# DSOs AS BENEFICIARIES OF INNOVATIVE CONTRACTS AND SERVICES, FACILITATED THROUGH LOCAL ELECTRICITY MARKET STRUCTURES

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## *ABSTRACT*

*This paper focuses on contracts that a distribution system operator (DSO) would find attractive given it can utilise the flexibility offered through a local electricity market environment. The context for this research work is based on the E-REGIO project that investigates the roles of a local system operator (LSO) as related to the facilitation of grid and community services. The current paper builds upon previous research by paying particular attention to the DSO's needs and how these can be satisfied through innovative services and contract regimes Once a context of grid needs and the associated local market solution is set, and the theoretical description of the contracts and services is provided, the paper continues with an overview of the pilot-based approach used to verify the contract's implementation as an instrument to meet the needs of the grid operators.*

## INTRODUCTION

The LSO is the most central concept within the E-REGIO local market design, ensuring the efficient and seamless operation of the local electricity market [1]. The LSO should have a minimum number of local flexibility providers (members of the local market) in order to successfully offer flexibility services to customers. The DSOs are among the important customers of the LSO, as the LSO entity can offer grid operators a range of services to help them meet the challenges and needs they face. These could be, for example, associated with congestion management, voltage/reactive power control and controlled islanding [2].

The various needs of DSOs and how these can be catered for through utilisation of local energy and flexibility resources has been discussed in previous research. In particular, the benefits that a DSO may get through local market establishments and flexibility utilisation have been well summarised by [3]. According to the author local flexibility can aid in the planning and running of an efficient distribution network, in particular by: removing a capacity constraint on the network and thus enabling more generation or demand to connect; assisting DSOs in managing their network in response to events such as faults or bad weather; enabling DSOs to ensure their network is operated within its voltage, thermal and fault level constraint limits. To ensure that the distribution grid is operated within the safe operation zone, [2] proposes to classify flexibility requests according to a certain criterion and a good option could be the traffic light concept where the requests are prioritised with consideration of the system's state. Thus, three states are described: green (normal operation); amber (DSOs actively engage with the local flexibility market) and red (the grid operator needs to take control of flexibility market interactions in the area where the grid constraint has occurred).

As consumers and prosumers are among the key players within a local electricity market structure, it is important to consider the motivation and incentives for their participation. In this relation, the work in [4] suggests that consumers are generally willing to pay for technical support services, but when it comes to usage sharing, personal identification of consumption parameters and participation in automated demand response programs that involve remote monitoring and control, they are likely to demand significant compensations. Thus, the use of innovative contracts and services that motivate end-user participation (sufficient in numbers/volume) and deliver the needed flexibility to DSOs is crucial for the efficient operation of the local grid.

### DSO needs

Having briefly referred to the DSOs needs in the preceding introductory section, here this work will delve into a more in-depth description of the challenges that a particular DSO faces and how these can be solved through a local market offering of flexibility services.

Power distribution grids are traditionally built to supply distributed loads from centralised generation. For this purpose, the established grid capacity must be enough for all plausible combinations of demand and production. Today, several factors challenge this approach. Demand is growing, and bottlenecks are emerging in existing infrastructure which is still within its technical lifetime. Digitalisation and the green energy transition are also reshaping the energy sector. New solutions for cost effective, automated and active distribution networks are emerging, and the goal is a more intelligent system based on distributed energy resources and flexibility instead of more and more grid capacity investments.

Flexibility-based demand side solutions are attractive if they have lower life-cycle costs than traditional networks solutions and/or if the uncertainty related to future need for

grid capacity is high. The risks related flexibility availability should be within an acceptable range.

**Bottlenecks and network reserves**

In an active grid, the DSO may use flexibility to handle operational bottlenecks (regarded as places of congestion) and to reduce the need for network reserves in case of faults or maintenance. In Northern Europe there is a high seasonality in demand related to the use of electricity for heating. This has implications for network congestion patterns including rate of occurrence. Maintenance and network faults triggering the need for reserves happen, but the yearly probability at specific locations is normally low.

Local distribution grids are often operated radially. Low voltage networks and LV/MV-substations are commonly built without redundancy, while medium voltage networks often are built meshed and have reserve capacity, especially in more densely populated areas and where underground cables with long repair times are used. In case of a changing load patterns, a meshed built network may be split in different radially operated areas so that congestions are avoided. It is common that transformer stations and regional distribution grids are established according to the N-1 criterium, at least with respect to non-flexible loads. When possible, regional grids are operated as a meshed grid.

One challenge in using flexibility for congestion management and to reduce the need for network reserves is related to the DSOs flexibility recruitment base. This has implications for procurement of flexibility services.

Many types of contracts can be suitable for procuring flexibility at higher grid levels where the recruitment base is high. Normally, there are always actors willing to sell flexibility, and these sellers have a limited possibility to create a situation requiring the use of flexibility. The situation is somewhat different at lower grid levels. A LV/MV-substations may have a small flexibility recruitment base. The small number of customers may cooperate to create a situation where the DSO needs flexibility if the compensation for flexibility is high – a situation that may have adverse effects if not the contracting towards the providers of flexibility is properly defined.

**Voltage/reactive power control**

An important part of the green energy transition is the increase of distributed energy production. Solar panels are popping up on rooftops of both household and commercial buildings. This poses new challenges related to operating the network within its voltage constraints.

The traditional network is designed to supply connected customers with an acceptable voltage taking a changing voltage drop caused by network impedance and a seasonal loading pattern into consideration. A high prevalence of solar panels within an area may significantly affect the network flow during summer (reduction or causing it to reverse), while the effects during the cold and dark winter are less significant. This increases voltage variations, especially in weaker grids. Converters of distributed energy resources may be used for voltage regulation and reactive power can be sold to the DSO when needed.

Increased flow of reactive power in the network increases network loss. A DSO may procure reactive power services from a LSO and end-users to optimise network loses.

### Many a little makes a mickle

The LSO utilises on the local market members' flexibility to build flexibility contracts that can be sold to external buyers such as the DSO. When the number of members is large enough, the LSO is given good options to create variative contracts that can be adjusted according to volume, duration and obligation. The LSO can offer its own local flexibility providers access to various trading options – e.g., external electricity markets, direct sales, flexibility asset management and others. A local market member could thus choose what participation clauses to be defined in the contract and whether, for example the flexibility offered will be somewhat distorting the comfort zone (against compensation) or not at all.

Further, to be profitable the LSO may need to have more income sources – i.e., it may not be the case that the DSO's needs and willingness to pay are alone covering the local market concept centred around the LSO. Maximal profitability would mean that the resources the LSO governs upon on behalf of its members are optimally used given the opportunities available and the possibility to utilise on those through a combined approach. The LSO should thus be offering variative products related to electricity retail, energy efficiency and others, and also be able to align its optimisation strategy with the needs and ambitions of the local buyers and sellers of flexibility. Having an aggregator role, the LSO can make innovative flexibility packages for DSOs and other buyers and these would be more attractive than what the LSOs members could offer on their own.

## CONTRACT REGIMES

For a DSO it might be optimal to be able to freely choose among the flexibility services offered by one (or several - depending on the local context) LSOs, as well as from other independent actors. As part of the E-REGIO local market, the LSO is to offer a variety of contracts for energy and flexibility that will create a sound basis for a desired development of a flexibility market. The DSO needs a well-functioning market towards the LSO where it can trade flexibility of different types and observe the flexibility in real-time and in advance. To have a functioning model from a DSO perspective, the DSO should be offered various products with different

characteristics.

In principle, there are different options for adjustments related to grid operation: energy storage, micro-grid, end-user flexibility, tariffs (e.g., tariffs that act as long-term signals for load flattening), and others. In order to utilise the flexibility offered via the local market for improving on congestion management and reducing the needs for grid investments, for the DSO it is critical to have a market interface towards the LSO, through which the DSO can get the needed overview. The interface should provide information on, for example: the services offered by the LSO; the flexibility that can be activated/bought (in different future time slots, but also in real-time); the mechanisms for usage of services (flexibility); overview of the established long-term contracts; status of contracts; load, generation and voltage.

However, in order to build the overall picture around the LSO contracting (as seen in the context of LSO-governed local market operation), the following approach is used:

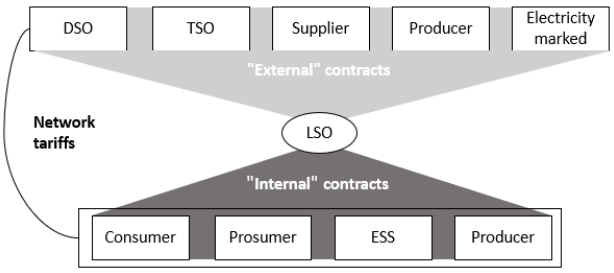


Figure 1 - Contract regimes around the LSO

The DSO's role is particularly important with respect to its obligation to deliver, connect and ensure a secure and high-quality supply. Consumers, prosumers, energy storage owners and producers are all subject to network tariffs. The contracts between the LSO and the providers of flexibility (local market members) constitute the basis of the flexibility products/services to be offered to the DSO. Thus, and aligning with the focus of this paper, in the following representation of types of contracts particular focus is paid to the DSO-related contracting.

**Contracts between DSO and LSO**

Flexibility contracts between DSO and LSO can be related to the following:

- DSO buys a volume of flexibility with a certain duration in an area where such is needed. Activation time varies from real-time to different periods of notice.
- DSO buys volume and duration via long-term contracts. Can be activated with different periods of notice.
- DSO buys limitation on the total consumption at an area. Can be activated with different periods of notice.
- DSO buys consumption limitation from selected clients which can be activated with different periods of notice.

Reactive power compensation contracts between DSO and LSO can be related to:

- DSO buys volume and continuation at an area where a need occurs.
- DSO buys long-term contract for reactive power supply. Can be activated during challenging situations related to voltage control.

In general, long-term (binding) contracts between DSO-LSO represent obligations for the LSO in situations when congestions are expected and there are a few LSO customers that the congestion concerns. The LSO could, for example, be obliged to have the total energy feed during activation not higher than a certain level. If the contract is not met, then the LSO may have to pay the DSO a "fine" for "not delivered flexibility". The sum could correspond to the fine the DSO has to pay for not delivered electricity. The long-term contracts help the DSOs in solving grid issues related to network congestions and need for supply reserves. Yet, the DSO would need security related to availability of flexibility when needed, as the alternative option is to not be able to supply. In addition to long-term contracts, short-term market can be utilised where DSOs and others could continuously trade with available flexibility (the availability can vary).

**Contracts between the LSO and other actors**

Besides offering contracts for flexibility and reactive power to the DSO, the LSO can be providing external contracts to other actors (Figure 1). Flexibility can be offered to TSO and producers while contracts for electricity retail can be signed towards producers (e.g., for direct sale), electricity suppliers (e.g., as part of product packages) and towards the power market.

**Contracts between the LSO and flexibility providers**

The main focus of contracts towards flexibility providers can be associated with:

- Flexibility – real-time purchases when needed. Criteria for flexibility provision versus comfort zone can be utilised, where the profitability of potential decrease in comfort is considered.
- Electricity retail – the customer can enter its preferences as related to utilisation of own flexibility when purchasing electricity and selling own production (internally in the local market or externally – from producers, retailers, wholesale market).
- Tariff optimisation – given available flexibility.
- Reactive power – real-time purchases when needed
- Energy/flexibility asset management – can in some cases be referred to as prosumer optimisation and would normally contract a packaged deal where the LSO carries optimisation, ensuring lowest possible energy cost given the customer preferences for own energy consumption.

Now, a more elaborative discussion on the contracting related to the internal customers of the LSO will be provided. When it comes to ESS (energy storage systems) - an energy storage unit can be used in different ways. The contracts should be able to regulate the usage of this resource within the local energy community around which

the local market is positioned in order to cover various flexibility needs of the DSOs. In addition, community energy storage contracts are to regulate usage of energy storage towards the different buyers of flexibility, mainly the DSO, but are also relevant for others - energy suppliers, local market end-users, the balancing markets.

When it comes to end-users (consumers/prosumers), the LSO should offer a variety of contracts that are specified for utilising flexibility resources on regular or momentary basis. As an example, an end-user may offer 1MWh at a certain hour of the day, that the LSO would buy if the same amount of flexibility (if needed) is found more expensive other places. This type of contracts is a must and a prerequisite for the DSO-LSO contract, as it determines what flexibility can be available to help solve grid challenges.

**Combined contracts**

Various elements from the previously referred to contract types can be combined into single contracts. As an example of a combined contract, the LSO can sell energy from local renewable power producer at a spot price in combination with flexibility offered by the end-user to the LSO (from home storage, disconnection, etc.) Different mixes of power and flexibility should be possible, also for power with and without specified origin.

Examples of contracts that refer to a local market setting with "DSO-local market operator" and "consumer-local market operator" interactions has been provided by [5]. The main contract parameters discussed are: duration (start and end date/hour), renewal procedures, maximum load per activation, maximum number of activations per period, permitted intervals, maximum allowed activation time, tolerance (% deviation of requested load shedding), strike price, activation fee, non-conformance specifications, devices controlled and temperature constraints.

## CONTRACT IMPLEMENTATION

Having described the key contract regimes, the paper presents how a selection of these are implemented through real-life demonstrations as part of the E-REGIO project's piloting phase carried at Skagerak EnergiLab in Norway - a facility equipped with community storage, distributed PV generation and local market platform for flexibility trading (Figure 2).

As an overall ambition, the pilot aims to provide knowledge and experience related to efficient integration of large solar panel installations in the grid, utilisation of energy storage for the benefits of the DSO and other actors, and particularly to how energy storage, solar power generation and end-user loads can be exercised in an efficient and collaborative manner

This E-REGIO project pilot is managed by both Skagerak Nett as a DSO and Skagerak Kraft as a retailer, and as most important services to test are defined the following:

- Congestion management – for the purpose it should be ensured that flexibility is available when it is needed. It may be required that the consumption within an area is less than a certain volume.
- Reactive compensation (reduced losses and voltage drop), e.g. with respect to batteries and local production.
- Peak shaving – e.g., through flexibility/tariff incentives.

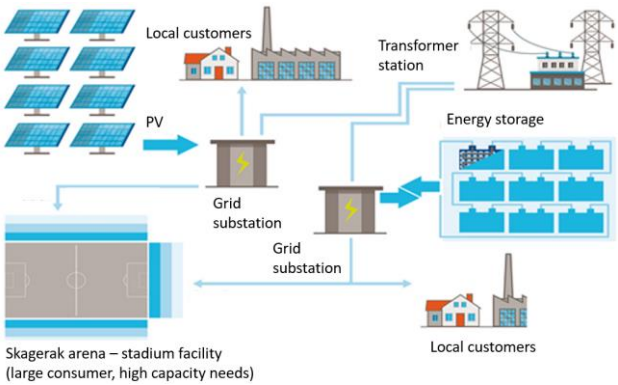


Figure 2 - Illustration of SkagerakEnergiLab's main elements

Additionally, some general contract conditions have been specified: long-term contracts between DSO and LSO are more attractive as they can be directly compared to grid investments; sufficient flexibility resources within an area are needed; flexibility trade should be in full compliance with the EU regulations; the LSO is to act as BRP. Furthermore, if power-based tariffs have been applied optimally further activation of flexibility could negatively impact flexibility providers' comfort. Thus, additional flexibility activation might become more and more expensive.

Considering the above specifications of the contract environment and requirements, the following contracts to be implemented within the Skagerak pilot have been defined:

**LSO-DSO: Flexibility contract on consumption limitation**

This contract would normally be continuous of nature, with long notice period for contract termination. Several main types can be considered:

1. Capacity constraint
2. Pre-ordered power capacity limit (overconsumption has to be notified in advance). If the LSO does not deliver, an economic penalty for the LSO, e.g., based on the costs associated with not delivered energy, can be applied. Alternatively, the LSO may disconnect customers and pay them compensation. Thus, the non-conformance costs for the LSO are associated with "not delivered energy" and reputation. In general, the needs of the DSO may variate with seasons. And the price of not delivered flexibility service can be specified within the bilateral DSO-LSO contract.

**LSO-DSO, LSO-Producer, LSO-Battery owner: Reactive power compensation**
The DSO needs to know what is available and what is the price. The DSO will buy if the price is acceptable.

**LSO-Producer: Power**
This could be a long-term or on-demand type of contract that relates to curtailment (reduction up to 0), regulation of production and provision of flexibility. Contract prices will depend on the electricity spot price and/or what the LSO has contracted with, e.g., battery owners, consumers.

**LSO-Battery owner: Charging/discharging**
A long-term contract that is linked to the spot price, the load charged or discharged and that can include subscription fee. In the context of this contract it is important to consider the ownership of the battery.

**LSO-Prosumer: Prosumer optimisation**
A long-term contract that would normally be based on subscription fee. The flexibility assets at the prosumer side are optimised for the purposes of, e.g., self-balancing, profit making and sustaining comfort limits.

**LSO-Prosumer: Inclusion into a portfolio**
Typically, a long-term contract that can be customised to mirror the flexibility characteristics of the device included. Defines the usage preferences as well as the terms related to benefits stemming from the participation into the portfolio.

## Characteristics and goals of the test area

The piloted business case has a strong focus on the grid services to be offered by the LSO. In particular, the following challenges are elaborated upon: optimal grid operation given large-scale PV installations; energy storage as a balancing tool; services to facilitate local market operation; live-tests of technology, operation and business models.

Local flexibility services are provided primarily to the end-users related to the pilot area (a stadium facility). Attractive products/services to attain high user-involvement level have to be offered. More specifically, the following services are to be considered: possibility to store surplus production (from prosumer/producer point of view); peak shaving for specific load and grid fee reduction; peak shaving for component capacity/life time optimisation; hybrid island mode (for local bottleneck management); emergency power/island mode; voltage support/grid loss reduction (load shift and reactive energy management); arbitrage (producer point of view); frequency support (producer/DSO point of view).

## CONCLUSIONS

This paper has focused on the implementation of various innovative contracts and services that can be facilitated through local market structures. The contracting and service delivery has been facilitated through the LSO – an entity responsible for the local market trade and optimisation.

It is expected that the set of contracts described can provide the requested by the DSO services, as related to: surplus-compensation for grid effects (DSO point of view), peak shaving for specific load and grid fee reduction, peak shaving for component capacity/life time optimisation, hybrid island mode (local bottleneck management), emergency power/island mode, voltage support/grid loss reduction (load shift & reactive energy management), arbitrage (producer point of view), frequency support. Thus, local market structures can efficiently support grid operation and help solve existing and emerging challenges.

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