NORFLEX: ACCOMMODATING E-MOBILITY IN THE DISTRIBUTION GRID. UTILISING A FLEXIBILITY MARKET TO MANAGE GRID CONGESTION

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ABSTRACT

In Norway more than 64% of all new car registrations in 2021 were electric vehicles (EVs). We have investigated the opportunities, challenges, and potential value of E-mobility as part of a flexible energy system. This paper provides insight into how to accommodate E-mobility in the local distribution grid, in addition to functioning as an asset to manage grid congestion and system services with a marked-based approach.

The project has developed and tested technology and business models enabling more efficient and sustainable power grid operations. This includes utilising market-based flexibility from the growing number of domestic EV chargers, and hence accommodating E-mobility in the distribution grid.

Key to this project in NODES and its innovative approach is an integrated market design that allows for the reservation (LongFlex) and activation (ShortFlex) of local flexibility to be transacted between Flexibility Service Providers (FSPs) and the DSO & TSO.

Results from the project show a willingness to implement smart charging, optimised to both hourly energy prices and local explicit flexibility price in NODES. Flexibility volumes have been increasing as FSPs have developed their system to support the new digital value chain and the DSO has automated their processes in GridTools.

1 INTRODUCTION

NorFlex is a large-scale innovation project, run from 2019 to the end of March 2022, by Agder Energi (project owner), Glitre Energi, NODES, and Statnett (NorFlex, 2022). The project is funded by Norwegian Enova. This paper focuses on flexibility from E-mobility and how the management of charging infrastructure can be extended to provide usefulness to constrained networks.

1.1 E-mobility in Norway

The Government of Norway has invested substantially in the electrification of the transport sector in recent years. The investments cover incentives programs for EVs and government-supported programs for the rollout of fast charging infrastructure.

Private Charging Point Operators (CPOs) were invited to bid for both construction and operation of the charging infrastructure. Today Norway has a network of fast chargers on the major corridors. The public fast (50kW) and ultrafast (>150kW) charging points are accessible 24 /7 and open to all types of EVs. In addition to CPOs developing fast chargers, other companies are developing AC charging at home and building complexes.

We see new business models developing. CPOs are offering energy and energy companies are offering CPO services even with limited public funding.

Norway is the frontrunner in terms of EV adoption, boasting a 65% market share of new-sales last year, displayed in Figure 1 (Elbil.no, 2022).

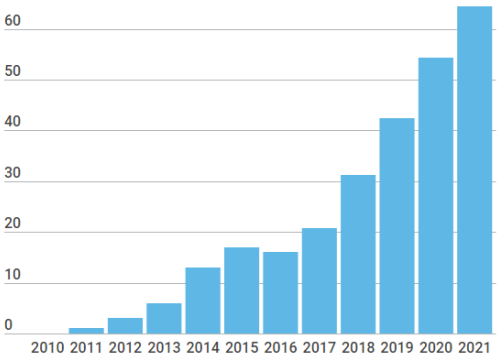

Figure 1 - EV market share (%) of new-sales in Norway (Elbil.no, 2022)

1.2 Smart EV charging

New innovative technology enables EV charging to become smarter. Remote monitoring and activation of charging enable new business models to develop. This creates value to the customers that are willing to make upwards or downwards adjustments in their consumption. EVs are well suited to provide these services provided they are connected to the charging points and managed remotely.

Traditionally, flexibility has been optimised towards spot prices and grid tariffs, a behind-the-meter optimisation. The introduction of an independent flexibility marketplace in the value chain opens up for market-based optimisation. Competition between flexibility assets and technologies effectively addresses challenges in the power system and offers flexibility to DSO/TSO at a lower cost.

This has given NorFlex a valuable opportunity to cooperate with leading smart charging operators to acquire knowledge regarding the full potential of E-mobility.

1.3 E-mobility impact on grid congestions

The uptake of EVs is growing rapidly, resulting in an associated charging infrastructure being rolled out. As the number of EVs increases, so does the electricity grid load and the potential need for grid reinforcement.

The power grid must constantly remain in balance. Earlier small-scale projects have demonstrated that EVs can play a role in maintaining the frequency balance of the power system (Lehmbruck, 2020; Statnett, 2021; Bach Andersen, et al., 2019). The NorFlex project demonstrates the use of flexibility from E-mobility can be used to manage grid congestions and system balancing. Since EVs spend a large amount of stationary time connected to the grid, they can create value when charging is flexible. Such flexibility can be made available almost immediately and there are low start-up and disconnection costs. To be able to do that the system operators need to buy flexibility from users of the grid. Utilising the flexibility embedded in the power system could help to limit some of the reinforcement needed. EVs are believed to be able to offer a large amount of flexibility to the system.

So far, the development of E-mobility has not had a direct impact on local congestions, but Agder Energi Nett (DSO) wanted to test a hypothesis that flexibility from E-mobility could be part of the solution for managing grid congestions. The NorFlex project wanted to document how well flexibility from the different technology would scale and how domestic flexibility from EV chargers would perform in this respect.

Charging EVs might represent a problem for the grid. Either when uncoordinated charging is started based on consumer behaviours from multiple chargers or started because of a coordinated charging process optimised on energy price alone. Smart charging represents both a challenge and an opportunity for the DSO in this respect. EVs have the potential to play an important role in the short-term flexibility market for the DSO. In these markets, there will be a demand for capacity that can be regulated rapidly upwards and downwards.

2 MARKET-BASED APPROACH

2.1 The flexibility value chain.

Unlocking the value of flexibility in the smart charging process requires buyers, sellers, and a marketplace trading flexibility. The party taking the main role in the value creation will be the new independent market operator.

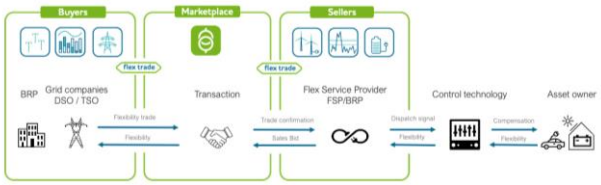

Figure 2 - Digital flexibility value chain

The smart charging process typically involves several parties like the CPO, the aggregator (could be the CPO in Norway), and the EV manufacturer.

The CPO operates and maintains the charging infrastructure, and the aggregator service the customers (EV drivers or owners of charging points) and therefore handles all communication with the asset and settlement with the asset owner. Depending on the charging infrastructure (AC or DC charging) the roles of the parties involved may vary.

The customer's role: A typical residential end-user and the driver of the EV with an AC charger at home, able to profit from flexibility if connected to an FSP. The operator of public charging stations: The operator adopts the role of a customer and will be able to profit from flexibility if connected to a buffer battery at the charging station.

The customer can use its flexibility to profit from incentives offered by aggregators if the aggregator can manage the AC charger and aggregate loads to the local flexibility market.

2.2 NODES marketplace

NODES as an independent market operator has been operating the flexibility market in NorFlex. NODES market design allows flexibility to be offered bottom-up and bought top-down (NODES, 2022).

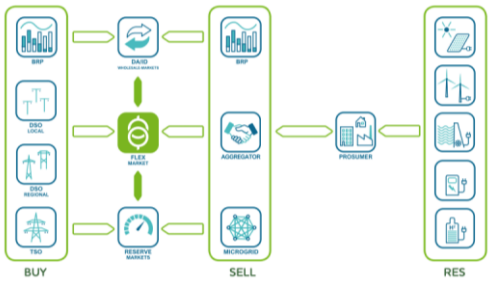

Figure 3 - NODES integrated market design

2.3 NODES Rule Book

NODES Rule Book is a framework for buyers and sellers which allows for reservation of flexibility (LongFlex), activation of flexibility (ShortFlex), and automation of the transaction including trade signals for activation and finally validation of delivery and settling of the transaction.

In NorFlex there have been developed local rules, as an addendum to the NODES Rule Book. This includes accepting bids down to 0,001 MW, defining the opening of the activation market to be 7 days in advance, and closing 120 minutes ahead of operational hour.

2.4 Encouraging the sellers (FSPs)

In the value chain for market-based procurement of flexibility services, the FSP/aggregator offers flexibility to the independent local free marketplace. Different players can take the aggregator role (e.g., CPO, FSP, retail suppliers, independent market party).

Therefore, smart charging can be distinguished by differences in the relationship between the aggregator and the retail supplier of electricity to the customer. Both parties could have a contractual agreement, or the aggregator could operate independently.

If an aggregator is operating independently, transfer of energy could be applied to compensate the supplier for the effects of demand-side flexibility activation. By doing so, the aggregator is neutralising the energy position of the retail supplier and the balancing position of the BRP from the impact of the activation.

Other models would also be possible. When there is no contract between aggregator and the retail supplier, an uncorrected solution is also an option. With an uncorrected model, there is no transfer of energy to the retail supplier. The result of the activation will then result in an imbalance for the aggregator. That is what we have been practicing in NorFlex.

NODES has been encouraging the FSPs to place orders by providing transparency via order books, displayed in Figure 4:

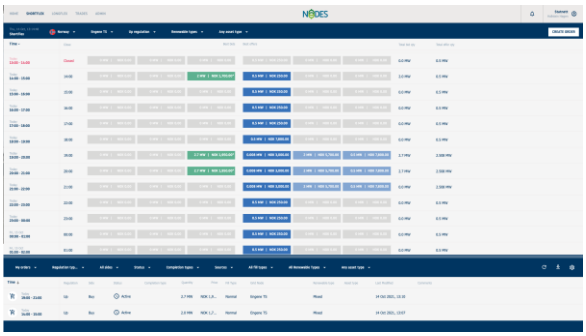

Figure 4 - NODESmarket order book

In addition, market data has been published on the NODES website, and NODES have been providing activity reports which in addition to traded volume with min and max prices, included spread of unmatched orders per order book.

2.5 Demonstrating business models

Sellers place sales bids of flexibility on NODES based on portfolios with one or more assets. Portfolios can be offered in the order book located at the lowest level of the grid and will be visible through linked order books on NODES. Each bid needs to have an associated baseline which will be locked in the event of a matched trade. The seller then provides meter data to the project's Asset Hub at a minimum of 2 hours before and 2 hours after the activated period. NODES uses this meter data to validate the delivery. Local market rules regulate how much of the value of the matched trade gets paid depending on the verification of delivered flexibility:

Figure 5 - Payment rules and delivery percentage (blue area represent no payment)

NorFlex has demonstrated different business models including testing a trading membership and transaction fee structure. NorFlex has not implemented any further penalty for lack of delivery, only reduction of payment. Trading fees have been paid by the buyer.

NODES has provided validation and settlement for local ShortFlex transactions. Flexibility sold to the TSO through the manual frequency restoration reserves (mFRR) interface has been settled by the TSO according to existing market rules.

3 AGGREGATING DOMESTIC FLEXIBILTY FROM E-MOBILITY

Tibber is an energy company mainly focused on residential customers. Tibber interacts with its customers via its app. When a person downloads the app and becomes a customer, they can pair electric appliances to the Tibber app. Smart Charging guarantees the customer a discount for their EV charging cost in exchange for letting Tibber control the device, always complying with the constraints previously defined in the app by the customer (Tibber, 2022). These local constraints can range from time of departure to fuse size limitation.

To be able to offer the price reduction, Tibber actively uses arbitraging of the energy prices, either spot price or intraday asset back trading; or by using the assets in flexibility markets, which can be provided to the TSO or DSO.

Tibber provides spot price, insights from energy consumption, and the possibility to optimise heating and EV charging. As data collected from the edge of the grid increased dramatically, it became apparent that steering those loads could not be solely optimised by looking at the spot price. Tibber has participated in Norflex by aggregating local EV chargers. Each asset is not only optimised against spot price and user's constraints, but also considers the flexibility price on NODES. Tibber currently controls approximately 1500 EV chargers in the area. Processes such as asset registration, creation of portfolios, calculation of baselines, trading, activation, and reporting have been automated and processed through the NODES API.

4 RESULTS

4.1 Modelling the congestion areas/order books

Building up the value chain and business models has been done by defining an area of the distribution grid where flexibility from various sources, levels, and providers has been incentivised through an open tender process. FSPs were invited to define and develop a business model using the market design of the flexibility market platform where the DSO and the TSO were the participants for utilising local aggregated flexibility. The pilot area is defined by the regional distribution grid transformers modelled in a DSO tool (GridTools) for assessing, optimising, and trading flexible resources through an API to the NODES market platform. The various grid areas are shown by a polygon in a map and as separate order books to visualise location where the need for flexible resources is.

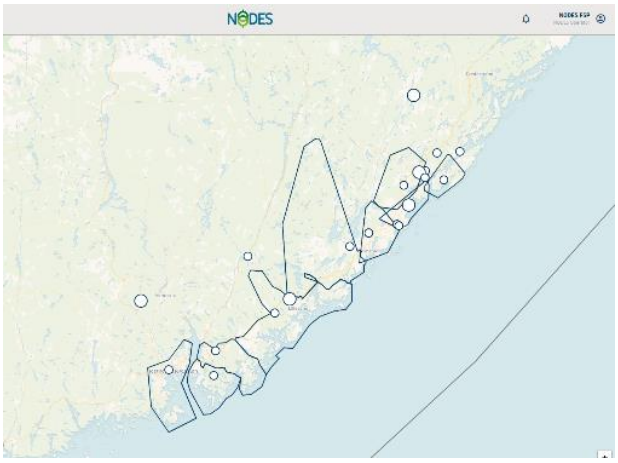

Figure 6 - GridNodes resulting in corresponding ShortFlex order books

To accommodate different business models, GridTools has been developed to have an automated approval process of new flexible resources based on using unique MeterPoint ID registered by the FSP in the registration process in NODES. Early in the pilot, tests showed that the manual approval did not scale and was hindering the business model utilisation. Depending on the automated process of the FSP, new flexible assets are now onboarded without any manual invervention in the value chain. This is a prerequisite for a process where a substantial number of flexible resources like EV chargers are added or removed by the FSP as resources and customers are changing behaviour. GridTools has integrations to internal systems with continuously updated customer grid connections.

4.2 Domestic E-Mobility increasing their share of the traded volumes in NorFlex

It has been an interesting observation to see how the automated aggregation of domestic EV chargers has resulted in traded volumes on NODES. As Tibber managed to automate processes, the project experienced the scalability of the business model as seen in Figure 7.

Expanding the trading location to a new location, Kristiansand, resulted in an overnight request to approve several hundred assets from Tibber.

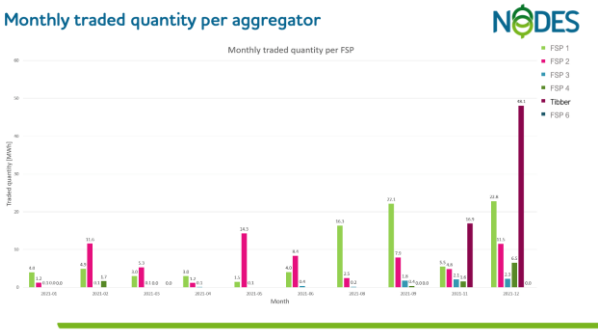

Figure 7 - Flexibility from domestic E-mobility results in Tibber being "best in class" selling flexibility in NorFlex

4.3 Aggregation to existing TSO market (value stacking)

Integrations to other markets are essential to provide enough liquidity in a market. This is to develop a new market and also to unlock the true value of distributed flexibility. In the NorFlex pilot, the integration to the TSO capacity market for mFRR has been done. Any available flexibility not utilised by the DSO 2 hours before the operating hour is automatically bundled and aggregated up to the mFRR as a separate bid to be used to either congestion management or frequency balancing by the TSO. In many ways, a simplified TSO-DSO coordination scheme where the DSO needs to rely on good forecast models, the imbalance prices are not as relevant, and the TSO are provided with flexible volume from resources and levels of the grid that alone are not able to participate in the existing market model. In the pilot, an exception from the 10 MW volume rule for participating in the mFRR market has been granted and has been tested with whole numbers down to 1 MW.

4.4 Delivery quality

All flexibility offered on the NODES platform has a baseline requirement. That means that all resources, either

single or bundled in portfolios, need to be registered with a baseline before a offer can be placed. Baselines must be provided for every hour either as 1-min, 15-min, or 60 min values. In order to verify the trade to the actual delivery, baselines are changed to 1-min values and compared minute by minute to the uploaded 1-min values in the flexibility register AssetHub, developed specifically for the pilot.

Results from the pilot so far show a great variation in delivery quality. This could mean that either the forecast and baseline are of poor quality, or that the model used for verifying needs a different approach.

4.4 Tibber reflections

Forecasting load on a portfolio level for baselines has been a very difficult challenge to solve, considering the size of each fleet and the randomness of customer behaviour. When it comes to trading, algorithmic automated trading was developed for the project, which would need to be further developed as market liquidity increases.

FSPs believe that other products should be investigated for local grid markets. Potential is seen especially in a kind of "insurance of consumption" where the aggregator ensures that a certain load will not be used during a defined period of time. In this way, the aggregator doesn't need to make predictions that are prone to large errors, and the settlement doesn't need to be done on those values.

In Norflex, meter data is reported to AssetHub. AssetHub is a platform developed by the DSO. Tibber believes that this is not a scalable solution, considering that there are hundreds of DSOs in Europe. Developing a custom solution for each market would limit the expansion of aggregators and impair the use of those assets. An ideal solution would be to have one platform at a country level.

5 CONCLUSIONS

This paper has described how smart charging of EVs in Norway can stimulate the use of EV flexibility to offer new services for solving congestion management in distributed grids via a new marketplace, NODES, and for balancing services to the existing mFRR market operated by the TSO.

While some market barriers have already been solved, others still require attention. There is still a need for more testing of baseline methodologies for congestion management and testing of independent aggregation.

Smart and flexible solutions are required in order to facilitate a cost-effective development of the power system. Electric transport is one of the options that have the potential to start playing a key role in developing a smart network.

During the NorFlex project, real trading has been successfully demonstrated with both the sellers and buyers posting bids in the market. NODES market has matched, validated, and settled these trades. From Jan 1 2021 to Jan 31 2022, a total of 318 MWh has been traded for activation (ShortFlex) as a result of 12 618 trades at a volume weighted average price of NOK 8 381,00 per MWh. The lowest traded volume was 0,001MWh, and the largest traded volume was 5 MWh (NODES Market Data, 2022).

ACKNOWLEDGMENTS

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