

Maximizing the utilization of DERs with the Interflex Aggregation Platform for Flexibility

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ABSTRACT

With renewable generated electricity becoming a significant part of the energy mix, aggregated demand response from Distributed Energy Resources is becoming a front runner as a new participant in the energy markets. A big barrier for the integration of aggregator services into market participation is knowledge of the current and future aggregated flexible capacity, or better, the lack thereof. In the Interflex Horizon 2020 project, the Aggregation Platform for Flexibility (APF) was developed: a software solution that empowers aggregators to create a powerful Virtual Power Plant (VPP) that is able to quantify the current and future flexible capacity of a cluster of DERs. The APF enables the aggregator to optimize the trading of flexibility of DERs, such as electric cars, batteries and solar panels, to be utilized in both energy markets as well as ancillary service markets. With the APF the value of flexibility can be maximized by performing value stacking of flexibility, which improves the business case of the aggregator. The following three core principles of the APF are the basis for this. Firstly, insight: the Flexibility Engine provides detailed insight of the current and future available flexibility in the portfolio of the aggregator. Secondly, adaptability, the modular setup of the APF and the ability to define Trader modules make the platform highly adaptable to the aggregators needs. And finally, interoperability: the APF implements open interfaces to easily be incorporated in the operation of an aggregator. The APF is successfully field tested in the Interflex project, where it controls DERs and optimizes the available flexibility to maximize value on a day-ahead market while, at the same time, using the DERs flexibility for congestion management purposes.

INTRODUCTION

With the growing share of renewables in the energy mix a decrease of available controllable capacity on the supply side of the electricity system is expected. Controllable capacity is needed to guarantee a stable, reliable and affordable operation of the electricity system. Since the need for controllable capacity is not decreasing during the transition towards renewable energy, new possibilities of creating large amounts of controllable capacity are

currently explored. Demand response of DER units is one of these possibilities. Hereby the flexibility of DER units is exploited to be available as controllable capacity for the electricity system. The party providing flexibility to flexibility requesting parties as the TSO, DSO and BRP is referred to as an aggregator. The role of the aggregator is to monetize the energy flexibility of DER units, typically by aggregating the flexibility and trade it on one or more energy markets or for providing ancillary services. Exploiting the maximum monetary value is a challenge for the aggregator. There are various energy-, reserve-, ancillary service markets all coming with their own specific constraints; for instance in the form of a minimum bidding volume, time horizon for bidding or spatial location of the flexibility. What the majority of the markets have in common is that they are forward markets, therefore to be active on those markets the aggregator needs a thorough insight in the future available flexibility of its cluster of DERs. The need for insight in available flexibility is getting even more stringent when aggregators have to optimize in multiple markets, which all have their own bidding requirements. If an aggregator decides to participate on a congestion management market, there is a need for locational awareness and knowledge of the aggregators flexibility. This is caused by the local nature of congestion management problems. Considering the former, the aggregators challenge to gain insight in the available flexibility is challenging since it needs fine grained insight in the flexibility of sub-clusters as well as insight in available flexibility of the complete cluster given congestion constraints. This leads to a multi-objective scheduling problem. The APF provides this fine-grained insight to the aggregator and empowers the aggregator to maximize the value of flexibility.

RELATED WORK

The work presented in this paper follows up on various studies and projects done previously. In this section the most important ones are stated. The USEF publication [1] describes the principle of value stacking of flexibility in to maximize the utility of flexibility by aggregators. The APF provides a solution for performing this value stacking principle to aggregators. To do this detailed knowledge in current and future available flexibility is needed, this results in a computational challenge referred to as multi-objective scheduling problem. The multi-objective scheduling problem is presented as ‘Smart Charging

Problem' in [2] by de Weerd et al. The study reveals the computational scalability issues of the algorithms finding the optimal solution for the 'Smart Charging Problem'. MacDougall et al. present machine learning techniques for the forecasting of aggregated flexibility in [3], however these techniques assume the aggregator only has limited information on the state of DERs because of privacy reasons. In the Interflex project we assume no information limitations caused by privacy issues. The communication interfaces implemented by the APF are EFI [4] and USEF [5]. EFI is used for communication between DERs and aggregator, and USEF is used for the purpose of communicating congestion management information between aggregator and grid operator.

MAXIMIZE THE VALUE OF AGGREGATED FLEXIBILITY

As stated, the role of the aggregator is to monetize the value of aggregated energy flexibility of DERs. This can be achieved by trading on energy-, ancillary service- and/or congestion management markets. On which market the most value can be gained depends on several things. There can be distinguished between two main categories: the characteristics of the flexibility and the characteristics of the market. The characteristics of the flexibility determine whether the available flexibility is qualified to be bid into a certain market. These characteristics are: available capacity, ramp up and ramp down rates, longevity and location. For instance, if the ramp up and ramp down rates of aggregated flexibility are slow (minutes / kW) than the flexibility is not qualified for fast responding markets such as primary reserve markets. This has an impact on the maximum value an aggregator can yield with its flexibility. Secondly, the aggregator should be well aware of market characteristics such as the value that can be gained per MWh flexibility on a market. This value can fluctuate highly on small timescales (daily spreads) and can rise or decrease significantly on larger timescales. For instance, the value of flexibility on the market for primary reserve could significantly decrease when high volumes of battery capacity will enter the market, this is likely to happen when prices of batteries further decrease. Therefore, an aggregator should ideally not be restricted (technically or regulatory) to participate in only one market. To avoid the technical dependency of an aggregator to one market, an aggregator can use generic technologies for flexibility unlocking, such as flexibility communication interfaces that are designed for multi purposes use of flexibility, such as the Energy Flexibility Interface [1] and OpenADR [6]. Furthermore, multi-objective optimization engines can be used such as the APF. Using these technologies gives the aggregator the freedom to dynamically switch to the most beneficial market for its flexibility or even stack the value of its cluster flexibility by operating on multiple markets at the same time.

Market characteristics

Energy and reserve markets typically are systemwide (nationwide) markets. The main differences in requirements for participating in the different energy and reserve markets are in terms of reaction time (ramp up and ramp down), longevity and volume of aggregated flexibility. However, congestion management, especially for the distribution grid, is a local challenge. Participating in a congestion management market results in new requirements for the aggregator: the aggregator should consider the spatial location of the flexible DERs. Furthermore, the number of DERs situated in a specific congested part of the grid is typically a subsection of the complete aggregators' portfolio of DERs, and often other aggregators can be active. The behavior of small sets of DERs is harder to forecast than the behavior of large sets of small DERs because in the latter case statistics can be used for reliable forecasts. An aggregator that participates on both systemwide as well as local markets needs fine grained insight in the characteristics of its flexibility on both local scale as well as system wide scale.

AGGREGATION PLATFORM FOR FLEXIBILITY

Aggregators can use the APF to effectively trade flexibility of a heterogenous set of DERs on multiple markets in parallel. The APF allows aggregators to maximize the value of their flexibility because it enables the aggregators to easily trade flexibility towards both local as well as systemwide markets.

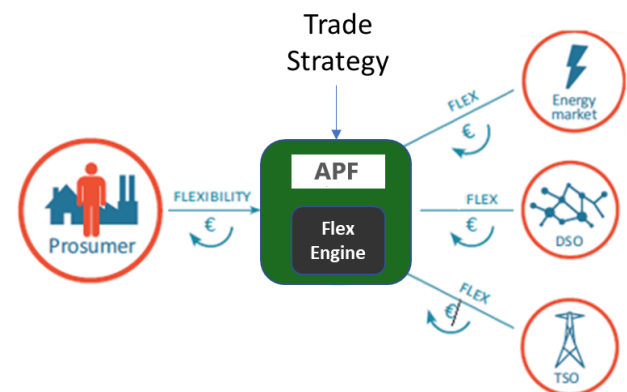


Figure 1: Aggregation Platform for Flexibility in flexibility value chain

Figure 1 depicts the position of the APF in the value chain of flexibility. The figure shows that the APF is between DERs, that are owned by prosumers, and markets for flexibility products such as: wholesale- and ancillary services markets. The APF is a software solution that is developed to be deployed in the operation of an aggregator and it consists out of the following three core principles:

Insight

The beating heart of the APF is its Flexibility Engine. The Flexibility Engine contains the complex mathematics that are needed to gain detailed insight into the available flexibility (current and future) in a portfolio of connected DERs. Moreover, it provides insight into the consequence of (hypothetical) dispatch choices. This functionality reveals the state of the flexibility in the portfolio after a dispatch action. With this functionality the aggregator can determine upfront potential overshoots and undershoots of the aggregated flexibility after a dispatch, as well as other information such as recharge rates. Resulting in detailed knowledge on the available aggregated flexibility in the aggregators portfolio and the ability to utilize it with the highest impact while minimizing trading risks. The Flexibility Engine can provide insight of the flexibility characteristics of sub-cluster of the DER portfolio as well as providing insights in the flexibility characteristics of the complete portfolio given local network constraints. This empowers the aggregator to be active on both systemwide markets and local markets at the same time, maximizing potential revenue. To achieve this the algorithms used in Flexibility Engine needed to overcome the scalability issues of the multi-objective scheduling problem, or smart charging problem [2].

Adaptability

An aggregator has a commercial role in the energy system and to be competitive, it needs to develop smart trade strategies to utilize the flexibility in its portfolio. These trade strategies are an integral part of the identity of the aggregator. To facilitate this, the APF supports configurable trade strategies (business rules), with which the aggregator is always in full control of the flexibility in its portfolio. A trade strategy is implemented in a Trader module. There can be multiple Trader modules active simultaneously. A Trader module queries the available flexibility from the Flexibility Engine. With this information a Trader module makes buy/sell decisions on the market where the Trader module is active. After a buy/sell decision the Trader module sends the dispatch information of the trade to the Flexibility Engine and the Flexibility Engine determines and handles all the necessary allocation to the DERs to fulfill the dispatch. Typically, a Trader module is only active on one market, so a Trader module is implemented for every market the aggregator decides to be active on. This keeps the logic of the module simple and the behavior analyzable. Simultaneous dispatch actions from multiple Trader modules can lead to unintentional behavior, therefore the actions of Trader modules can be prioritized over each other.

Interoperability

The application of open communication standards is an essential feature of the APF. The aim of this feature is to simplify and accelerate the ability to incorporate the APF

in the operation of aggregators. To achieve this the open communication protocol used for the southbound interface of the platform, the communication towards DERs, is the *Energy Flexibility Interface* (EFI) [4]. The EFI protocol is an initiative of the Flexible Power Alliance Network and is specifically designed for expressing the flexibility characteristics of DERs into an abstract information model. On the northbound of the platform, where the communication towards markets takes place, the communication protocol of the *Universal Smart Energy Framework* (USEF) [5] is implemented. This communication protocol can be used for participating in congestion management markets, for example of DSOs.

Architecture

An abstract view of the main building blocks of the APF architecture is depicted in Figure 2, the gray area represents the APF. In the center of the platform the Flexibility Engine is shown, which is connected to the Resource Managers modules on the below the Flexibility Engine. The Resource Managers are virtual representations of the connected DERs shown on the bottom of the figure. The DERs are connected to the Resource Managers via the EFI interface.

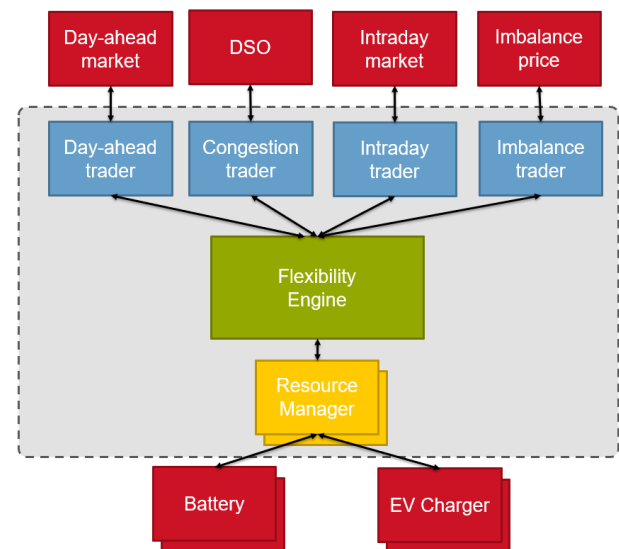


Figure 2: The APF architecture

Above the Flexibility Engines several possible Trader modules are depicted. These Trader modules connect to the markets on the top of the figure.

USING THE APF IN THE FIELD TEST

Description of Interflex pilot

In the EU H2020 Interflex project five field tests are being performed [7]. One of these tests is the Dutch field test,

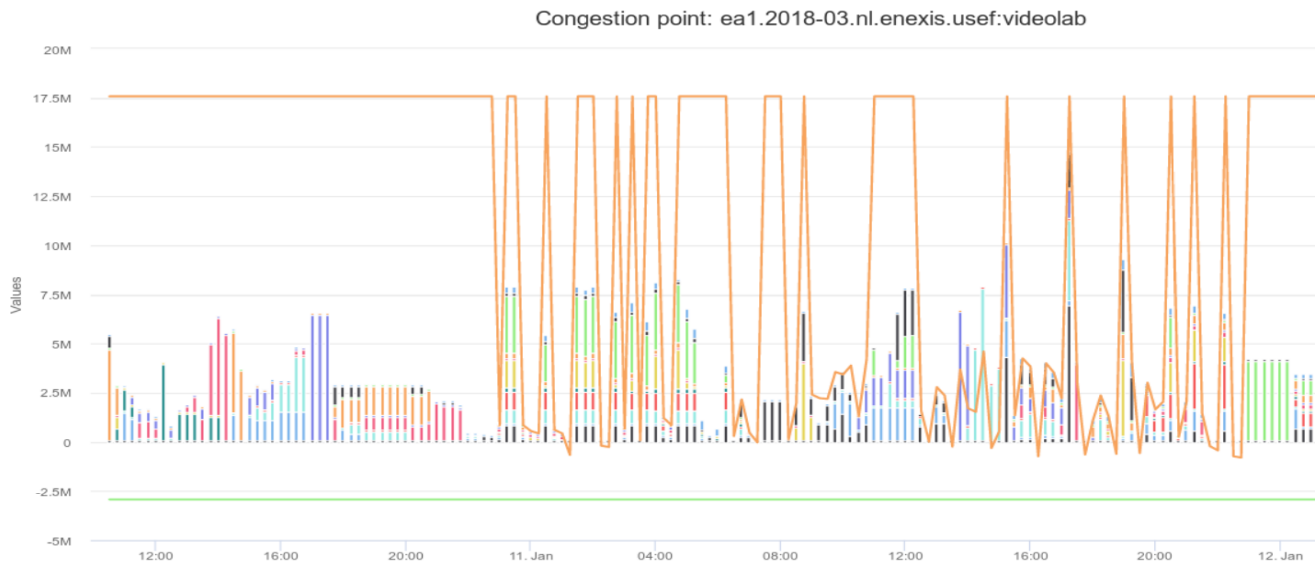


Figure 3: Snapshot of APF reacting on a local congestion constrained received from the DSO (Enexis)

executed in Eindhoven[8]. The overall purpose of this field test is building and validating a system in which flexibility is used as alternative to grid reinforcement, both from a technical and businesswise perspective. The field test does not only comprise the development and validation of multiple IT-systems, but also includes contracts between all actors and business models for the actors. The field test takes place in the operation area of Enexis, a Dutch DSO, Enexis procures flexibility from multiple aggregators via an auction-based market which is based on USEF. The APF is deployed in this field test as an IT platform of one of the aggregators, where it is controlling the flexibility of a 315-kWh battery, a curtailable PV installation, and simulated electrical vehicle charging poles. To test various kinds of scenarios and scale sizes, the APF is also connected to simulation models of batteries, charging poles and PV installations.

USEF flexibility market

In order to trade flexibility between the aggregators and the DSO, a USEF based congestion management market is set up for the field test. Trading on the congestion management market takes place day-ahead and once a day. To come to a trade, an aggregator first sends its daily aggregated demand prognose to the DSO. Afterwards, if the DSO expects congestion it sends out flexibility requests to all aggregators active in the congested area. The aggregators can then offer (parts of) the requested flexibility together with an associated price. After the DSO receives the offers, it determines which offers to accept and then orders that flexibility from the aggregators. Finally, after the period in which flexibility has been traded is elapsed, the DSO and aggregator continue to the settlement phase in which is determined how much of the flexibility has been delivered. In this way expected congestion can be avoided.

To enable the APF to join this congestion management market, the USEF interface was implemented. Furthermore, a Congestion Management Trader module was developed. The Trader module uses the Flexibility Engine for two purposes. Firstly, to determine the day ahead aggregated demand prognose for the DERs connected to the platform. And secondly, to determine the amount of flexibility that is available for answering the flexibility request of the DSO and the associated price of the flexibility. If a flexibility trade is established, the Trader module informs the Flexibility Engine, which will execute the dispatch the flexibility in the portfolio. This process of trading flexibility on the congestion management market takes place after another trading module in the APF traded on the day-ahead wholesale energy market. This way, value stacking of flexibility is performed.

Results from Interflex pilot

A successful demonstration of the APF is given in the Interflex field test. In this demo, the APF contains two Trader modules. The first Trader uses a prediction of the prices in the day-ahead wholesale energy market to optimize the energetic behavior of the whole cluster. The second Trader, which is connected to the DSO (Enexis) via the USEF congestion management interface, subsequently optimizes, in case of the presence of local constraints, the use of flexibility on the USEF congestion management market. A result is shown in Figure 3 where the plan for the DERs under one congested area is shown. For this congested area, a trade on the USEF congestion management market has been made for the next day. The upper orange line shows the congestion constraint received from Enexis. The colored bars represent the adjusted behavior of the connected DERs calculated by the Flexibility Engine to not violate the constraint. After the

plan is established, the APF controls the connected DERs to realize the plan. For the battery and PV installation in the field test, this means that the APF sends EFI messages to the party operating the battery and PV back-end control system.

FUTURE WORK

Currently, the field test considers only day-ahead trade for congestion management. However, given the unpredictable nature of electrical vehicle charge sessions, the next test case is to add intraday (congestion management) trade as well. To do this with the APF, one simply adds an intraday congestion trader with corresponding business logic to add another optimization goal to the platform. The same applies to the balancing markets.

CONCLUSIONS

Value stacking of flexibility by selling it on multiple markets improves the business case of the aggregator. To effectively schedule a vast number of DERs, an aggregator has to solve a multi-objective scheduling problem. Furthermore, the aggregator needs to be able to deal with heterogeneous bid requirements, forecasts of both global and local events and forecasts of both system wide energy markets as well as local energy markets. The Aggregation Platform for Flexibility (APF) empowers the aggregator to perform value stacking. With the APF an aggregator can effectively create a VPP. The following three core principles of the APF are the basis for this. Firstly, insight: the Flexibility Engine provides detailed insight of the current and future available flexibility in the portfolio of the aggregator. Secondly, adaptability, the modular setup of the APF and the ability to define Trader modules make the platform highly adaptable to the aggregators needs. And finally, interoperability: the APF implements open interfaces to easily be incorporated in the operation of an aggregator. To demonstrate and validate the concepts of the APF, it is field tested in Interflex Horizon 2020 project, it has shown to be able to serve the DSOs congestion management needs while maintaining day-ahead schedule that is based on prices on the wholesale market.

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