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OPTIMAL CAPITAL INVESTMENT STRATEGY THROUGH A FLEXIBILITY SERVICES APPROACH

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Abstract. As the demand for electricity consumption and generation connection capacity to the infrastructure of the distribution system operator managed by JSC "Sadales tikls" (ST) increases, a shortage of available capacity is observed due to physical constraints of the network infrastructure. Historically, the company has addressed capacity constraints through capital investments in network upgrades, thereby increasing the nominal capacity of the elements installed in the network and increasing the capacity of the network. European experience shows that capital costs in network reinforcement can be deferred by offering the customers their desired capacity with temporary constraints. This study defines a process for designing an optimal investment strategy, which allows ST to compare the investment in network reinforcement against restrained capacity offer through customer demand flexibility.

It was concluded that the concept of flexibility services versus reinforcing the existing network is the most cost-effective option to maintain a consistently high quality of energy supply while minimising the cost to the utility if the customer flexibility cost does not exceed 300 EUR/MWh. Adding that only by updating and improving input data, calculations and forecasts flexibility services can be further developed and implemented in Latvia.

Key words: flexibility services, investment strategy, network development, capital investment deferral.

JEL code: E22, G11, O13, Q41, Q42, Q56

Introduction

The development of the distribution system operator's (DSO) electricity network has historically been driven by the need to renew the network infrastructure for its security and the energy well-being of society, resulting in network reinforcement through the construction of complementary or new infrastructure to replace technically obsolete infrastructure. The emergence of new commercial or industrial customers may also require the rebuilding of a distribution network that is in a technical and operational state in order to provide the necessary connection capacity and to protect the electricity network from overloading. As a result, "premature" capital investments are made in both ST and customer infrastructure, replacing network elements, whose economic life cycle has not yet ended. This in turn results in an increase in the overall cost of the electricity network, which feeds through to the electricity distribution system service tariff.

The need to increase network capacity is driven in particular by the European Union's (EU) policy initiative - the Green Deal. One of its key components to address decarbonisation is increased electrification and the massive use of renewable energies, which includes sustainable electricity. To achieve this goal, support is being developed for the transition from fossil fuels to renewables in power plants, including the creation of a decentralised energy system with a primary focus on increasing solar, wind power generation capacity and micro-generator capacity for household self-consumption (Green Deal, 2019). Although local renewables are highly welcomed, the connection of high-capacity grids to the distribution system in regions of Latvia, far from consumption centres, leads to the need to invest in grid reconstruction.

Demand for renewables has increased further in the face of geopolitical instability, the risk of supply disruptions and high electricity prices in the EU. In Latvia, a total of 32 solar power plants with a total capacity of 3.2 MW were connected to the ST infrastructure in 2021, but in 2022 capacity grew around three and a half times – 121 plants with a total capacity of 11 MW. The number of rooftop solar PVs on private homes has reached almost 12 000, with a total generating capacity of almost 100 MW. At the same

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time, the capacity reserved for the construction of power plants throughout the network already exceeds 1 000 MW.

The urgency of the problem is demonstrated by the fact that a consumer or generation-driven network reinforcement may not be economically viable option. The security of supply requirements of the grid require that the grid infrastructure follows the N-1 design theory. For example, if the peak load is 1.0 unit and the maximum ability that network element can handle is 1.0, then the network operator must provide a minimum capacity of 2.0 units so that, in the event of a single element failure, the distribution system operator is able to supply the relevant customers. However, if a new consumer joining the grid would reach a peak load of 1.1 units and would occur only a few times a year, the N-1 principle would no longer provide the highest economic return - the design and maintenance principles of the grid would need to be changed. Thus, the current approach of grid reinforcement, which does not consider the potential magnitude and frequency of grid congestion, may lead to under-utilisation of available capacity after grid reinforcement and stranded costs (Jing, Zhou, Wu, 2022).

In recent years, there has been a growing practice in Europe to assess the possibility of introducing **flexibility services** as an alternative (EURACTIV, 2022). One of the reasons for this development has been Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 concerning common rules for the internal market in electricity, which in Article 32 mentions incentives for the use of flexibility in distribution networks. According to Article 1(51) of the Electricity Market Law, which was implemented based on aforementioned Directive, a flexibility service is a temporary change in the use or production profile of electricity, which a user or producer has undertaken to perform voluntarily in a contract with another market participant. The implementation of flexibility services may enable a user to connect to the distribution system infrastructure at a lower cost without having to reinforce the network. At the same time, existing customers can increase capacity as needed (following the new principles of flexibility services, an approach in which a participant is able to reduce electricity use at a given time). The development of a market for these services brings added value to the power system - the possibility for electricity consumers to generate additional sources of income and, for example, for farms or entrepreneurs in the regions to suspend or postpone production to a later period of the day, when it's economically viable to reduce consumption (electrical load) (Silva, Alves, Ferreira, Villar, & Gouveia, 2021).

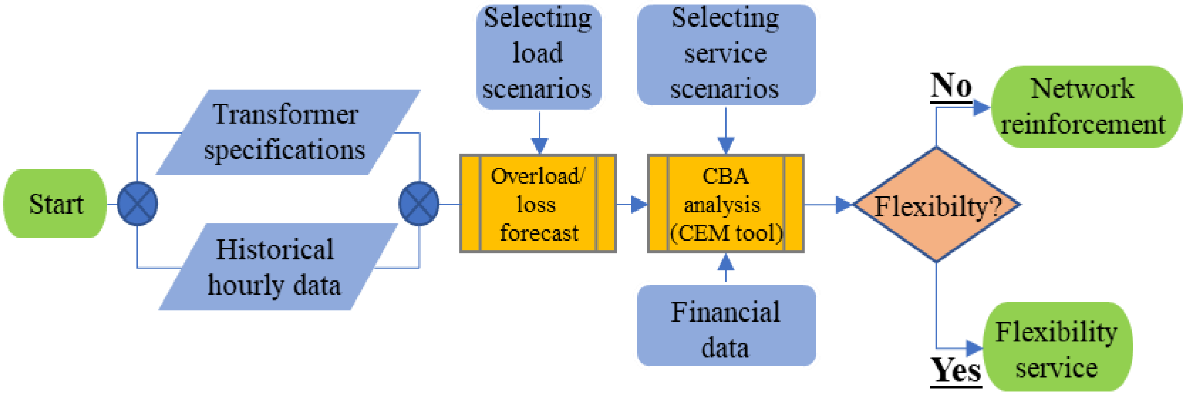
In the United Kingdom, DSOs are required to assess the options for a flexibility service as an alternative before each network reinforcement. The Energy Networks Association (ENA) has developed a publicly available cost-benefit analysis tool (ENA, [n.d.]) For the analysis, the study draws on the experience of the UK, where a common methodology - the Common Evaluation Methodology (CEM) - has been developed for six DSOs to evaluate flexibility services in the form of a tool (based in Excel) based on the principles of Cost Benefit Analysis (CBA). The main objective of the tool is to allow the user to find the optimal investment strategy by comparing network reinforcement options and flexibility service solutions for one or more years. It allows the user to test different flexibility strategies under different scenarios of capacity changes. The CEM tool also provides valuable insights to help make strategic decisions under uncertainty of future load growth (ENA, 2022). One of the major drawbacks of the tool is the manual preparation of the input data: in order to objectively assess the outcome of the proposed strategy, the user needs to carefully evaluate and prepare the input data according to its requirements, tailoring it to the specific situation. It is important to mention that the tool is adapted to the Latvian use case. Also, the price of flexibility services is currently unknown in Latvia since no such services have been provided to date. The methodology tool was developed by ENA together with consultants from Baringa Partners and is believed to be the first of its kind in the world. All DSOs in the UK agreed to use the CEM tool in April 2021. Based on the CEM tool, the majority of DSOs carry out two procurement processes per year. The tool should only be used to get an idea of the benefits and costs from the system operator's perspective (Smart energy, 2022).

The aim of the study is to develop a methodology for identifying and assessing flexibility needs in Latvia, in order to identify the criteria under which flexibility services are the most valuable network management strategy for business and society. The results will demonstrate at which congestion levels and prices flexibility services are a better approach than traditional approaches to distribution system management and development. This study is part of a larger project in which a number of EU network holders and related organisations are driving the research and deployment of flexibility services.

Methodology

1. Process of business analysis

In order to identify the congestion risks in the electricity distribution network and the possible assessment of flexibility services, a flexibility requirements determination process (Figure 1) based on the preparation and analysis of input data in the ST licence area was developed within the framework of this study. The business analysis process is developed using the CEM tool as a "backbone" before a decision is taken. The tool indicates in the process the optimal investment strategy for the connection. The company's Electricity Distribution System Development Plan 2023-2032 highlights its assets and forecasts that make up the electricity distribution network.



Source: author's study, 2023

Fig. 1. **Flexibility requirements determination process in JSC "Sadales tikls"**

It should be noted that the process of defining flexibility requirements also indicates the optimal duration of the use of flexibility services, which gives an indication of the desired procurement and contracting period. The possibility to provide indications on flexibility need is noted, with the aim of helping to build an understanding of the size of the market for potential participants.

2. Input data

Input data for the business analysis (describing all the data used for the study) is obtained during the study. Overload forecasts were made for a period of 40 years, assuming useful lifetime cycle of network elements mentioned in the study. The forecasted values, such as the maintenance and deployment costs of flexibility services, the discount rate, the price of power outages, etc., are influenced by real-time events. Therefore, the projections made in this study are valid for the next year - looking at the current economic situation, where high inflation and increasing energy costs are noticeable, the projections of values for the next planning periods should be reviewed.

In this study, flexibility services are applied to **110 kV transformers**, which are the ownership and service boundary between distribution and transmission network operators. And it is the overload management of these elements that is the focus, as:

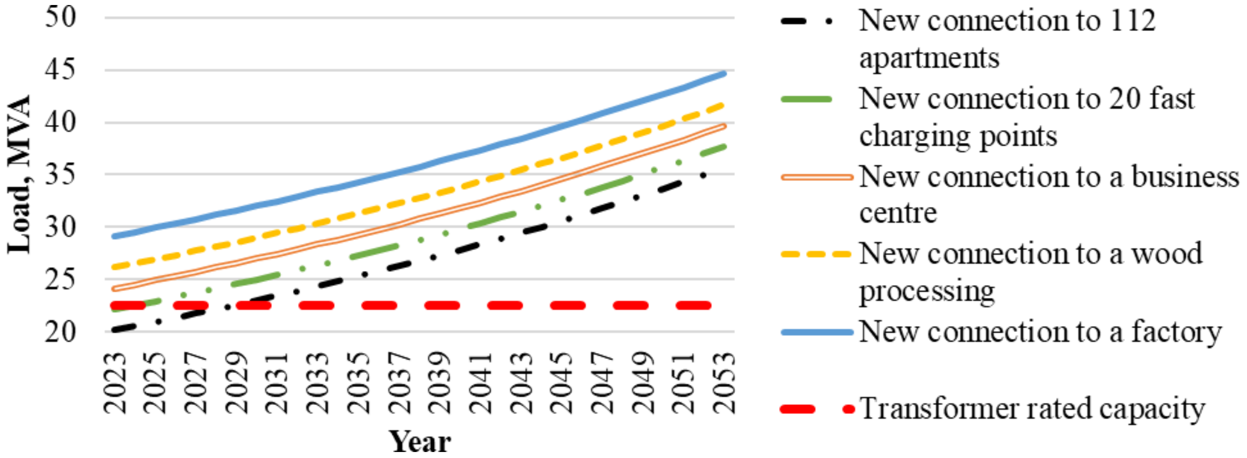
- Equipment failures affect large areas of the electricity supply and a large number of system users;
- Estimated installed surplus transformer capacity in 2022 is ~1000 MVA;
- The cost of building a new transformer can be € 0.5-2 million. EUR and more.

According to the System connection rules for the electricity distribution system, all of the transformer construction costs must be covered by the user. As a result, this section of the Latvian electricity grid limits further development of customer consumption (electrification) but in particular the development of generation (decentralised electricity production) on a national scale. In addition to the impact on the distribution system operator, the under-utilisation of installed transformers increases its costs (electricity losses) and, consequently, the electricity tariff component in Latvia.

The analysis consists of the cost of 6.3 MVA to 32 MVA transformers, their purchase, installation, and maintenance costs. The organisation studied has set the load capacity at 70-90% of the rated capacity to avoid unexpected overloading as well as to reduce energy losses in the equipment. Consequently, the transformer capacity is assumed to be 90% of the peak for the calculations.

Historical hourly data informs the need for flexibility services. This data answers the question - how much time or electricity will be needed in a given period. The hourly data in the study represents the consumption and the reserved grid connection capacities of 2021, depending on the scenario - generation or consumption. The CEM tool inputs are entered - the average number of hours per day, the total number of hours per year, the total number of days per year and the amount of energy per year that needs to be activated through flexibility services.

The study includes the calculation of **overload and loss forecasts** using the Python programming language (an interpreted, object-oriented, high-level programming language with dynamic semantics (Python, [n.d.])). This section of the input data considers **scenarios of load demand** from new customers and additionally assumes a load growth of 2% per year from existing customers, resulting in network overload forecasts. In the CEM tool, the calculations are made assuming three activation prices and five required flexibility capacities, which can also be called new loads (**1, 3, 5, 7, 10 MW**). New loads are compared to the averages of loads existing customers have, as apartment buildings, where 9 kW of capacity is most commonly available to owners, which equates to 112 apartments of 1 MW respectively. Fast charging points are installed with a capacity of 150 kW, which makes a set of 20 points, reaching a capacity of 3 MW. Other load comparisons are based on data available from ST, regarding the nature of new connections. As an example, see the #1 Substation overload forecast in Figure 2, given the above input data.



Source: author's calculations based on input data, 2023

Fig. 2. **#1 Substation transformer rated capacity vs. new load growth forecast, MVA**

Looking at the projections in Figure 2, the increase in new consumption capacity will require network reinforcement. The increase in new consumption load compared to the 90% rated capacity of the existing transformer is 22.5 MVA. As a result, under the consumption flexibility market scenario, this forecast reflects at which of the selected load levels it is feasible to substitute network reinforcement with flexibility services, or when it would be economically feasible to do so.

Part of the input is a **choice of service scenarios**, which includes the cost of flexibility services:

- Implementation costs, which are incurred regardless of how long the flexibility strategy is implemented, even if the planned network reconstruction is postponed, e.g., for only one or two years (EUR/year);
- Administration costs, which are only incurred while the flexibility strategy is being implemented. For example, if the network reinforcement is deferred for two years, these costs will only be incurred over a two-year period (EUR/year).

Implementation and administration costs depend on the desired growth rate of flexibility services. In turn, the projections of how these costs relate to the network units are assumed for the whole system (all 132 Substations), thus ensuring the possibility to deploy the service in several substations, achieving a high platform utilisation.

Financial data consists of monetary parameters (shaped by monetary policy), monetizable costs, rates, and ratios. They include the weighted average cost of capital, the capitalisation rate and the discount rate. As part of the study, it is important not to forget the costs that relate to the organisation and its existing or potential customers - capital and operating expenditure. "*Understanding the difference between capex and opex is very important for any company trying to make the best use of funding, making sure the right approach is used for capital expenditure and other types of expenditure*." (Carey, Knowles, Towers-Clark, 2017). Both types of costs are important when planning the implementation of a new service, as they affect the incentives of market players to offer and buy. Outside the scope of the study, the design of the service is planned for wider market growth, with the aim of creating competitive conditions and more favourable conditions, offers for all players. Faced with these motivations, the costs and attractiveness of using flexibility services must be seen not only on the system operators side, but also on the customers side.

The CEM tool is driven by scenario control, depending on the selected event scenario, it may not be necessary to use all input data. As an example, consider an event scenario where one specific connection case is evaluated, where a specific load forecast for an individual customer is known.

3. Cost-benefit analysis

CBA illustrates several important points in decision-making. Strengths include cataloguing benefits (positive) and costs (negative), assessing the impact in monetary terms (assigning a value) and then determining the net benefit of the proposal relative to current policy (net benefit equals additional benefits minus additional costs) (Boardman et al., 2018). CBA is a systematic and analytical process that compares benefits with costs to assess the potential of a project or programme - most often of a financial nature. The objective of the analysis is to answer questions such as the merits of the proposed project, the optimal scale at which to implement it and its respective constraints. CBA is fundamental to management decision-making and has proven to be a common technique for making sound decisions using the resources of an organisation (Mishan, Quah, 2020). The CBA analysis is implemented in the CEM tool, which performs the calculations taking into account the analysis framework.

4. Common decision-making based on the tool's results

The tool's outputs include tables and graphs for each scenario, demonstrating the benefits of flexibility at a given price and a weighted average analysis of the benefits of deferring network reinforcement and a detailed CBA for a given number of deferral years for a given scenario. A standard case for which the CEM tool is used is the calculation of flexibility to find out the future financial savings from network reinforcement deferral. Other use cases include the use of flexibility to manage different maintenance situations or temporary outages, to reduce the number and duration of customer interruptions, and flexible grid interconnections in current and low load regimes (Smart energy, 2022). Once the CBA has been carried out, it needs to be interpreted in a coherent way, using the results provided by the CEM tool, to determine the future direction of the strategy for the development of the network. The CEM tool has demonstrated the results used in the study in a number of ways (but not limited to):

1) **strategy benefit** – for a set of base costs and user-defined flexibility costs (reservation, activation and software costs), the model shows the net benefit of flexibility solutions over the forecast period;
2) **insights and reports** – show summary tables of the benefits of the strategy outcomes. Additional analysis is provided to allow comparisons between strategies under different scenarios;
3) **CBA summary** – although the user cannot edit this results section, it is possible to check the detailed CBA calculations performed by the CEM tool (ENA, 2022).

The results of the study are based on the results of a weighted average analysis, which allows the prediction of the percentage of scenarios realised, with each scenario being accompanied by its percentage probability of occurrence.

Research results and discussion

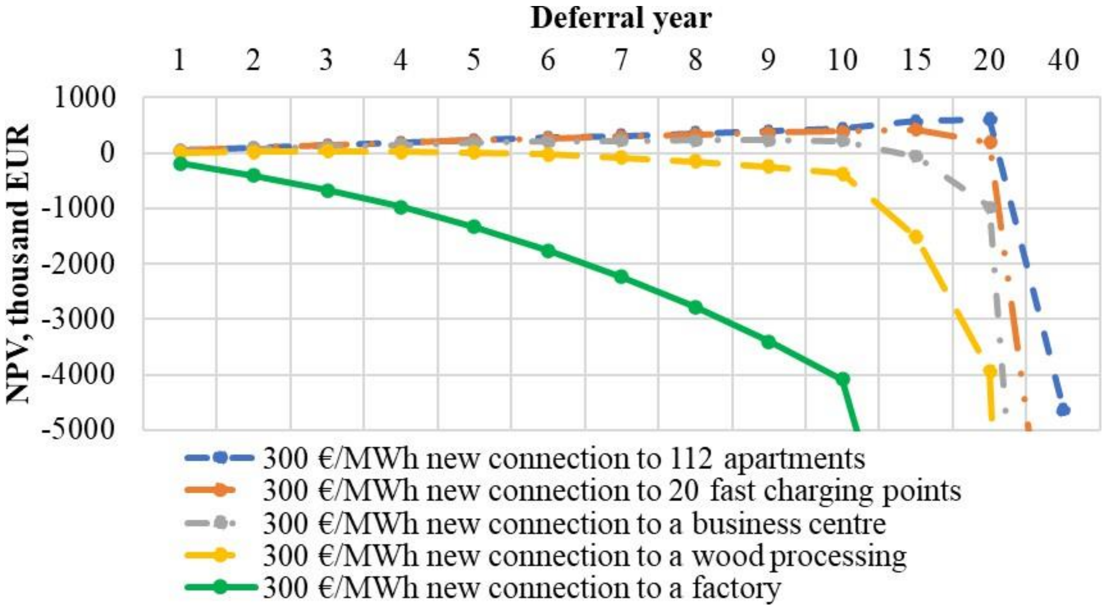
Given the lack of prior knowledge of the compensation price at which customers would be willing to provide flexibility services, three price scenarios were evaluated, corresponding to the current exchange electricity price range of **100**, **300** and **500** EUR/MWh.

The development of flexibility services and their market design starts with a **market scenario for consumption flexibility**, where it is assumed that the consumption of the new customer is not flexible and that this customer compensates the service providers for their flexibility. In order to create an incentive to compensate the service providers (flexibility implementers), the system operator has to bear the costs of the network reinforcement and by limiting consumption for a certain period of time they will receive compensation for the limited capacity (EUR/MWh), which is the activation price as defined in this chapter.

One of the two transformers is normally in an off state and no new transformers are being built at the substations. This scenario requires the ability to dynamically change the operating modes of the equipment in a timely manner in order to maintain the safety of the network in case of default by the participants. Based on an assessment of the future development of the network, the authors have determined the probability of the loads filling up to a uniform level (**20% each**). The aim is to investigate at which price it is more profitable to buy flexibility and at which required flexibility capacity this is possible. In this scenario, a full flexibility market with compensation for **consumption perspective** is created.

Five Substations have been selected for the study. The main reasons are based on electricity consumption data and a forecast of future load or generation increases made by the Network Development function of ST. The names have been changed to ensure the safety conditions of the infrastructure, names #1 to #5 are given. The results for Substation #1 are presented in more detail later in the study.

Substation #1 is planned to have a third transformer installed with a rated capacity of 25 MVA in addition to the two existing transformers, making it the largest of the five substations in the case study. Hence, following the above business process steps and calculations in the CEM tool may be indicative in favour of deferring the cost of the Substation #1 reinforcement. According to electricity price indicators in Nord Pool power market based on data from 2022, 300 EUR per MWh is the closest to a realistic price that could be paid to compensate customers for their flexibility in the Baltic region. Analysing the results of Substation 1# at this price (Figure 3), the economic benefit of flexibility services at new loads between 1 and 7 MW can be identified. If 10 MW flexibility capacity is needed for new connections or load increases, a network reinforcement is required.



New connection is calculated in MW, where 1 MW – 112 apartments, 3 MW – 20 fast charging points, 5 MW – a business centre, 7 MW – a wood processing, 10 MW – a factory.

Source: author's calculations, 2023

Fig. 2. **#1 Substation transformer rated capacity vs. new load growth forecast, MVA**

As the graph shows, there is no cumulative deferral benefit (NPV) in euros at 10 MW load. In this case study, deferring the network reinforcement for at least three years would be the most favourable option. The projections adopted in the CEM tool indicate an 80% probability (4 out of 5 cases) of saving money by not reinforcing the network, while at the same time generating income from new sources of connection. After the third year, as the new load reaches 7 MW, the efficiency of the flexibility service approach decreases. There is no change in the graphs as the activation price changes. Changes only occur in the monetary value of the benefit and in the period.

With an activation price of € 100/MWh, flexibility services are not more cost-effective than network reinforcement option at 10 MW load, while at 7 MW load it is possible to defer network reinforcement for more than five years (compared to € 300/MWh). At an activation price of 500 EUR/MWh for flexibility services, a 7 MW load does not offer any benefits, which is clearly seen in more detail in Table 1.

Table 1

Results of the market scenarios for consumption and generation flexibility Substations 1# - 5#, thousand EUR

Substation Serial No.	Price EUR/MW	Consumer flexibility market					Generation flexibility market				
		Load, MW					Generation, MW				
		1	3	5	7	10	5	10	15	20	25
1#	100	734.22	596.64	390.76	186.52	-34.59	1442.53	1442.53	1442.53	1442.53	1135.22
	300	605.55	423.00	225.53	30.29	-187.02	1442.53	1442.53	1442.53	1442.53	520.60
	500	544.93	362.75	154.42	-5.67	-339.45	1442.53	1442.53	1442.53	1442.53	-94.02
2#	100	310.29	13.76	-418.24	-1600.99	-4321.95	1282.31	1282.31	1282.31	1282.31	1258.69
	300	255.40	-37.61	-1327.05	-4875.31	-13038.18	1282.31	1282.31	1282.31	1282.31	1211.45
	500	235.15	-86.79	-2235.86	-8149.62	-21754.41	1282.31	1282.31	1282.31	1282.31	1164.21
3#	100	1321.80	895.21	873.60	723.26	275.25	1602.75	1602.75	1602.75	1594.33	1179.38
	300	896.83	891.95	827.13	583.73	119.81	1602.75	1602.75	1602.75	1577.49	332.65
	500	896.83	888.69	780.67	510.24	63.86	1602.75	1602.75	1602.75	1560.65	-514.09
4#	100	296.55	23.60	-233.32	-985.77	-3203.87	1282.31	1282.31	1282.31	1071.75	-1199.34
	300	198.36	-35.49	-773.48	-3030.83	-9685.12	1282.31	1282.31	1282.31	650.63	-6162.63
	500	158.47	-83.65	-1313.63	-5075.88	-16166.36	1282.31	1282.31	1282.31	229.51	-11125.93
5#	100	367.64	-76.49	-1607.87	-3551.09	-6466.03	729.34	575.07	0.00	0.00	0.00
	300	300.07	-264.13	-4858.29	-10687.94	-19432.75	729.34	266.53	0.00	0.00	0.00
	500	292.05	-451.78	-8108.70	-17824.79	-32399.48	729.34	-42.01	0.00	0.00	0.00

Colour identification of results for monetary values: green - gain, pink - loss, orange - calculation was not performed due to low transformer power.

Source: author's calculations, 2023

The results summarised in the table above show that for 3 out of 5 Substations, reaching the required capacity of 3 MW for a new connection or load growth is not economically feasible to implement the flexibility services approach. It is important to mention that ST often receives connection requests with capacities below 3 MW. In most cases, it is possible to implement a flexibility service approach, especially if the customer (demanding party) has assessed the required electricity capacity according to accepted standards and forecasted its consumption based on real data. On the other hand, looking at the results of the generation flexibility market scenario, in most cases it is a reasonable option, but the generation capacities do not reach the levels assumed by the authors at the time of the study according to actual indicators. This points to the need for a reassessment of the situation when the power generation capacity of the Substations studied will increase. Complementary indications are the results of the CEM tool on the years of deferment of grid reconstruction, shown in Table 2.

Table 2

Results of the market scenarios for consumption and generation flexibility
Substations 1# - 5#, years

Substation Serial No.	Price EUR/MW	Consumer flexibility market					Generation flexibility market				
		Load, MW					Generation, MW				
		1	3	5	7	10	5	10	15	20	25
1#	100	20	20	15	8	0	40	40	40	40	40
	300	20	15	8	3	0	40	40	40	40	40
	500	15	10	6	0	0	40	40	40	40	0
2#	100	9	2	0	0	0	40	40	40	40	40
	300	8	0	0	0	0	40	40	40	40	0
	500	7	0	0	0	0	40	40	40	40	0
3#	100	40	20	20	20	9	40	40	40	40	40
	300	20	20	20	15	5	40	40	40	40	40
	500	20	20	20	15	3	40	40	40	40	0
4#	100	10	2	0	0	0	40	40	40	40	0
	300	7	0	0	0	0	40	40	40	40	0
	500	6	0	0	0	0	40	40	40	40	0
5#	100	20	0	0	0	0	40	40	0	0	0
	300	15	0	0	0	0	40	40	0	0	0
	500	15	0	0	0	0	40	40	0	0	0

Colour identification of results for monetary values: green - gain, pink - loss, orange - calculation was not performed due to low transformer power.

Source: author's calculations, 2023

The results of the generation flexibility market scenario described in Table 2 point to the aforementioned conclusion that there is not enough generation capacity to trigger a network reinforcement study. The 40-year result in all categories, with some cases at 25 MW, confirms this. In contrast, the market scenario for consumption flexibility shows results for different periods of years. The economic rationale is mainly developed in the short term (1-5 years), where the deferral of network reinforcement can lead to a continuous increase of connections in substations with low overcommitted capacity. At the same time, developing solutions for network reinforcement and carrying them out over a 3-5-year period, which is the average duration of major capital projects such as Substation reconstruction, modernisation, increasing capacity.

The results lead to the conclusion that the higher the price of flexibility compensation, the higher the total cost of flexibility. At the same time, if the required load exceeds the rated capacity of the transformer from the first year onwards, flexibility services are more expensive than reinforcing the network (note: it is technically impossible to provide such a large overload compensation). As the amount of flexibility required (MW) increases, the number of compensations paid when activating them also increases.

Concluding that the results are positive, and the service has the capacity to deliver economically viable benefits, the following study focuses on further research opportunities and conclusions.

Conclusions and proposals

Within the framework of this study was developed a unique business analysis model for selecting the optimal investment strategy. This is the first project of its kind involving Latvia's largest distribution system operator, opening the door to new types of congestion management services. However, this research also highlighted a number of limitations of the proposed business analysis methodology for flexibility services, which are recommended to be improved in future iterations. The findings presented here should be considered as a discussion and recommendations for further research and development of flexibility services.

Conclusions

1) **The CEM tool has weaknesses**. Given that ST has to cover network technical loses, the business case for flexibility services does not include it and the corresponding costs in the calculations. This constitutes a significant cost category when choosing between flexibility services or a traditional network reinforcement approach.

The financial data is forecasted for the next 10 years with increasing certainty over time. 10 years can also be considered a short period relative to the useful life of the asset. Currently, the functions responsible for finance generate costs for discount rates, purchase prices for losses and other financial parameters. This period should be extended to at least 20 years.

2) **The future development of flexibility services is based on assumptions**. While the costs of a traditional network retrofit are well known, the costs of developing a flexibility platform were identified through a price survey with a developer of such a platform in the UK. At present, the study does not reflect a specific direction on how developers plan to address the flexibility platform issue - no decision has been taken whether ST will build a new platform with its own resources or purchase and integrate an existing solution. This may lead to inaccurate input data projections.
3) **About 95% of 110 kV transformers in substations are not owned by ST**. The situation with the ownership boundaries of substations makes the implementation of the service more complicated, as the operation is performed by the transmission system operator's staff. ST is the largest customer, but decisions related to the safety and operation of the network are taken by the network owner. The company's managing directors have already decided to evaluate investments in their assets by purchasing transformers through the procurement process when replacing transformers in high voltage (110 kV) substations, thus moving the boundary before the transformer, but this has only been done in a few substations. The switching of the equipment mentioned in the study is currently primarily motivated by safety reasons rather than economic factors.

Further recommendations for the development of the study

1) **Forecasting**. Short and long-term forecasting needs to be improved. For short-term forecasts, forecasting algorithms based on mathematical models such as regression algorithms or machine learning algorithms are needed. In this work, data for 2021 were used and exploited to the future. However, when working with forecasts, it can be concluded that the cost of flexibility services would be higher due to the appearance of congestion when it was not forecast. There would also be times when the overload forecast did not come true. However, the customer is still entitled to compensation for the flexibility service provided. For short-term forecasts, SCADA data should be used in the forecasting, as using data at one-minute intervals would give a more accurate view of load peaks than using hourly average load values. The problem here would be with data storage, as it is logical that 60x the amount of data would need to be stored using minute-by-minute data.

To improve the long-term projections, it is necessary to compare the traditional reinforcement investment scenario with flexibility services, where the analysis should cover the entire life cycle of the asset (in the context of the study, the economic life cycle of a transformer is 40 years). The study concluded that limited information is available on how customer consumption will evolve over such a period. There is a large uncertainty factor in long-term projections. In this work an annual 2% load growth was used, but this method is too simplistic for large-scale investment project forecasts.

Use 15-minute data. It would be equally important to use shorter smart meter intervals in the future so as not to overpay for the flexibility provided by the customer. For example, it may be the case that an overload is only expected for 15 minutes. However, if the minimum meter reading interval is one hour, then the shortest period for which flexibility can be purchased is also one hour. Consequently, both the distribution network overcharges the customer and the customer's commercial or industrial operations may be interrupted for longer than necessary.

2) **Improvements in calculations including electricity losses**. Given that the system operator has to financially cover network losses, the business case for flexibility services should include a calculation of electricity losses and associated costs for all present and future scenarios. In this way, the decision on the optimal investment strategy would become even more accurate.

3) **Creating load profiles for new connections**. It is important to use the available information about the new customer's expected load. In this work several scenarios were considered assuming that new customers will demand 1,3,5,7 and 10 MW. However, in practice it is possible to replace this unknown factor by carrying out a business process and operational analysis of the new customer. For example, if a new farm wants to apply for a new electricity connection, it is possible to carry out a load profile analysis of similar sized farms to understand when and how much electricity this type of customer is likely to consume. It is equally important to start this discussion with the demanding party of the connection to understand their business needs. As a result, one scenario can be used that would very accurately reflect the expected load changes when a new customer comes on board.

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