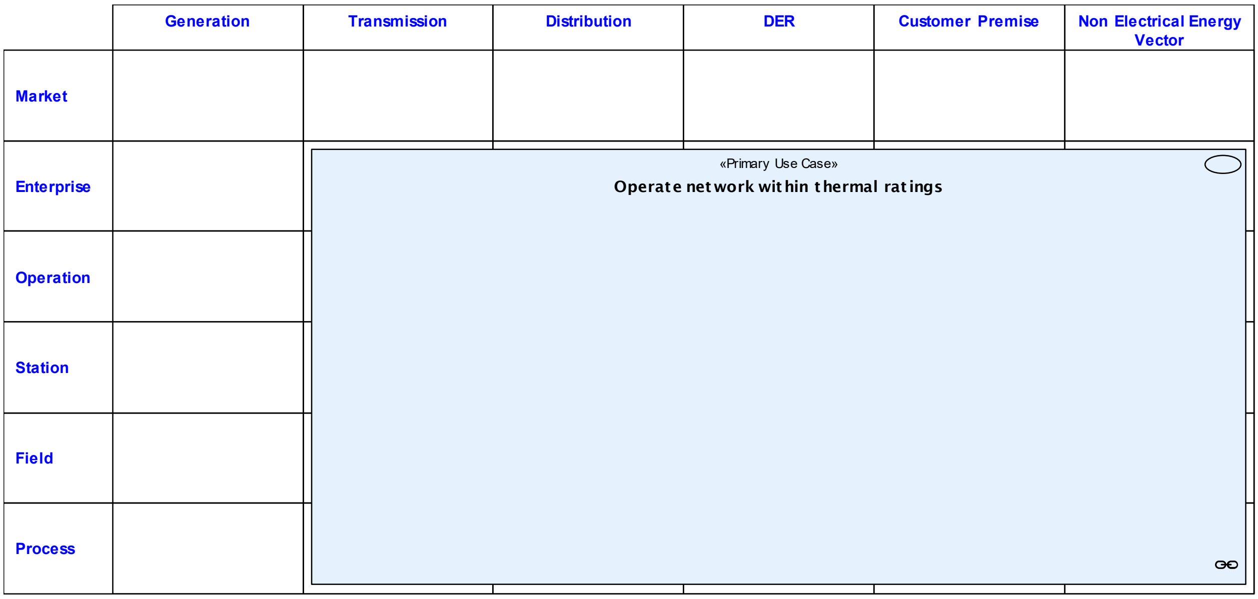
Figure 29 Transformation of business actors into logical actors

Function layer

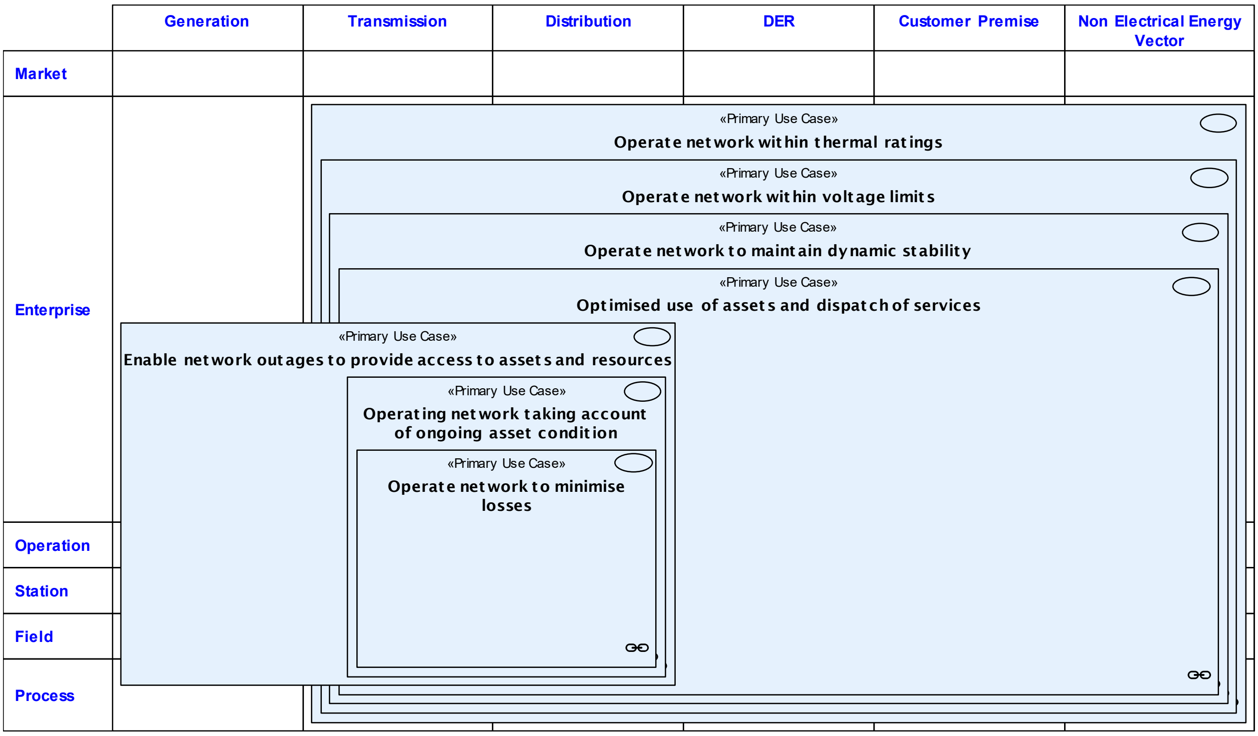
The function layer spatially distributes all PUCs (i.e. DSO activities) involved in a HLUC (i.e. DSO function) across the domains of the electrical energy conversion chain and the zones of the information management hierarchy (refer to Section 3.1 for further information). In this sense, the function layer is developed separately for each HLUC. Figure 30 sequentially develops the function layer in three steps for the 'DSO function: network operation' and 'DSO world B. Coordinated procurement and dispatch'.



(a) DSO process: Distribution network constraint management



(b) DSO activity: Operate network within thermal ratings



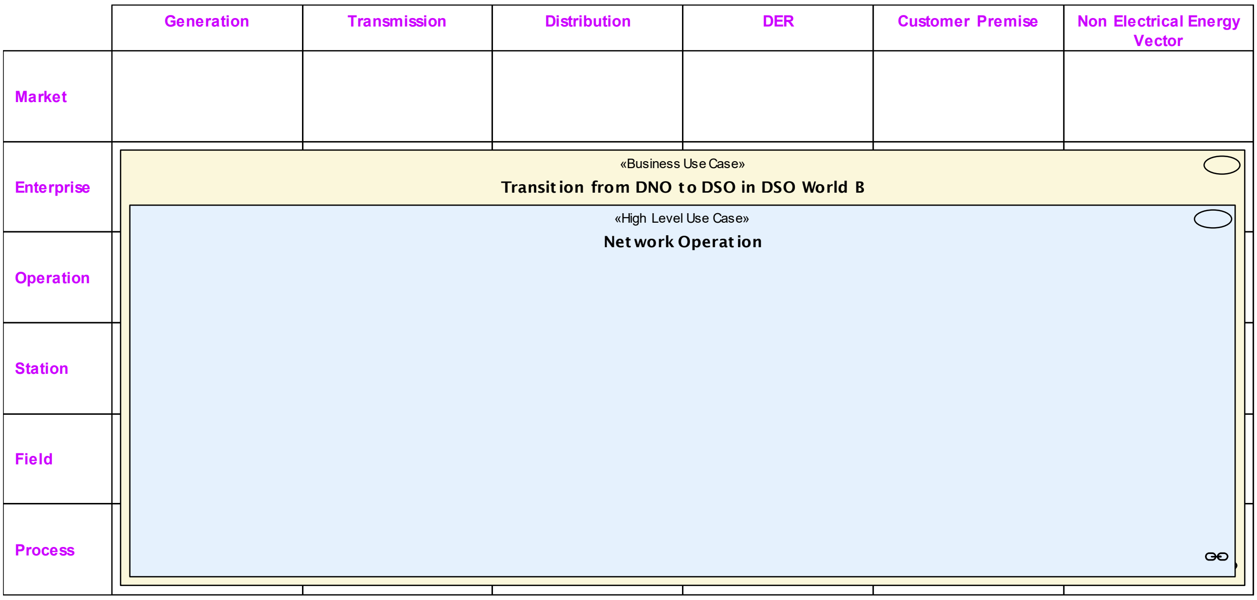
(c) DSO function: Network operation

Figure 30 Function layer

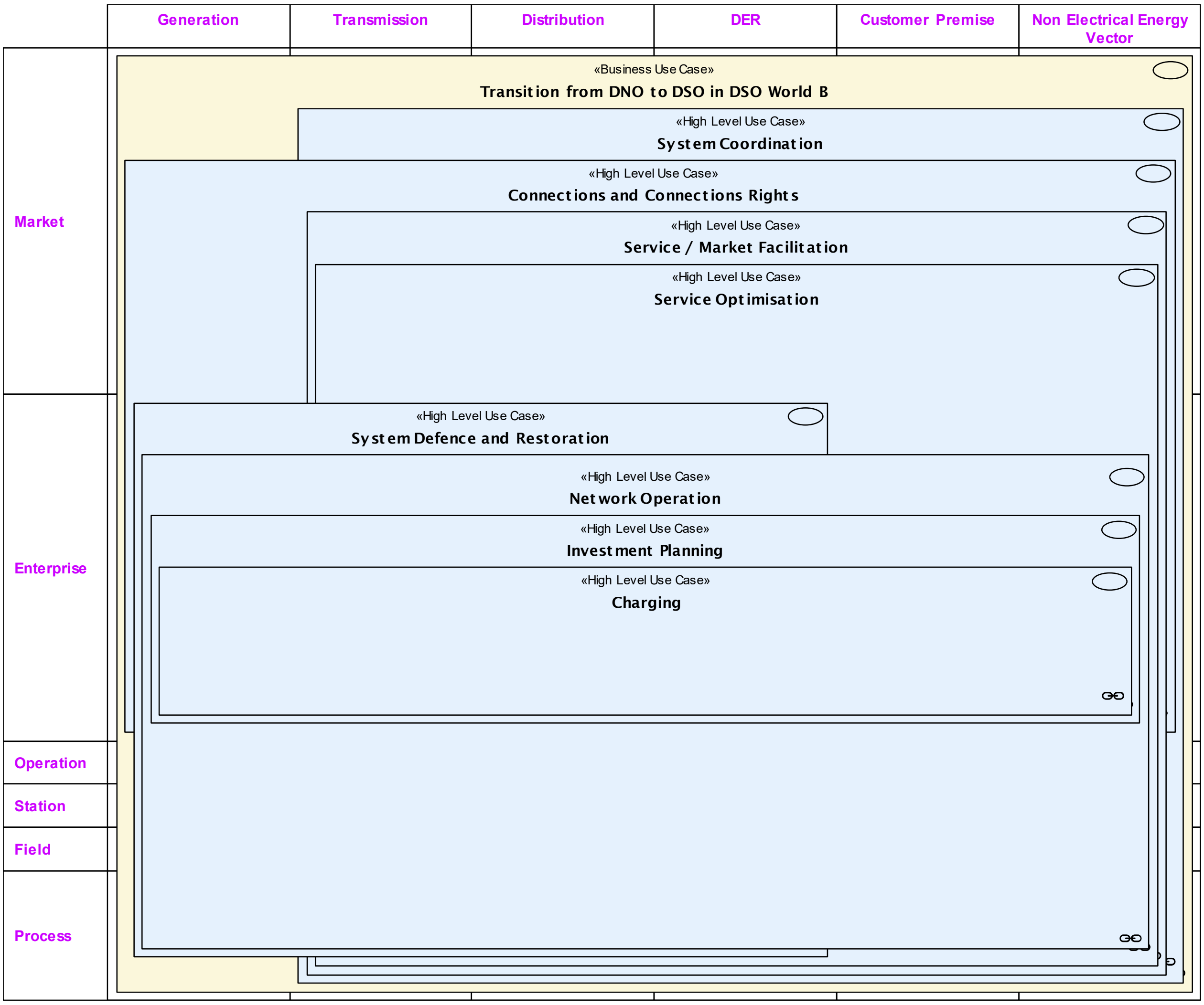
Figure 30a shows the function layer for the 'DSO activity: operate network within thermal ratings' and the 'DSO process: distribution network thermal constraint management'. Nonetheless, as described by primary use case model in Figure 25, the 'DSO activity: operate network within thermal ratings' is actually composed of five distinct DSO process. Therefore, Figure 30b expands the function layer of Figure 30a to include the five DSO processes. As the function layer ought to spatially distribute all PUCs of a single HLUC, Figure 30c details the function layer for the 'DSO function: network operation' and 'DSO world B: Coordinated procurement and dispatch'.

4.3.3 Business layer

The business layer spatially distributes all HLUCs (i.e. DSO function) across the domains and zones of the 'smart grid plane' (refer to Section 3.1 for further information) for every BUC (i.e. DSO world). In this sense, there will be a single business layer per DSO world. Figure 31 sequentially develops the business layer in two steps for the 'DSO world B: Coordinated procurement and dispatch'. Figure 31a shows the business layer with respect to the 'DSO function: network operation' only whilst Figure 31b expands the business layer to include all eight DSO functions and therefore represent the 'DSO world B: Coordinated procurement and dispatch'.



(a) DSO function: network operation



(b) DSO world B: Coordinated procurement and dispatch

Figure 31 Business layer

4.4 System Architecture Phase

The system architecture phase aims at mapping the functional requirements of the system into a high-level architecture. This high-level architecture describes the key functionality of the main subsystems / components and their interactions without detailing their inner composition. Thus, the system architecture can be interpreted as a black box model of all involved subsystems / components with the description of the interactions between them being the key difference and focus across the component, information and communication layers. Similarly, to the function layer, these three SGAM lower layers are developed for every HLUC (i.e. DSO function).

Following discussion with the ON-PRJ Workstream 3 group, EA Technology was requested to produce SGAM models from the business layer to the information layer only. The rationale behind this is:

- The importance of making the outputs accessible to a non-technical audience as part of wider consultation; and

- To avoid potential lock-in to a given system architecture at this early stage in the process.

In this respect, the outputs of the SGAM modelling work are presented in the form of activity and sequence diagrams as described in Figure 27 and Figure 28.

4.4.1 Component layer

The component layer directly maps the functional requirements of the system into a high-level architectural solution composed by subsystems / components. To this end, logical actors are converted into components. This is a model transformation of type *n*:*n* as different logical actors can be converted into the same physical component and vice versa. Figure 32 illustrates the transformation of logical actors into components for the ‘use case’ under analysis.

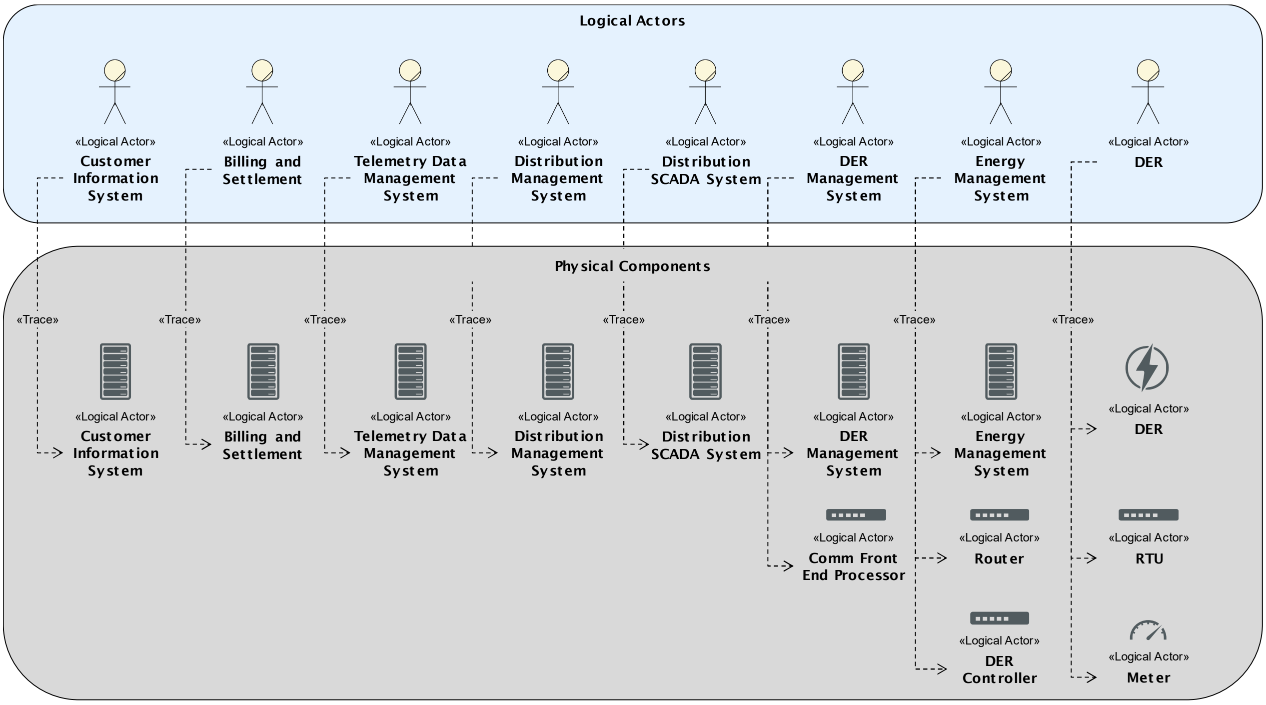


Figure 32 Transformation of logical actors into physical components

The physical components are now spatially distributed across the domains and zones of the ‘smart grid plane’ to form the component layer. As previously indicated, the key focus of this layer lies on the physical connections between components, i.e. both general network topology and ICT network architecture between components, rather than on the components themselves. Figure 33 introduces the component layer of the ‘use case’ under analysis.

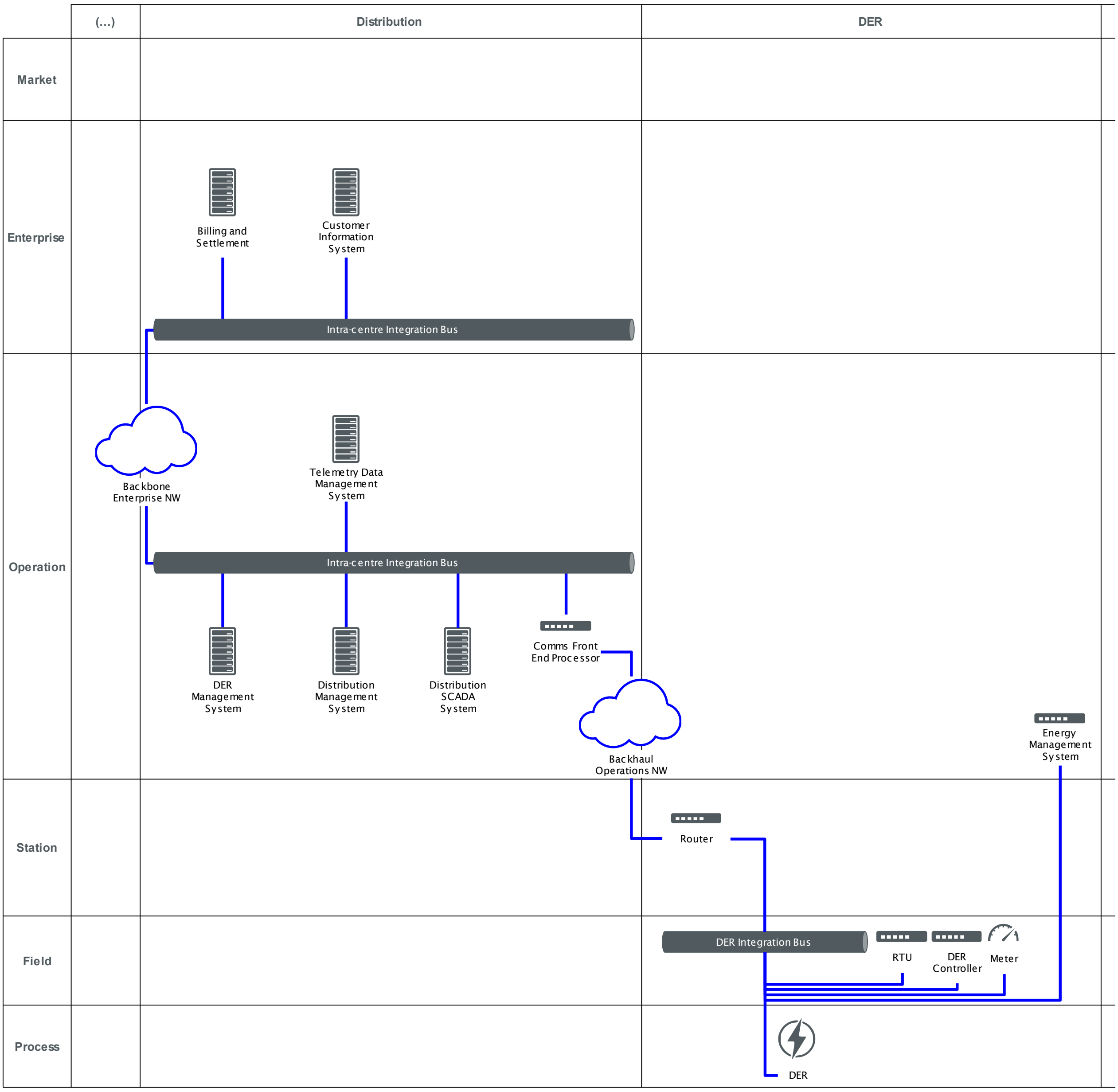


Figure 33 Component layer

It should be noted that the architecture of the 'DSO process: distribution network constraint management' (i.e. Figure 33) shall be considered in conjunction with the architecture of the other four DSO processes (see Figure 25 for further information) to form the full architecture of the 'DSO activity: operate network within thermal ratings' being analysed (i.e. PUC). In turn, the architecture of all nine DSO activities (see Figure 20 for further information) belonging to the 'DSO function: network operation' shall be combined to produce the full component layer for this DSO function.

4.4.2 Information layer

The industry workshops asked stakeholders to specify the information being exchange between business actors in a particular DSO world, DSO function and DSO activity (i.e. Workshop Question 2). As a result, several 'information objects' were created during the functional specification to characterise the information exchanged (see Figure 27 for further information). The information layer considers the 'information objects' and maps them onto the information layer grid across the relevant physical components. Figure 34 displays the information layer for the 'use case' under assessment.

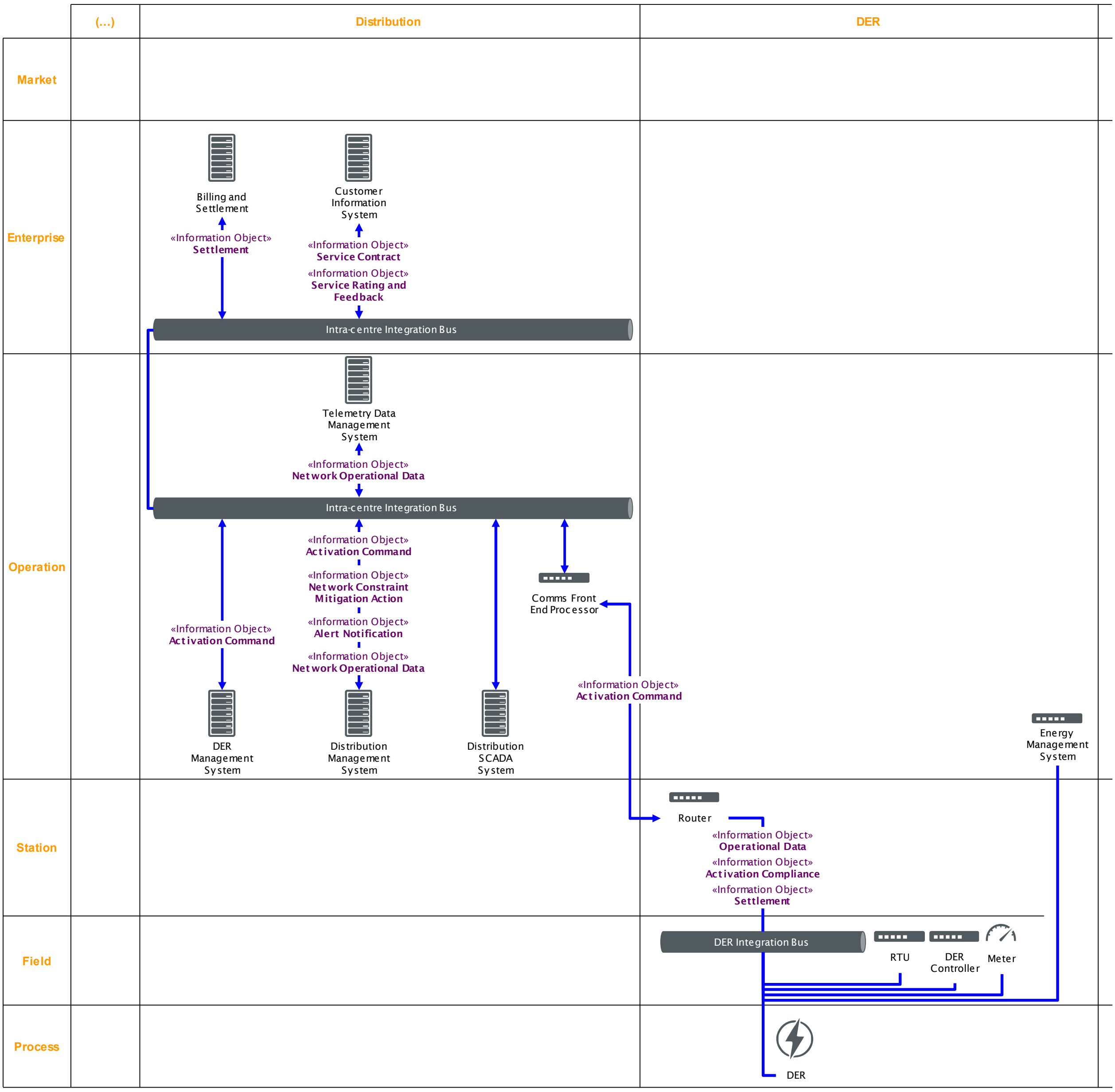


Figure 34 Information layer

4.4.3 Communication layer

The industry workshops asked stakeholders to specify how the business actors are communicating between themselves in a particular DSO world, DSO function and DSO activity (i.e. Workshop Question 3). As a result, the communication means were grouped into five generic communication types presented in Figure 35.

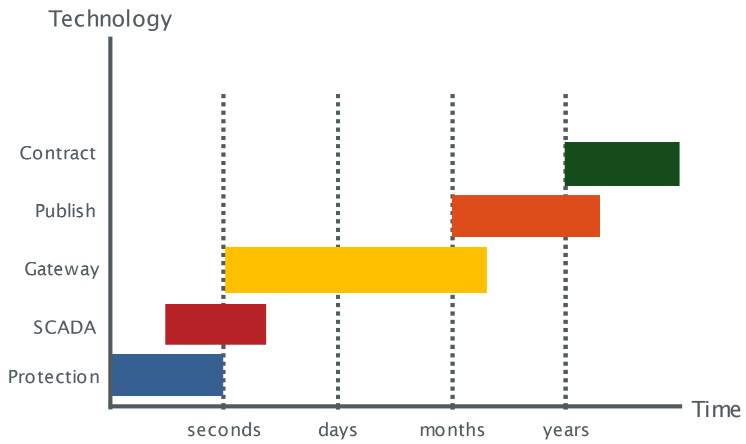


Figure 35 Generic communication types

Broadly, these five generic communication types are defined as follows:

- Protection: Hard wired communications; Timeframe: real-time (<1sec)
- SCADA: Electronic real-time communications within DSO; Timeframe: 1sec – 5mins
- Gateway: Electronic communications from / to outside world; Timeframe: real-time (sec), short-term (sec to days)
- Publish: Public statement; Timeframe: medium-term (months)
- Contract: Pre-defined / agreed / legally enforced communications; Timeframe: long-term (years)

The communication layer considers the 'communication types' and maps them onto the communication layer grid across the relevant physical components. Figure 36 displays the communication layer for the 'use case' under assessment.

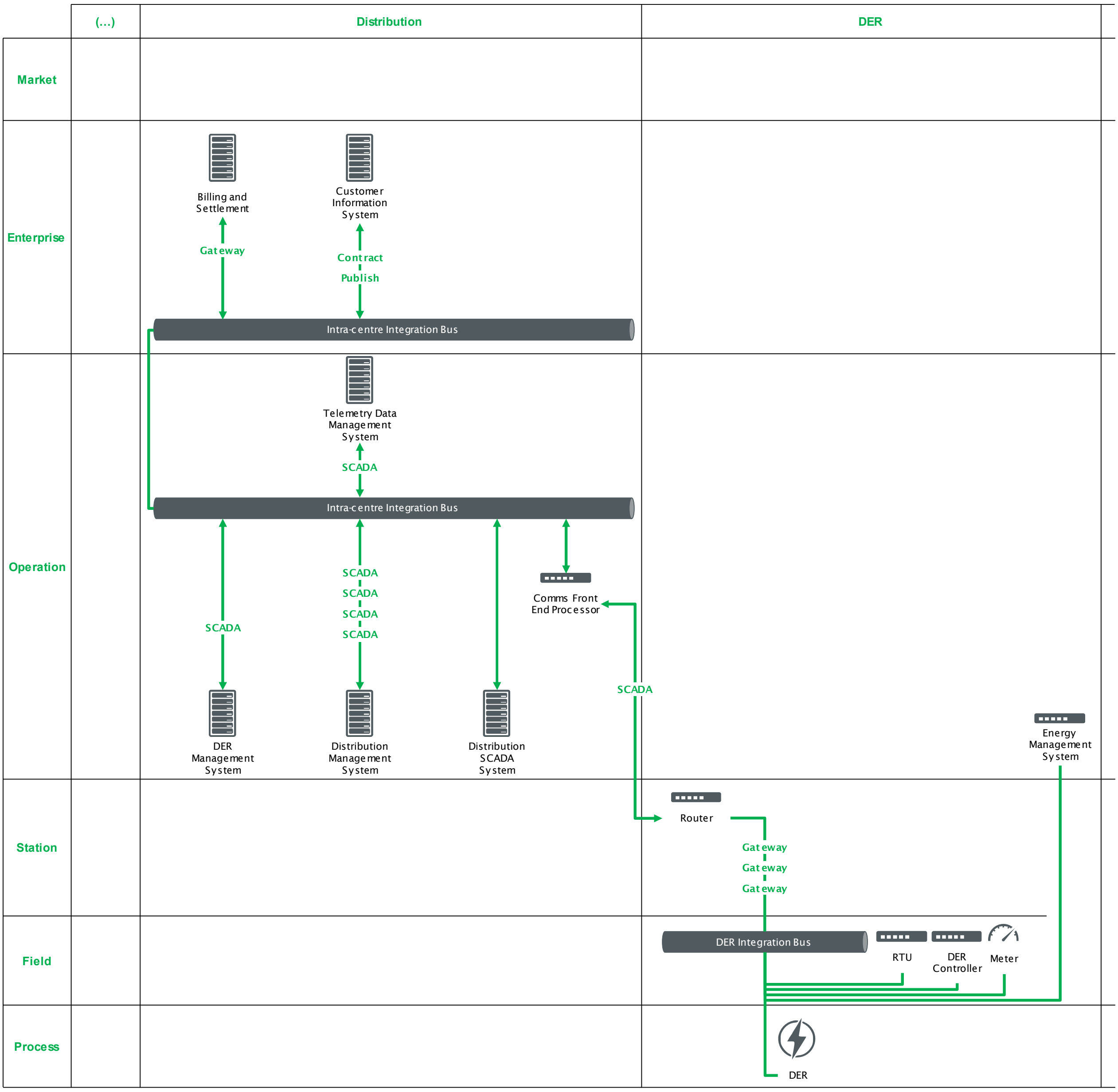


Figure 36 Communication layer

5. Overarching risks and benefits

5.1 Methodology

The various worlds considered within this project have a high degree of variability from both a technical and commercial perspective. For example, there is the need to understand from a technical standpoint, which party has the decision-making power? In DSO Coordinates, clearly this is the DSO, while in ESO Coordinates, the ESO has the responsibility. In other worlds the responsibility can be shared or fall to a third party.

From a commercial perspective, there are differing degrees of market facilitation that are required for the different worlds. It is therefore important to consider both the technical and commercial challenges associated with the worlds when evaluating them.

Furthermore, it is important to try to understand the level of change involved in transitioning to any of these worlds. A 'baseline' case representing the current market framework and technical structure has not been modelled, so attempting to quantify the change from a baseline is difficult. However, it is possible to drive out where the complexity resides in the different worlds; i.e. is it focused on the relationships and interactions that the DSO has, those that the ESO has, or is there a considerable amount of complexity regarding the transmission-distribution interface between DSO and ESO?

This section seeks to draw out some of these points and looks to address the issue regarding complexity by ascribing values to the relationships based on their nature and volume.

5.2 Summary of key features of the worlds

The five worlds considered are varied and complex. Having workshopped and developed SGAM models for each, EA Technology has observed the following characteristics. These are listed below to aid a reader in understanding the relative complexities and hence the overarching risks and benefits associated with each.

5.2.1 World A: DSO Coordinates

- The DSO is more likely to be in tune with local stakeholder needs and best placed to understand the limits of the local network.
- The DSO can act as a technical gatekeeper to ensure network performance remains as required.
- This world is highly effective at managing local constraints using local resources, however it is more difficult in this world to achieve national efficiencies
- A reasonable amount of interplay between the DSO and ESO is necessary as all contracts for service provision will run through the DSO.
- Regulatory oversight would be necessary to ensure transparency in decision-making; i.e. to demonstrate that the DSO does not merely take the actions that are easiest for it to implement.
- As the DSO is responsible for coordinating the services to resolve a ESO issue, there is a requirement for a team of people within the DSO charged with performing a function that is not necessarily aligned with the current drivers and objectives of the DSO.
- A variety of approaches is likely to manifest across different DSOs, which could lead to confusion for service providers operating across different portions of the country; regulation and standards may be required to manage this.

5.2.2 World B: Coordinated Procurement and Dispatch

- This world has the potential to optimise solutions across both local and national objectives.
- However, this very advantage has the consequential effect that optimisation processes could be inserted into every business function, e.g. connections, markets operation, network operations, etc.
- Each of the parties (DSO and ESO) is setting up contracts to directly meet their requirements (so internally interests are aligned rather than in the DSO Coordinates model above; i.e. there is no need for a business function existing solely to serve the needs of another party).
- Market participants have more routes to market (they can sell to DSO and to ESO), potentially opening greater revenue opportunities.
- There is a need for careful management of conflicts and greater control measures to eliminate the possibility of the same actor being called upon by each party to resolve an opposing issue (such as charging a battery to increase demand or discharging a battery to provide greater levels of demand in response to competing network needs).
- No single party has ownership of the decision-making process; meaning that conflicts can arise, and their resolution could be complex.
- Conflict resolution requires near real time communication and decision making between the DSO, ESO and actors to ensure secure and reliable operation of network.

5.2.3 World C: Price driven flexibility

- This world is concerned with a truly market led approach, which should therefore deliver value.
- There is an assumption that participants will respond to price signals (which need to be sufficiently strong) to ensure efficient network operation.
- There is also some uncertainty regarding the real-time nature (or otherwise) of the price signals.
    - If the signal is real-time (or near-real-time) then there are significant costs in establishing the infrastructure to facilitate this, but the market should deliver value.
    - If the price signals are longer-term, then it may be more difficult to manage local constraints efficiently, either leading to 'false constraints' being imposed on participants through artificially high/low price signals, or excessive risk being taken.
- This model establishes potential conflicts of interest between the physics of the network and the requirements of the market, which would need to be resolved by the DSO.
- The variable nature of the price signals could be a complex idea to message to market participants regarding local constraints, the availability of services at different times of day/year, etc.
- Significant effort is required to establish this market framework and signal to actors, however once in place, it could deliver long term value.

5.2.4 World D: ESO Coordinates

- This model is best aligned to deliver national objectives.
- This would deliver significant benefits where the flexibility is large scale, however it can overlook smaller actors with highly distributed flexibility resources.

- As per the DSO Coordinates world, there is a reasonable amount of engagement between ESO and DSO.
- Regulatory oversight would be necessary to ensure transparency in decision-making; i.e. to demonstrate that the ESO does not merely take the actions that are easiest for it to implement.
- Engagement with very small participants is challenging in this model, one solution might be that ESO retains the decision-making authority, but the information regarding these small participants is aggregated by the DSO and passed on to ESO.
- As for DSO Coordinates, there is a risk that ESO is having to take decisions to benefit DSO; i.e. expend time and effort on something that is not directly aligned with its own business goals and drivers.
- Having ESO as the sole decision-maker would lead to greater levels of consistency for market participants rather than having a range of different decision-making entities across the country.

5.2.5 World E: Flexibility Coordinators

- This model seeks to address many of the conflict resolution issues identified in World B.
- Engagement with market participants via the Flexibility Coordinator is likely to result in simpler messaging, resulting in a more responsive market
- The significant drawback in this world is the transfer of network risk and who takes responsibility for a network exceeding its limits: the question of whether this is the DSO/ESO, or the Flexibility Coordinator is a vital one and represents a potentially significant shift in the philosophy of network operation.
- Depending on how much network risk is transferred there may need to be a large amount of data processing in real time, to provide headroom and capacity limits to the Flexibility Coordinator.
- Regulatory frameworks will need to be adapted, and potentially applied to Flexibility Coordinators, to manage the transfer of network risk between parties.
- This results in clear delineation between market and network activities of ESO, DSO and Flexibility Coordinators.

5.3 Comparison of complexity of different worlds

In order to assess the relative complexity of the five different worlds, a measurement was constructed, composed of the nature of the links involved between actors, and the number of actors involved in the links.

This ‘complexity index’ is derived by taking each of the links captured during the workshops and assigning it two values which are then summed. The first value (linkage index) is concerned with the type of link and is designed to show the relative complexity in establishing such a link. For example, providing a SCADA link that facilitates the near-real-time exchange of data is inherently more complex than publishing a charging statement to several connected users.

Therefore, the following set of scores was established for linkage indices:

- Publish = 1
- Contract = 2

- Gateway = 3
- Protection = 3
- SCADA = 5

The second scoring metric is concerned with the amount of actors that the link involves: the 'replication index'. This attempts to represent the fact that if the link is to the Regulator, for example, then this is only one entity with whom the communication is occurring. However, if the link is with all customers connected to the network, then this means there are millions of instances of it that are present. This scoring metric seeks to capture the complexity associated with having to replicate the communication depending on the actors involved.

Therefore, the following set of scores was established for replication indices:

- Single actor (e.g. Regulator, Government, ESO) = 1
- <50 actors (e.g. DSO, Suppliers, Gas networks) = 2
- <150 actors (e.g. Aggregators) = 3
- <1,000 actors (e.g. Heat networks, SSP, LES) = 4
- <10,000 actors (e.g. Active Participants) = 5
- <5,000,000 actors (e.g. Active Customers) = 6
- <25,000,000 actors (e.g. Passive Customers) = 7

Using this scoring mechanism, every link that was captured at the workshops was assessed and scored by adding the linkage index to the replication index. All the links within a given world could then be summed to discover the total complexity index.

However, one further layer of granularity was added to understand whether the complexity resides with the DSO, ESO or in the interface between them. Some worlds will naturally have more responsibility (and hence complexity) falling to one or the other of these actors, and this represents a way to demonstrate this. Figure 37 below illustrates the relative complexity of the five worlds.

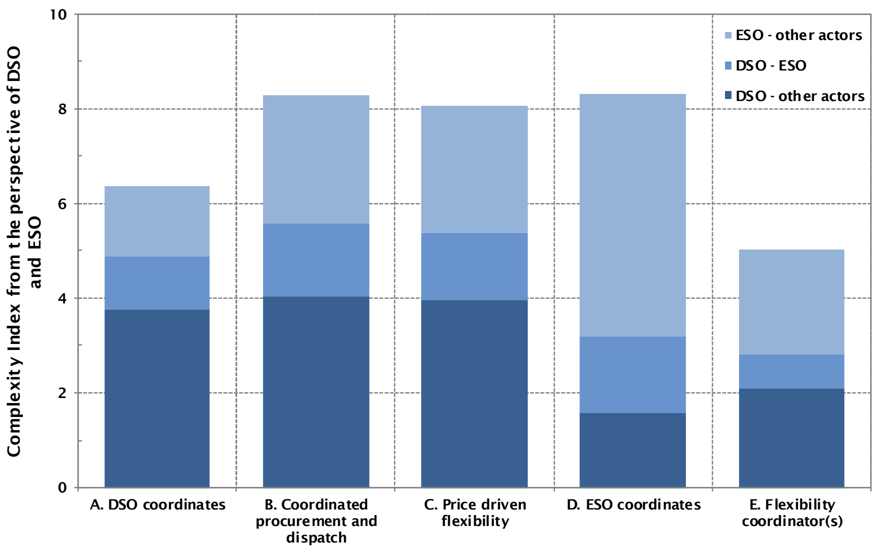


Figure 37 Relative complexity of the five DSO worlds

It can be seen in Figure 37 that the relative complexity of Worlds B, C and D are very similar. However, the split indicating where the complexity lies is quite different for World D: ESO coordinates as the ESO take son far greater responsibility than the DSO in this instance.

World A: DSO coordinates, shows the mirror of this to an extent (as one would expect), with the DSO taking the greater share of complexity. While it appears that overall this is a less complex world than some of the others, care should be taken with this particular world as it was the first to be considered by the stakeholders in the workshops. It is quite likely that as the stakeholders became more familiar with the process that they captured greater numbers of linkages for some of the latter worlds and hence there may be value in the future in reviewing this world and confirming whether there are more linkages to be added within it.

World E: Flexibility Coordinators is an interesting case as the complexity is significantly lower than other worlds. This was one of the final worlds to be considered and hence the argument that that less information was captured due to unfamiliarity is not valid here. Instead, the reason for the lower score is that the Flexibility Coordinators take on a significant amount of the responsibility (and hence the complexity) in this world. Given that the workshop sought to capture the links between DSO – others and ESO – others then the level of complexity appears reduced for the DSO and ESO, but this is not a statement that the overall 'whole system' is necessarily less complex; rather that the complexity has been transferred to a third party.

6. Fewest regrets analysis

6.1 Methodology: technical and commercial

In order to explore the potential least regrets actions and pathways that can be taken forward irrespective of the world that manifests, the information exchanges captured in the workshops were compared across all worlds to determine whether they were repeated, or whether they were unique to a particular framework.

Further to this analysis, it is important to also consider that the similarities and differences between worlds can be thought of as existing on two axes. The first of these is the technical axis or 'physics-led' concerned with the technical nature of the framework and considering the role of the DSO and ESO as a decision making body and gatekeeper of the network. The two worlds (D and A) represent opposing ends of this spectrum, being coordinated by the ESO and DSO respectively, while world B exists in the centre, with both parties jointly having responsibility.

Then there are the commercial considerations, or the 'market-led' view of worlds. In this context, one can consider a world with high levels of facilitation such as world E where Flexibility Coordinators behave in a highly active manner to facilitate the market. Alternatively, there is the low level of facilitation where it is achieved purely through the issuing of and response to price signals by the system operators. Again, in this context, world B sits somewhere centrally as it is facilitated by both DSO and ESO, but with neither necessarily having the most active role.

Figure 38 below illustrates this. It should be stressed that the fact that world B sits most centrally should not be interpreted as representing the best compromise across these axes, rather that it forms something of a hybrid that is actually very difficult to realise. (More extreme worlds towards the edges of the chart have clearer responsibilities set out amongst actors.)

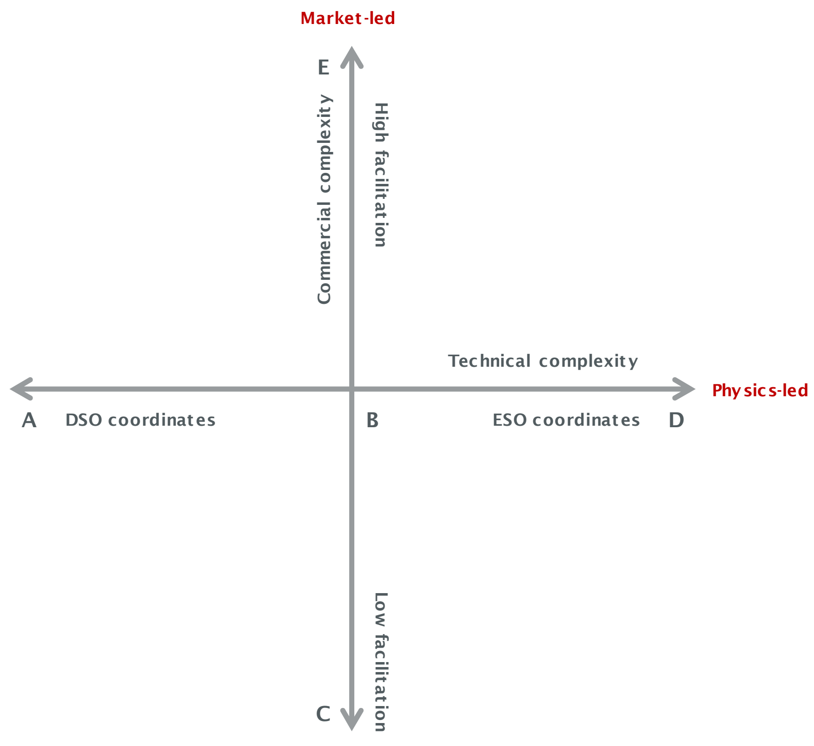


Figure 38 Comparison of worlds from technical and commercial perspectives

6.2 Areas of commonality across all worlds

As previously stated, an assessment was carried out of information exchanges within all worlds to ascertain the levels of similarity that exist and the number of areas that are unique to different worlds. Information exchanges were assessed in lieu of individual process steps to prevent minor mismatches in the order process steps were captured in workshops skewing the fewest regrets analysis. This analysis is helpful in understanding whether following a particular pathway will ‘box in’ the approach and make it difficult to move to an alternative framework, or whether frameworks are broadly compatible and can be switched between without excess work and investment being sunk and the value not realised.

Figure 39 below shows the proportion of the information exchanges within each world that are unique to that one world; i.e. that the relationship transferring that particular information object between actors was not also found in any other world when the workshops were carried out. It should again be noted that these figures are indicative rather than absolute because workshop participation varied from one world to the next and hence individual perspectives can be slightly different. As far as possible, the various means of capturing the linkages and exchanges have been rationalised into a common language as part of this project, but some variation will always exist.

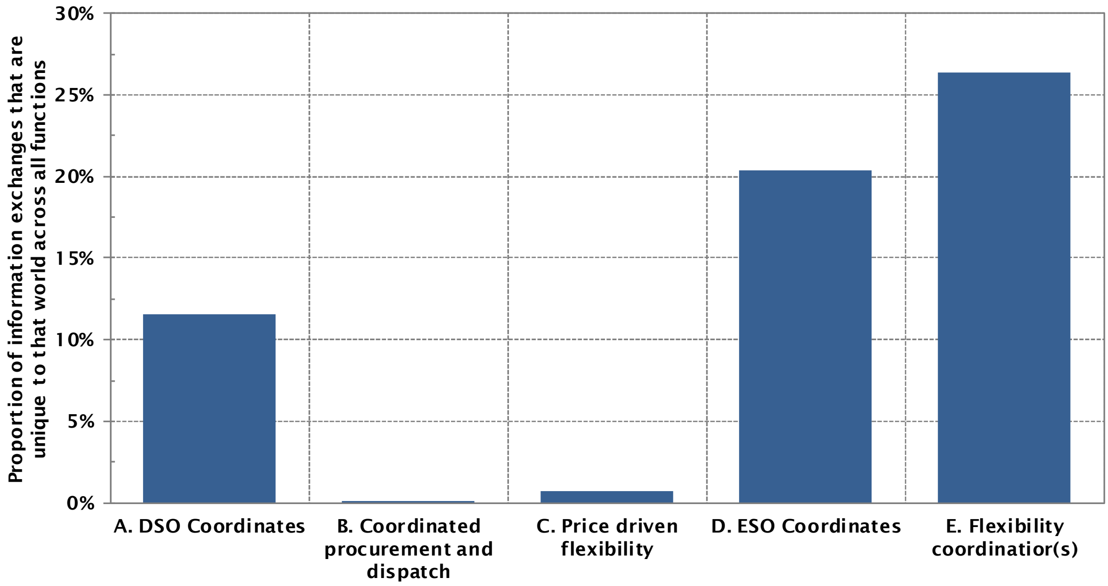


Figure 39 Proportion of links that are unique to that world

It can be seen in Figure 39 that worlds D and E have approximately 20 – 30% of their information exchanges unique to that one world while a little over 10% of exchanges in world A are not found in any other world. Worlds B and C however have very few unique exchanges by comparison and this illustrates the large amount of overlap that exists between these two worlds.

The following chart (Figure 40) goes one stage further and illustrates the level of similarity between all world combinations. The height of the bars represents the proportion of information exchanges in the given world that are also found in the other respective worlds. Each world has four bars associated with it, representing the alternate four worlds while the fifth bar is missing (as this corresponds to the world under consideration).

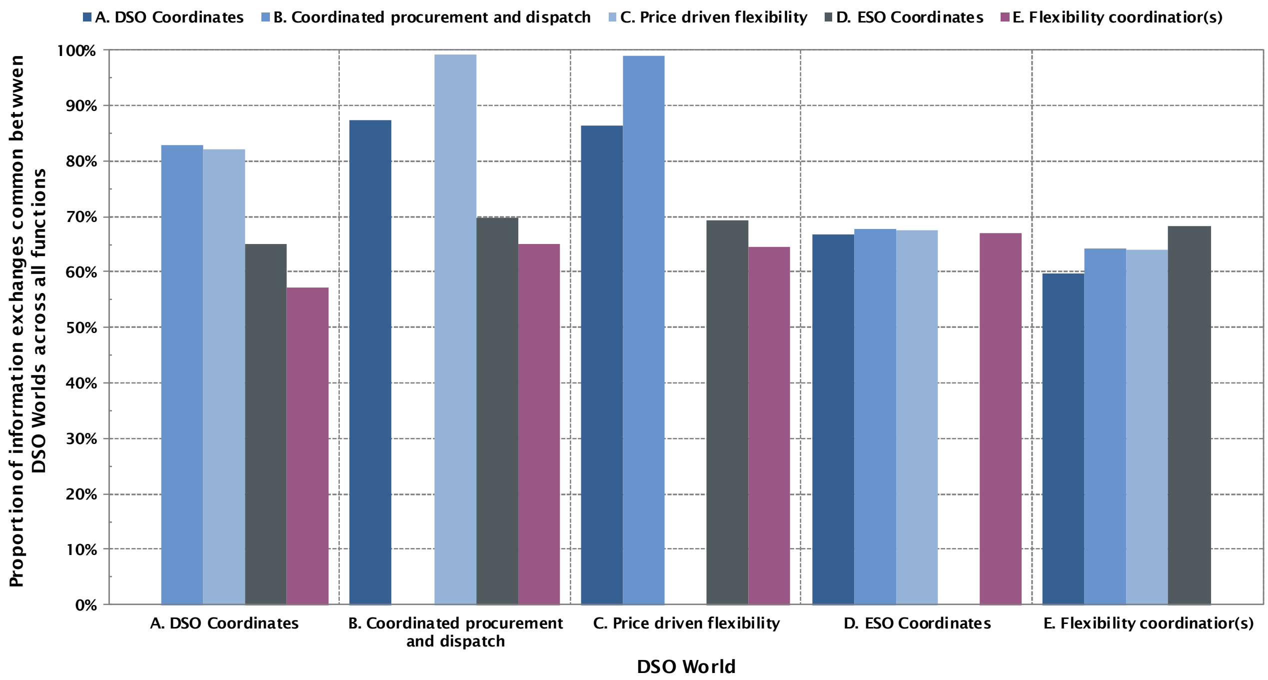


Figure 40 Level of similarity between worlds

As previously stated, there is a very high degree of overlap between worlds B and C, which is clearly indicated here. High levels of overlap are also present between worlds A, B and C with worlds D and E being somewhat more outlying.

Table 15 below quantifies this to aid the reader in identifying the actual amount of overlap where it may be difficult to discern from the chart above. The table illustrates the level of correlation between any two worlds by showing what proportion of the links found in any given world can also be found in any other given world. The table is asymmetric (e.g. if looking along the top to world A and comparing this down the side with world B, there are 82% of information exchanges that are similar, but if taking world B along the top and comparing with world A, there are 87% of identical exchanges). The reason for this is that the absolute number of information exchanges in world A is different from world B, resulting in slightly different proportions. However, percentage figures are presented here rather than absolutes to allow a fairer comparison. For example, world A had fewer information exchanges captured in the workshops than many other worlds so would skew the figures if they were presented in absolute terms.

The cells are colour coded to illustrate the amount of correlation that exists for each pair of worlds.

Table 15 Level of commonality between pairs of worlds

DSO World	A	B	C	D	E
A		87%	86%	67%	60%
B	83%		99%	68%	64%
C	82%	99%		68%	64%
D	65%	70%	69%		68%
E	57%	65%	65%	67%	

6.3 Likely least regrets actions

There are a considerable number identical of information exchanges that occur across all worlds. This is no surprise given that irrespective of which DSO world is realised the problems that the future electricity network will face – as identified today – are the same. Consequently, approximately 31%

of information exchanges have been identified as common across all 5 worlds. These information exchanges constitute our least regrets actions that may be taken in the near-term before the DSO worlds begin to diverge as illustrated in Figure 41.

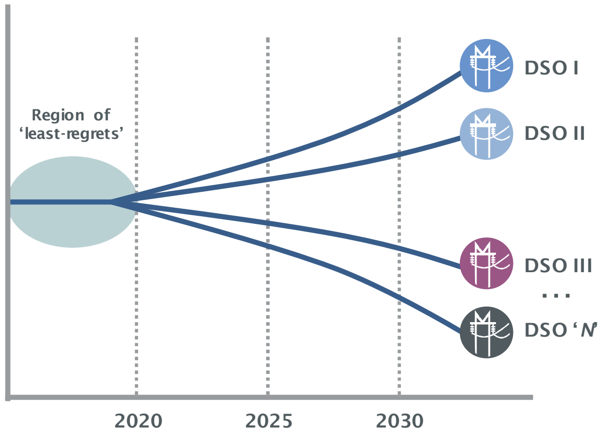


Figure 41 Illustrative example of least regrets

The most common actors present within the least regrets actions are DSO, ESO and Regulator; illustrating the fact that the areas of commonality tend to be aligned with ensuring the achievement of national (or whole-system) objectives and are largely concerned with the development of frameworks that underpin and support this. For example, they are concerned with processes to ensure efficient whole system planning and robust emergency response procedures (e.g. black start).

By its nature, network operation and more day-to-day issues vary more widely across the different worlds and hence there are fewer least regrets actions that occur within these business functions, clearly illustrating the bias towards longer-term actions (planning timescales rather than operational timescales).

Figure 42 further illustrates the least regrets actions grouped by DSO function. Each function will now be briefly examined in turn.

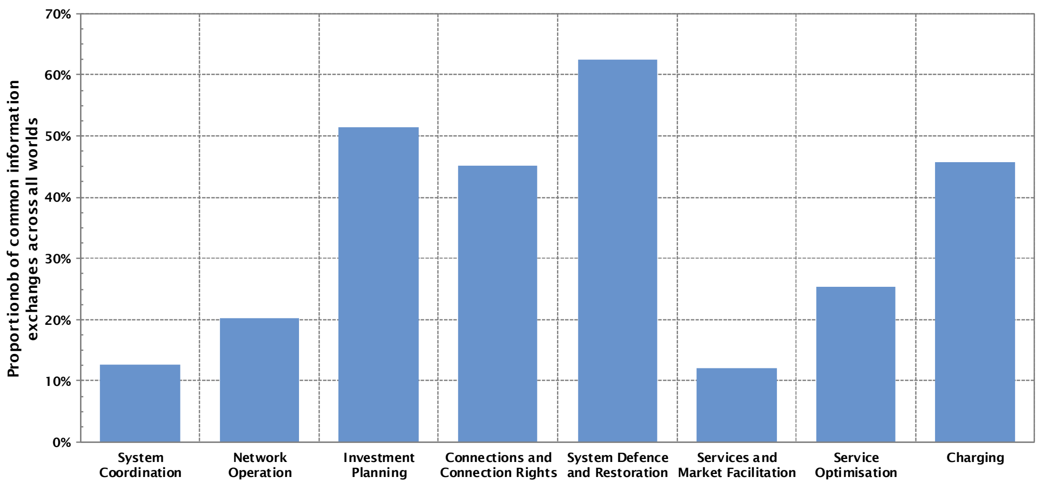


Figure 42 Fewest regrets actions by function

System Coordination

Approximately half of least regrets actions within the System Coordination function concern the exchange of information between the DSO and ESO for the purpose of coordinated outage planning as set out in process "T&D boundary information exchange". Further common actions include consultation on regulatory frameworks for flexibility service provision, and requirements for flexibility to comply with activation/dispatch signals.

Network Operation

Network operation least regrets can be categorised as actions occurring in the day-to-day running of the transmission or distribution networks, or as actions taken as part of network planning. Day-to-day actions include the real-time monitoring of the network in order to send out information on thermal and voltage excursions, and to activate mitigation mechanisms such as the dispatch of flexibility services. At the planning stage, the process "Development of network dynamic stability mechanisms" has been identified as containing a large number of least regrets actions and will be enacted between the DSO, ESO and Regulator well in advance of real-time network operation. In addition, as with the System Coordination function, many least regrets actions are for the purpose of outage planning; specifically outage requests.

Investment Planning

The majority of least regrets actions with the Investment planning function fall within the "Traditional investment planning" activity. Many of these actions may be considered as business as usual and will not be considered further. Remaining least regrets actions have a regulatory focus and set up network security and quality of supply design and planning standards.

Connections and Connection Rights

The cornerstone of the least regrets actions identified with the Connections and Connection Rights function involve coordination between the DSO, ESO and Regulator for the development of standard connection agreements with provision for the connection of flexibility resources. Remaining common actions in this function implement the revised framework, provide for modifications to existing connections, and allow for the recovery of unused network connection capacity by the system operator.

System Defence and Restoration

This function possesses the greatest commonality across all five worlds which may be expected as market arrangements (which are one of the greatest areas of divergence across the worlds) do not have a strong presence within System Defence and Restoration activities. There are high levels of least regret actions within the "Black start", "Resilience (Islanding)" and "Resilience (Voltage Reduction, LFDD, HFGD)" activities which discuss arrangements under market failure. The primary difference in the resilience activities are minor and revolve around the involvement of the Flexibility Coordinator actor in world E.

Services and Market Facilitation

At 12%, this function is the most divergent across the five worlds. The areas of commonality within Services and Market Facilitation are in the requirements: to define a Price Control Model for distribution network connected flexibility resources; to assess requirements for flexibility services; procure and active flexibility services; and to create a regulatory framework for conflict mitigation and resolution.

Service Optimisation

Most of the least regrets in the Service Optimisation function are within the "Conditions/process of market failure" activity which requires the development of the regulatory framework governing market failure, provision for the activation of last resort measures such as voltage reduction, and the development of emergency assistance services through smart grid solutions or other means. This function also separately sets out: the creation of a regulatory framework for last resort service provision which will have scope to allow distribution connected flexibility resources to provide last resort services; and steps for the initial development and use of smart grid flexibility solutions.

Charging

In the Charging function approximately 46% of actions are least regrets across all worlds. The largest part of these are the contractual arrangements between parties which facilitate the exchange of information necessary to determine various network charges. Across all five worlds the arrangements for Use of System charges, T-network exit charging and access charges for flexibility resources remain common while other charging arrangements such as those around network infrastructure development/reinforcement are more divergent.

6.3.1 Least regrets across less than five worlds

The greater the number of worlds that are considered, the fewer common areas one finds. For example when all five worlds are analysed 31% of actions can be found in each world, but when we look for commonality across a subset of only three worlds then the amount of overlap increases significantly, as is shown in Figure 43 which gives the intuitive result that when only a single world is being developed, all actions are least regrets. However, in order to derive additional least regrets there needs to be timely agreement of the likely worlds that will be taken forward in the longer term. We expect this to be informed by the Economic Impact Assessment (Cost Benefit Analysis) and by innovation trials, which will assist in determining the feasibility of different frameworks.

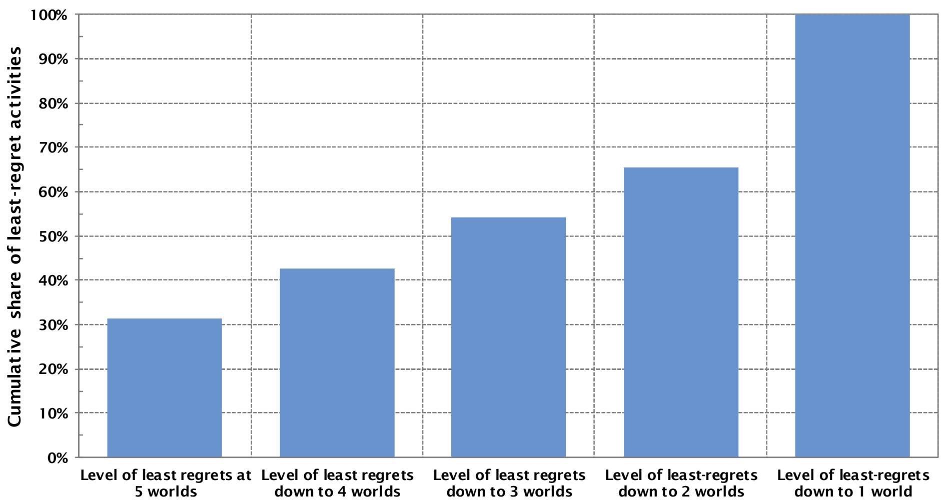


Figure 43 Increased commonality across fewer worlds

7. Localised issues

7.1 National objectives and local objectives

In order to understand the part that localised issues will play and the need for potentially different models in different regions, it is important to understand which actors are concerned with 'national' objectives and which with 'local' objectives.

For example, local energy systems (LES) are, by their nature, highly localised and will be trying to achieve different objectives from each other. Their drivers might be non-rational (economically). For example, they might be looking to improve air quality, or minimise carbon footprint of a community. The achievement of such 'non-financial' goals can therefore be challenging when considering these actors providing flexibility services to the market and how the provision of such services may be weighted and judged by the market operator (e.g. the Flexibility Coordinator).

Other actors have more national interests and will be seeking consistency in approach. Examples of this include ESO and gas networks, but this is not to say that they will not also be concerned with the delivery of local objectives. Hence while some actors will retain a solely local focus, others will have a range of business drivers to ensure they meet both local and national objectives.

It should be noted that some actors, while they may exist locally, actually have common objectives and hence will act more in the national interest. For example, Passive Customers will have common objectives in that they merely want low cost, reliable energy supply and do not wish to engage in the market. Their objective is therefore common across all such actors nationwide hence they can be thought of as being a single large actor concerned with a national objective.

Active Customers on the other hand could be local and national. They may well have a more local interest (trying to maximise their financial return), but need national consistency to ensure that they are not disadvantaged in comparison with their peers depending on location; i.e. a customer in south-east England should have the same opportunities as one in Scotland.

System Service Providers (SSP) can also vary where they act. Those SSP who manage a large portfolio have national interest whereas smaller players (such as farmers with single turbines) are concerned with achievement of more local objectives.

Most of the least regrets actions listed in the above section are more 'national' interest (relating to DSO – ESO – Regulator) whereas other actions relating to LES etc are more varied across the worlds (meaning that there is less commonality associated with more local objectives).

There is a need to consolidate on simple messages for the likes of active customers so as to ensure fairness and transparency. A high priority should be the requirement to avoid customer confusion in different areas through non-compatible frameworks. There are several examples of initiatives that vary on a highly local basis (council by council) such as recycling schemes that have the possibility to cause confusion for customers and LES providers.

7.2 Impacts on DSO model adoption

Regional drivers (from legislation etc) could lead to different behaviours and requirements, potentially even for the same company. As an example, different targets in Scotland to England and Wales would lead to different responses for SP Energy Networks in their SPD licence areas (in Scotland) in comparison with their SPM licence area (in England and Wales). Similarly, UKPN's approach in London where targets will be driven by mayoral ambitions is likely to differ significantly from the EPN region in East Anglia which has very different demographics, drivers and objectives.

Localised issues will emerge where there are devolved administrations (such as metropolitan mayors) which will drive different issues in areas such as London, Birmingham, Manchester, Liverpool etc. This will need to be taken into consideration by individual DSO businesses who will need to ensure that the model that they seek to adopt is compatible with the achievement of these local objectives and is non-prejudicial in the way it treats system service providers who are attempting to meet these local objectives, but may not operate on the same level as larger service providers who are seeking to alleviate national issues. Any potential conflicts between these two groups will need to be carefully managed and this may pose a challenge for whomever the decision-making body is (ESO, DSO or Flexibility Coordinator) regarding the order in which to dispatch services to ensure alignment between these local and national objectives is achieved.

It seems highly unlikely there will be fundamentally different market structures in different areas; much more likely is an overarching national market. Within this analysis we are considering different market structures, which are more incompatible with each other than the sorts of scenarios that are often considered for future strategy within the DSO sector. Market frameworks are more mutually exclusive than potential uptake rates for DER, for example, meaning that while different DSOs will have different approaches, it is far more likely that they will fit into some overall ‘umbrella’ market structure rather than have vastly differing approaches in this regard.

Clearly there will be local drivers that will be experienced (such as the metro-mayors point previously referenced) and there will always be edge-cases which may require special treatment. Through further trialling and research in innovation projects, it will be possible to explore the ways in which these various frameworks can support the successful delivery of the DSO transition and supporting the whole system by examining specific trial areas and conditions.

8. Conclusions

The key findings of the analyses performed by EA Technology can be summarised as follows:

- An in-depth approach to analysis of the different worlds is important as it uncovers hidden details that were previously not considered. This is evidenced by participant comments at the workshops.
- This work is not seeking to identify the 'optimal' framework, but to recognise that some models are more complex to implement and present a larger step change from the status quo
- The level of commonality between the five worlds is considerable, meaning that there are a number of fewest regrets actions which could be progressed with minimal risk.
- Many of the areas of commonality that exist tend to focus on the establishment of high level processes and regulatory frameworks and are found in longer-term planning timescales rather than in operational timescales.
- Different actors are attempting to achieve a range of local and national objectives and the alignment of these objectives can cause conflict and need to be carefully managed and considered as part of any framework
- The five SGAM models in Enterprise Architect provide the basis for refinement and further development as learning increases and viable options are narrowed
- The level of detail necessary to model the lowest layers of SGAM means that it is best to embark on this task once there is greater certainty regarding the likely market frameworks and the existing five worlds have been condensed to a smaller number.
- HTML versions of the SGAM models have been made available to facilitate dissemination and to support the stakeholder consultation, avoiding the need for users to have the Enterprise Architect software

Appendix I Definition of actors and goals

Actors

Acronym	Description
ESO	National Electricity Transmission System Operator
TO	Transmission Owner
TG-SS	Transmission connected Generation providing System Services
TD-SS	Transmission connected Demand providing System Services
DNO/DSO	Distribution Network Operator/Distribution System Operator
Energy Supplier	Energy Supplier
Aggregator	Energy Aggregator
SSP	System Service Providers
AP	Active Participant
LES	Local Energy Systems
AC	Active Customer
PC	Passive Customer
Gas	Gas energy resources
GSO	Gas System Operator
Heat	Heat energy resources
NEWSAC	North East West South Area Consortium
Regulator	Energy Regulator (Ofgem)
Central Govt	Central Government (BIES)
Local Govt	Local Government
SA	Settlement Agent
Supply Chain	Supply Chain
DCC	Data Communications Company
FC	Flexibility Provider
IDSO	Independent Distribution System Operator
CPP	Customer Protection Party
LMO	Local Market Operator
IDSO	Independent Distribution System Operator

Electricity System Operator

Electricity System Operator

Electricity System Operator

Actor	Definition	Goals
ESO	The ESO is responsible for the operation of the electricity transmission system by balancing electricity supply and demand, ensuring the stability and security of the electric power system, maintaining satisfactory voltage and frequency profiles and managing transmission network constraints.	• Coordinate whole system security through defence and restoration plans • Provide fair and cost-effective transmission network access for customers • Coordinate with T- and D- network owners and DSOs to assess and decide on whole system investment options • Facilitate markets to provide services through the operation of market arrangements. Provide data / information to facilitate markets and service provision • Set and administer Connection and Use of System charges for parties connecting to and using the GB electricity transmission system. • Procure services from T- and D-network connected flexibility resources and potentially from T- and D-networks • Act as residual balancer for the GB electricity transmission system

Transmission Owner

Transmission Owner

TO

Actor	Definition	Goals
TO	The TO is responsible for investing, building and maintaining the electricity transmission network. The TO provides network customers with a safe, secure and reliable network ensuring they receive high-quality network services at value for money. The TO takes advantage of the opportunities brought by smart grid technologies and an active distribution network management approach to deploy smart network solutions that enable the provision of a range of flexibility services (e.g. transmission flexible AC transmission systems (FACTS); special protection schemes (SPS), etc.).	• Invest, build and maintain the electricity transmission network • Deliver a safe, secure and reliable transmission network to network customers • Provision of flexibility services through smart transmission network based solutions

Transmission Generation – System Services

Transmission Generation – System Services

TG-SS

Actor	Definition	Goals
TG-SS	TG-SS are large scale electricity generators (e.g. nuclear, gas powered or coal fired power stations, etc.) directly connected to the transmission network that support the ESO balancing supply and demand and managing transmission network constraints (e.g. energy imbalance actions and system imbalance actions). TG-SS act as a source of flexibility to the ESO by making additional volumes of electricity available or by reducing the volumes of electricity being generated. TG-SS are offered as flexibility services to the ESO.	• Establish a commercial relationship with the ESO to derive revenue from the provision of flexibility services for electricity system balancing

Transmission Demand – System Services

Transmission Demand – System Services

TD-SS

Actor	Definition	Goals
TD-SS	TD-SS are large scale sources of demand (e.g. industrial demand such as steelworks, refineries, etc.) directly connected to the transmission network that support the ESO balancing supply and demand and managing transmission network constraints. TD-SS act as a source of flexibility to the ESO by reducing demand to make additional volumes of electricity available or by increasing demand to reduce reducing the volumes of electricity being generated. TD-SS are offered as flexibility services to the ESO.	• Establish a commercial relationship with the ESO to derive revenue from the provision of flexibility services for electricity system balancing

Distribution Network Operator/Distribution System Operator

Distribution System Operator

DSO

Actor	Definition	Goals
DSO	"A Distribution System Operator (DSO) securely operates and develops an active distribution system comprising networks, demand, generation and other flexible distributed energy resources (DER). As a neutral facilitator of an open and accessible market it will enable competitive access to markets and the optimal use of DER on distribution networks to deliver security, sustainability and affordability in the support of whole system optimisation. A DSO enables customers to be both producers and consumers; enabling customer access to networks and markets, customer choice and great customer service" Ref.: "Agreed in Principle & Updated 02/06/17 – DSO Definition and R&R", Energy Networks Association.	• Operate the electricity distribution network to maintain a safe and secure system • Coordinate and collaborate with ESO to support whole system optimisation • Enhance whole system security through the provision of local flexible services • Provide fair and cost-effective distribution network access that meets customer requirements and system needs efficiently • Coordinate with the ESO and T-network owners to identify and assess whole system investment options (including commercial DER and D-network investment options) • Facilitate markets to provide services through the operation of market arrangements. Provide data / information to facilitate markets and service provision • Interface with the ESO to enable: the development of distribution capacity products; the creation of local network service markets; and the participation of distribution connected flexibility resources in wider balancing services for whole system optimisation • Set Distribution Use of System prices for local network, determines Point of Connection, determines connection charges, informs connectees of Transmission reinforcement charges, where appropriate and considers the impact of Exit Charging • Access to services on behalf of other stakeholders (e.g. ESO, adjacent and other DSOs) or provide services to other stakeholders, conditional to maximising whole system efficiency and protecting competition • Operate local and regional balancing areas for whole system optimisation

Energy Supplier

Energy Supplier

Energy Supplier

Actor	Definition	Goals
Energy Supplier	An energy supplier is a company that buys electricity in the wholesale market or directly from generators and sells it on to end use electricity consumers. The supplier sets the prices that consumers pay for the electricity that they use. Suppliers work in a competitive market and customers can choose any supplier to provide them with electricity.	• Buy and sell electricity from and to customers to derive revenue from the provision of high quality energy services at value for money to customers

Aggregator

Aggregator

Aggregator

Actor	Definition	Goals
Agg	An aggregator is a company who acts as an intermediary between electricity end-users, DER owners and the power system participants who wish to serve these end-users or exploit the services provided by these DER. The aggregator groups distinct agents in the electric power system (i.e. consumers, producers, prosumers, or any mix thereof) to act as a single entity when engaging in power system markets (both wholesale and retail) or selling services to system operators (e.g. ESO, DSO, etc.).	• Establish commercial relationship with the ESO and the DSO to derive revenue from the provision of flexibility services for electricity system balancing and D-network constraint management through the optimisation of a portfolio of smaller network customers

System Service Providers

System Service Providers

SSP

Actor	Definition	Goals
SSP	SSP are small-scale power generation technologies (typically in the range of 11kW to 10MW and including electric energy storage facilities) and larger end use electricity consumers (e.g. industrial and commercial) with the ability of flexing their demand as part of their business (i.e. demand side response) that are directly connected to the electricity distribution network. SSP provide flexibility services to system operators (e.g. ESO, DSO, etc.) for electricity system balancing and network constraint management. SSP may enter into bilateral contracts with system operators for system support services. Ref.: "**Customer A: System Service Providers**". ON-PRJ-WS1-P1-Customer Category Description, ENA.	• Establish commercial relationship with the ESO and the DSO to derive revenue from the provision of flexibility services for electricity system balancing and T- and D-network constraint management

Active Participant

Active Participant

AP

Actor	Definition	Goals
AP	AP are small-scale power generation technologies (typically in the range of 11kW to 10MW and including electric energy storage facilities) and larger end use electricity consumers (e.g. industrial and commercial) with the ability to flex their demand (i.e. demand side response) that are directly connected to the electricity distribution network. AP participate in the wholesale electricity market and/or local electricity markets. Accordingly, AP may enter into bilateral contracts with energy suppliers and other relevant parties for the provision of energy services. Ref.: "**Customer B: Active Participant**". ON-PRJ-WS1-P1-Customer Category Description, ENA.	• Establish commercial relationship with energy suppliers and other relevant parties to derive revenue from the provision of energy services to the wholesale electricity market

Local Energy Systems

Local Energy Systems

LES

Actor	Definition	Goals
LES	LES aim to match energy supply and demand within a defined geographical area via peer-to-peer trading / local energy market to the benefit of its participants (e.g. communities, companies, individuals). LES participants to provide each other with energy and trade out the aggregate 'balance' in the wholesale electricity market. LES can provide flexibility services to electricity system operators (e.g. ESO, DSO) for electricity system balancing and T- and D-network constraint management. LES generally include distributed generation customers, demand side management, end-use prosumers and end-use consumers. LES incorporate innovative energy distribution, management and metering, novel business models and can include clean transport systems as well.	• Peer-to-peer trading / local energy market between customers to match local energy supply and demand. The surplus electricity is traded in the wholesale market and/or offered as flexibility services for system support to derive revenue

Active Customer

Active Customer

AC

Actor	Definition	Goals
AC	Active customers represent domestic or smaller non-domestic end-use electricity customers that are energy conscious and therefore have invested in off-the-shelf low carbon technologies to derive revenue from renewable energy schemes, to reduce their overall costs or for social responsibility reasons. Generation or demand is unlikely to be actively managed and is installed on a passive 'fit and forget' basis. Low carbon technology equipment includes solar panels, heat pumps, electric vehicles, electric battery storage. These customers are likely to be exporting to and importing from the D-network and would seek to benefit from supplier's time of use tariffs. Ref.: "**Customer C: Active Customer**". ON-PRJ-WS1-P1-Customer Category Description, ENA.	• To be supplied with safe, secure and reliable electricity with high quality of service and at value for money

Passive Customer

Passive Customer

PC

Actor	Definition	Goals
PC	Passive customers represent domestic or smaller non-domestic end-use electricity customers with little or no interest in low carbon technology based products and flexible energy market services. Passive customers include end-user electricity customers in social housing with or without access to a community energy supply contract via their landlord. Ref.: "**Customer D: Passive Customer**". ON-PRJ-WS1-P1-Customer Category Description, ENA.	• To be supplied with safe, secure and reliable electricity with high quality of service and at value for money

Gas

Gas

Gas

Gas System Operator

Actor	Definition
Gas	Gas represents an energy system from which useful gas energy resources can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. conversion of natural gas and derivatives into chemical energy). The gas energy vector makes this energy available for use away (time and space) from its source.
GSO	The Gas System Operator's key responsibilities are residual gas balancing and system balancing.

Heat

Heat

Heat

Actor	Definition
Heat	Heat represents an energy system from which useful heat energy resources can be extracted or recovered either directly or by means of a conversion or transformation process (e.g. conversion of heat exchanging fluids into thermal energy). The heat energy vector makes this energy available for use away (time and space) from its source.

North East West South Area Consortium

North East West South Area Consortium

NEWSAC

Actor	Definition	Goals
NEWSAC	NEWSAC is a mutual aid consortium formed by all distribution system operators. In an emergency, affecting one or more member companies, the NEWSAC group representatives assesses the availability of resources (e.g. skilled resources, such as linesmen and engineers) from those companies least affected and agree the allocation of these resources based on the level of damage.	• To offer mutual aid across distribution system operators, through the sharing of resources, under severe weather emergencies • To deliver network operational reediness to ensure that as an industry the impact of severe events on customers is minimised

Regulator (Ofgem)

Regulator (Ofgem)

Regulator

Actor	Definition	Goals
Regulator	The energy regulator is responsible for regulating the electricity industry. The energy regulator carries out functions to protect the interests of current and future consumers of electricity supplied by authorised suppliers, wherever appropriate by promoting effective competition between persons engaged in, or in commercial activities connected with, the generation, transmission, distribution or supply of electricity. The electricity regulator works closely with industry in carrying out its functions such as licensing electricity suppliers, generators, transmission and distribution, setting the levels of return which the monopoly networks companies can make and deciding on changes to market rules.	• To regulate the electricity industry • To deliver government schemes • To promote value for money to customers • To promote security of supply and sustainability • To supervise and develop markets and competition

Central Government (BEIS)

Central Government (BEIS)

Central Govt

Actor	Definition	Goals
BEIS	The department of energy is responsible for the design and implementation of national energy policy that delivers secure, clean and affordable energy supplies.	• To deliver a secure and resilient national energy system • To deliver secure low-carbon energy at the least cost to consumers, taxpayers and the economy • To reduce carbon emissions cost-effectively • To secure ambitious international action on climate change • To manage the nation's energy legacy safely and responsibly

Local Government

Local Government

Local Govt

Actor	Definition	Goals
Local Govt	Local Authorities and Local Enterprise Partnerships (LEP) are formed by a variety of stakeholders such as employers, landlords, policy-makers, energy consumers and energy generators. They promote the social, economic and environmental well-being of their community. They participate in the implementation of national energy policy that delivers secure, clean and affordable energy supplies through the application of measures that reduce energy use, promote the extensive use of renewable sources and tackle fuel poverty.	• To deliver secure low-carbon energy at the least cost to consumers, taxpayers and the economy • To reduce carbon emissions cost-effectively

Settlement Agent

Settlement Agent

Actor	Definition	Goals
SA	The SA is responsible for managing the settlement of payments to and from flexibility service providers. The SA collects, validates, processes and aggregates metered data from service provides (generation and demand based services); sets up and maintains the systems that allow to collect, securely store, and securely transmit the data necessary for settlement process; manages the settlement of payments by flexibility service providers; calculates payments and charges; and invoices and collects payments due.	• To operate and manage the system that enable settlement of payments to and from flexibility service providers

Supply Chain

Supply Chain

Supply Chain

Actor	Definition	Goals
SC	SC is a technology provider that designs, manufactures and supplies equipment and devices.	• To design, construct and supply products that comply with legal requirements when first placed on the market or put into service and that can be used safely and without harm.

Data Communications Company

Data Communications Company

DCC

Actor	Definition	Goals
DCC	The DCC is responsible for establishing and managing the data and communications network that connects smart meters to the business systems of energy suppliers, network operators and other authorised service users of the network. The DCC is a monopoly company regulated by the energy regulator.	• To establish and manage the smart metering data and communications infrastructure • To operate consistently for all consumers regardless of their energy supplier • To provide smart metering data to network operators in support of smart grids • To ensure smart meters send the right information to enables accurate customer bills • To allow authorised third parties to provide services to consumers who have granted them permission to use their data. Consumers can benefit by receiving energy services and advice on how to reduce their energy usage

Flexibility Coordinator

Flexibility Coordinator

Flexibility Coordinator

Actor	Definition	Goals
FC	World E requires the creation of a new role of Flexibility Co-ordinator. The FC is the responsible party for the management of the central hub(s) at which system operators request flexibility services and service providers offer their products. In this world the FC would be responsible for management of conflict of services. Whilst this actor could be a national monopoly party, there could also be regional flexibility co-ordinators.	• To establish and operate the central hub required to procure and activate balancing and ancillary services. • To manage the rules and obligations around this process. • To be a neutral facilitator

Independent Distribution System Operator

Independent Distribution System Operator

Actor	Definition	Goals
IDSO	An IDSO is a network company licensed by the energy regulator to own, develop, operate and maintain (including fault repair service) local electricity distribution networks. IDSO networks are directly connected to the DSO networks or indirectly via another IDSO. IDSOs are regulated in the same way as DSOs, however, the IDSO licence does not have all the conditions of a full DSO licence.	• Operate the electricity distribution network to maintain a safe and secure system • Coordinate and collaborate with other system operators to support whole system optimisation • Enhance whole system security through the provision of local flexible services • Provide fair and cost-effective distribution network access that meets customer requirements and system needs efficiently • Coordinate with the other network organisations to identify and assess whole system investment options (including commercial DER and D-network investment options) • Facilitate markets to provide services through the operation of market arrangements. Provide data / information to facilitate markets and service provision • Interface with the ESO to enable: the development of distribution capacity products; the creation of local network service markets; and the participation of distribution connected flexibility resources in wider balancing services for whole system optimisation • Access to services on behalf of other stakeholders (e.g. ESO, adjacent and other DSOs) or provide services to other stakeholders, conditional to maximising whole system efficiency and protecting competition • Operate local balancing areas for whole system optimisation

Customer Protection Party

Customer Protection Party

Actor	Definition	Goals
CPP	A Balance Responsible Party (BRP) is responsible for actively balancing supply and demand for its portfolio of Producers, Aggregators, and Prosumers. A BRP is contracted by the Supplier. In principle, everyone connected to the grid is responsible for his individual balance position and hence must ensure that at each settlement the exact amount of energy consumed is somehow sourced in the system, or vice versa in case of energy producton. The Prosumer's balance responsibility is generally transferred to the BRP, which is contracted by the Supplier. Hence the BRP holds the imbalance risk on each connecton in its portolio of Prosumers.	• Ensure the consumer impact is considered through the industry change process • Promote consumer value in industry discussions • Provide consumer advice and support to other actors • Ensure appropriate consumer protection arrangements are in place

Local Market Operator

Local Market Operator

Local Market Operator

Actor	Definition	Goals
LMO	The LMO is a third party actor responsible for building and operating flexibility platforms at the request of a system operator. These could be for specific products or geographic areas. They are neutral parties with responsibilities limited to the design and operation of the platforms requested.	• To design and build flexibility platforms to the request of a system operator(s) • To operate flexibility platforms as requested by the relevant system operator(s) • To provide transparent market information on their platform. • To ensure their platform is compatible with other flexibility service portals. • To meet all compliance obligations.

Appendix II Appendix II SGAM and the Enterprise Architect

The Enterprise Architect models for each world have been converted to HTML for accessibility. Links to each of these can be found at:

https://modela.eatechnology.com/
https://modelb.eatechnology.com/
https://modelc.eatechnology.com/
https://modeld.eatechnology.com/
https://modele.eatechnology.com/

To support the navigation and interpretation of these models there is a Quick Start Guide (video tutorial - https://youtu.be/bzzw5hbCuTM). The full User Guide, which provides information for three user levels: Viewer, Editor or Developer, is available at https://www.eatechnology.com/engineering-projects/open-networks-project/

In order to make it easier for stakeholders to view the worlds from the point of view of the actor in which they are interested, additional diagrams were created for the landing page. The following diagrams are taken from the landing pages of the HTML models. They show all of the actors involved and the main and differentiating information and contractual links between them.

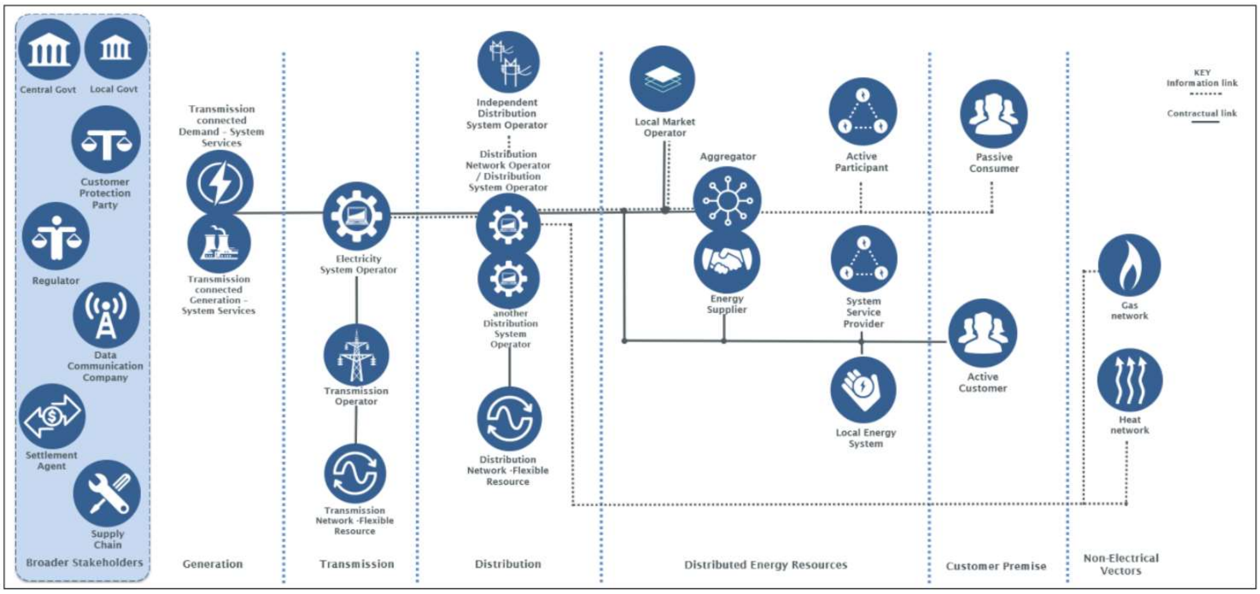


Figure 44 'World A – DSO Coordinates' landing page diagram

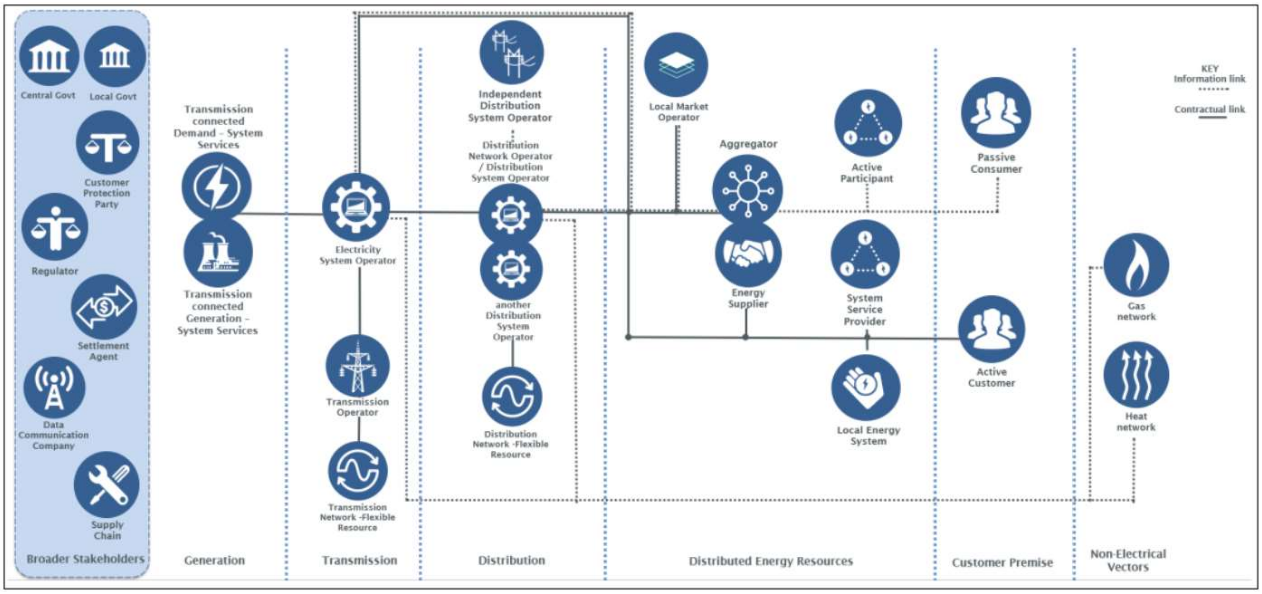


Figure 45 'World B – Coordinated Procurement and Dispatch' landing page diagram

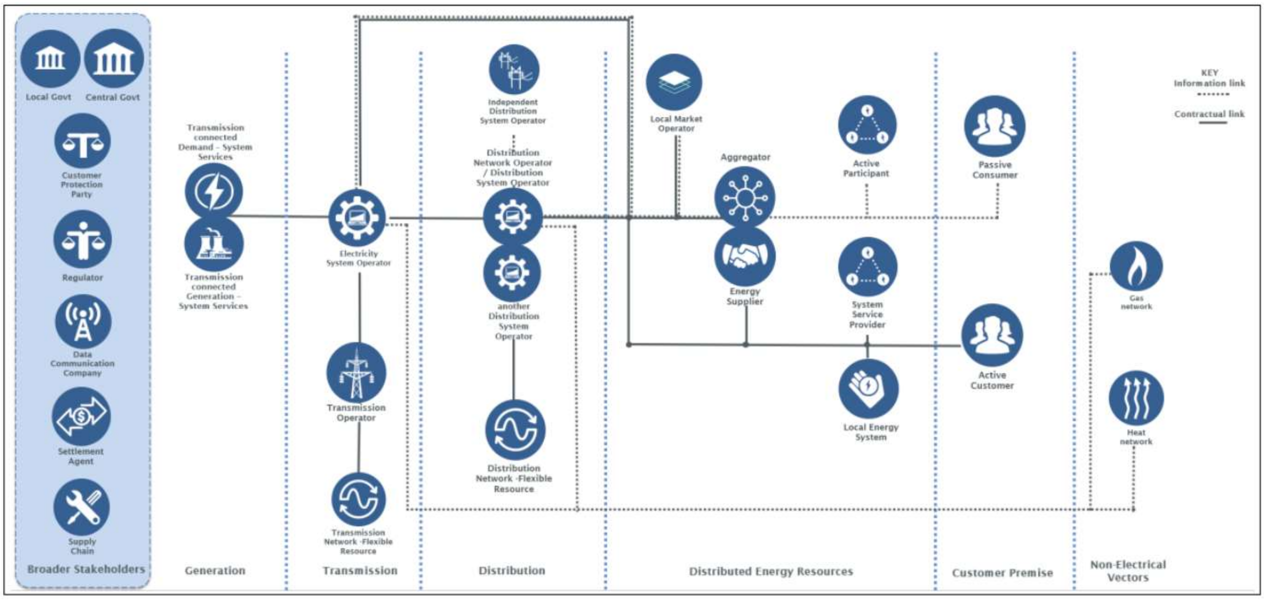


Figure 46 'World C – Price Driven Flexibility' landing page diagram

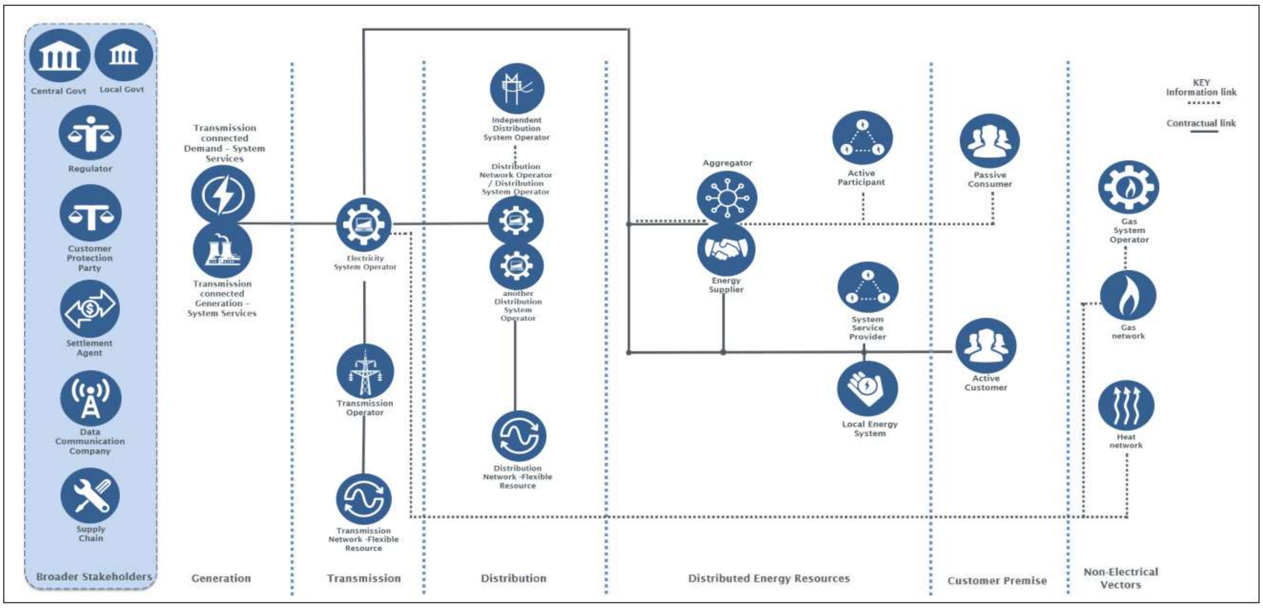


Figure 47 **'World D – ESO Coordinates' landing page diagram**

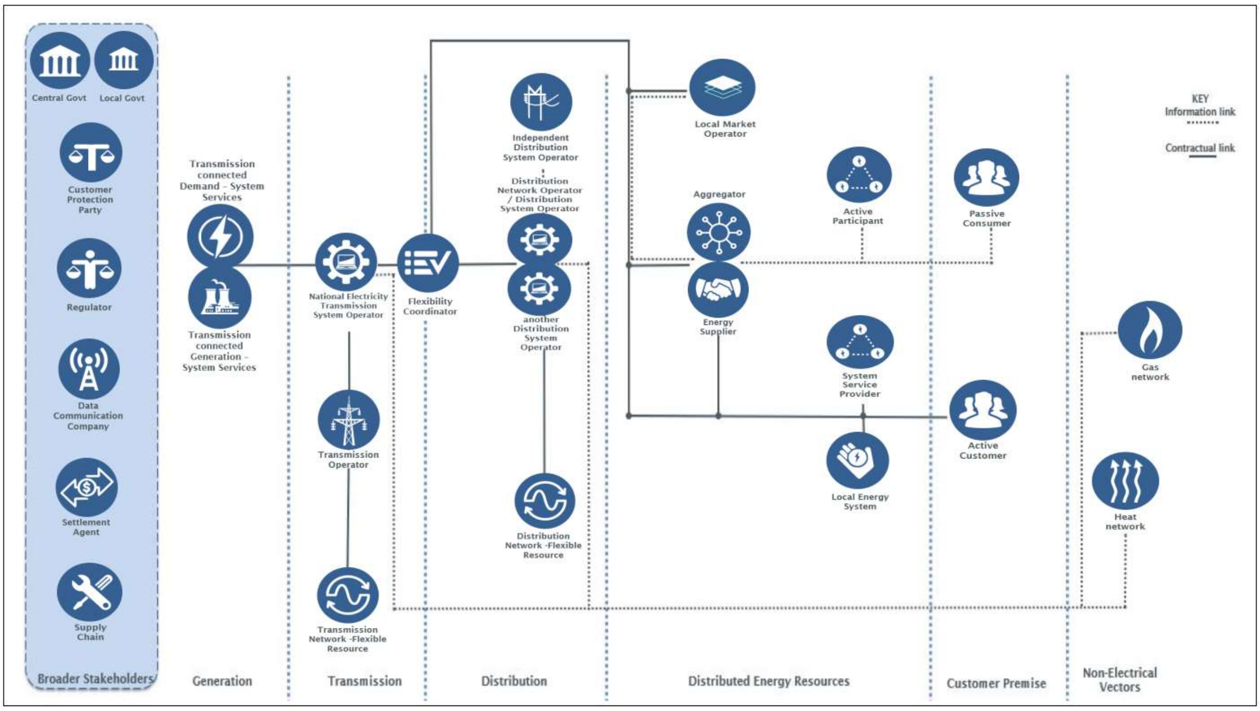


Figure 48 **'World E – Flexibility Coordinators' landing page diagram**

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- Make smarter investment decisions
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