GRID MANAGEMENT SYSTEM TO SOLVE LOCAL CONGESTION

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ABSTRACT

The energy sector is changing. The increasing amount of solar and wind energy has a considerable impact on the electricity grid. These renewable energy sources bring more volatility and less flexibility to the power system on the supply side. Therefore, we need more flexibility on the demand side for coping with operational challenges in maintaining the stability, reliability and efficiency of the grid. On the other hand, new patterns of energy consumption can be observed on the demand side too. The capacity of the power grid is dimensioned based on the peak load. The Distribution System Operator (DSO) is responsible for maintaining the grid and overcoming these challenges. Grid reinforcement as one of the traditional solutions to expand the grid capacity is time consuming and more often not a cost efficient approach to address this problem. By transition towards smart distribution networks, local flexibility on the demand-side can be employed as an alternative solution. Enexis builds a Grid Management System (GMS) which uses this information to forecast local loads and has a smart algorithm to decide where and when flexibility is required to prevent congestion.

Enexis develops, constructs, maintains and manages the electricity and gas grid in the North, East and South of The Netherlands for approximately 2.6 million customers.

In this paper you get detailed information about the functionality of the GMS and the challenges Enexis faced when building it.

INTRODUCTION

Nowadays, the power system is confronted with several challenges due to a high penetration of renewable energy sources (RES) and a growing number of new technologies such as the Electric Vehicle (EV) and Heat Pumps (HP) which are crucial for the transition towards more efficient energy generation and consumption. The power system, in particular the distribution network is exposed to all these new challenges. [5] The electrification of heating system (such as heat pumps) and mobility is resulting in increasing demand. Simultaneous charging of Electric Vehicles (EVs) leads to higher peak demand in the distribution network. This can result in violating the network limitations and lead to congestion problems at MV/LV transformer or its underlying LV feeders. Hence, it is essential to investigate alternative solutions and adopt an appropriate approach which can comply with the characteristics of the problem and also, benefit from the privileges that smart grids offer. Local flexibility on the demand side can be a great resource for DSO's to address the congestion problem [6]. As a result, a DSO can use the demand-side flexibility to control the peaks and prevent or postpone the reinforcement. In specific cases the use of flexibility can be more effective and efficient than reinforcing the grid. To employ flexibility, a DSO needs deep insights of the load behavior on the local electricity grid, to prevent congestion problems and contribute to a better utilization of the network capacity. Flexible loads such as electric vehicles and batteries can be used to deliver flexibility. This can be achieved by using a flexibility market, where local demand and supply can be optimized. In order to be able to participate and benefit from the flexibility market, a DSO has to identify potential congestion problems ahead. Predicting energy consumption and production is the key to have a clear insight of upcoming congestion problems. Congestion problems are strongly location dependent, thus a clear insight of the local network such as, asset information, historical measurements and weather data is required.

The development of the Grid Management System is part of the "Interflex" project. To make the energy transition smoother and faster in Europe, the Horizon 2020 "Interflex" project was initiated by the European Union. In total, there are six demonstration projects led by five DSOs in five different European countries. The Dutch pilot is conducted in the city of Eindhoven. The project has been started in 2017 and is expected to be completed by the end of 2019. Two knowledge institutions of the Netherlands (ElaadNL and TNO) are working in close cooperation with Enexis to test a local flexibility market. The goal of this project is to investigate the possibilities of using local flexibility and evaluate the efficiency of a flexibility market.

Distributed generations such as, solar panels and windmills cannot be controlled by a DSO or Transmission System Operator (TSO). The same applies to the large electricity consumptions, like EV charging poles and heat pumps.

Fortunately the retail market has changed dramatically during the last decade. Thanks to technology advancements, devices which are able to measure their environment and react automatically, so called "Smart Products", are becoming more common and pervasive. However, smart products are not adequate for our use-case to solve the grid congestion. We also need forecast models as well as specific communication between the different products in the network. A clear insight and detailed information about the peak loads, grid status, severity of the congestion and the maximum available capacity of the grid is required.

Briefly, it is essential to move towards a "Smart grid". In the future distribution networks both power and information flows are bidirectional. From a technology perspective, a smart grid can be defined as a "system of systems”. A smart grid is an electrical grid, using two-way communications and distributed intelligent smart products.

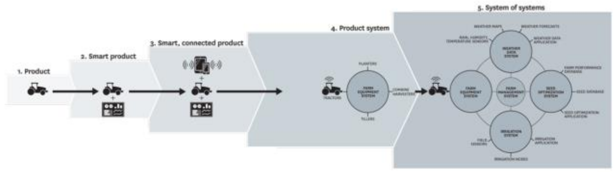

Figure 1: system of systems

In the “system of systems” model, every smart product needs to know its position in the system. In this case study, it is important to specify which assets are part of the system and how they are connected. The second function of “system of systems” is to predict the future.

If we define a smart grid as a “system of systems”, then the following components are required:

- Smart connected assets;
- A system that connects smart assets;
- Location dependent information.

Furthermore, a standardised open communication protocol is needed. For market communication, we have used a framework based on Universal Smart Energy Framework (USEF). In the Netherlands and in other European countries, USEF is already widely adopted.

A LOOK INSIDE

Since the main goal of the Grid Management System is to solve the local congestion, first we have to detect the congestion points and then, the “actors” which are active to solve the congestion problem. Congestion can occur on a transformer and on a feeder level.

Per congestion point, it is required to identify:

- The maximum capacity of the assets;
- The forecasted electricity consumption and production;
- The actors which are connected to that congestion point and are able to solve the congestion.

In the current version of the system, we implemented a market model which is aligned with USEF. Therefore, only aggregators are connected to a congestion point. In our pilot environment, multiple aggregators are connected to one congestion point.

> The definition of “actor” in this project:
>
> - A device or market participant that has a flexible load and can solve congestion for a specific congestion point.

In order to use the available flexibility efficiently, the GMS system follows predefined steps, as you can observe in the figure 2.

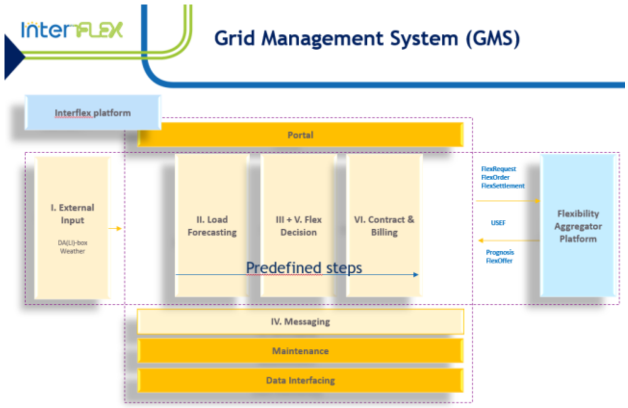

Figure 2: GMS system ICT architecture

The GMS system needs all the illustrated modules, in figure 2 in order to work properly. Only the main steps, in yellow, are described in the following paragraphs.

New modules can be added to the system and existing modules can be upgraded without changing the core of the system. The system is designed to be scalable and replicable. For more details see the paragraph “NEXT STEPS, technical”.

<u>Step I: External input, receiving and storing historical data</u>

The Enexis DALi (Distributed Automation Light) system is responsible for collecting the grid data from the measurement devices installed at the Medium Voltage (MV)/Low Voltage (LV) station. Widespread role out of DALi boxes is in order to improve the observability of the distribution grid. DALi is the Enexis light version of a SCADA system. Main goal is to switch public lighting and gathering measurements of 35.000 MV/LV stations. The DALi-Box measurements are including active/reactive power, voltage, current, harmonic distortion, open door and short circuits detection. Alarms are sent instantly and the measurement data is sent every 15 minutes or when a measurement exceeds a predefined threshold. At this moment (December 2018) the system processes 40.000.000 measurements per day for the 1.600 active DALi-boxes. The DALi-box can measure on a transformer level and on all of the underlying feeders.

Figure 3: DALi - box

The second data source for the GMS is weather data, which contains a local weather forecast including wind speed, temperature and solar irradiation.

All the data is stored in a BIGdata cloud environment to analyse trends and for possible future use. For the Interflex project, two DALi-boxes have been installed in the local MV/LV stations.

Step II: LoadForecasting, the use of data to predict congestion

The first step of every smart system is to "sense". Sensors such as DALi devices and historical weather data can provide us with some inputs for load forecasting. However, due to peak load fluctuations and uncertainty of solar energy generation or EV charging schedules, it is quite a tough task to achieve an accurate peak load and consequently, congestion prediction.

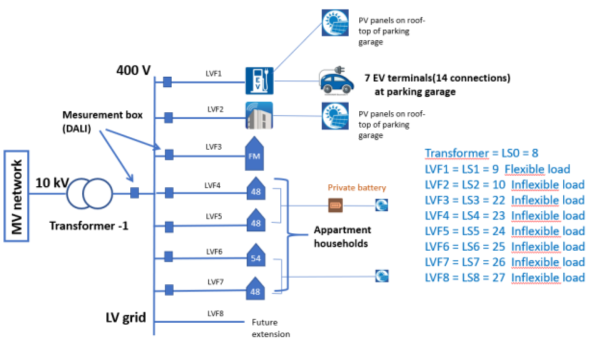

Figure 2: LV net topology at pilot area

The figure 4 picture above shows one out of two pilot locations in Strijp-S, Eindhoven.

For the loadforecast module, the historical 15 minute values (voltage and current) are used. This historical sensor data as well as the weather forecast data (sun radiation and wind speed) are the inputs of the load forecasting module.

The loadforecast is divided in two parts including the flexible and non-flexible load. A load forecasting algorithm specialized at forecasting residential loads is developed. The algorithm provides a 48-hour rolling window forecast, with 15-minute resolution on a MV/LV transformer level. Details can be read in the CIRED paper "Short-term load forecasting on mv/lv transformer level. Paper No. 559".

The flexible loads are forecasted by the aggregators and then sent to the GMS using the standardized USEF messages for receiving a D-prognose per aggregator per congestion point. In the Interflex pilot, there are several smart assets including, charging poles, solar panels, Smart Storage Unit (SSU) and a smart building, which results in several D-prognosis. The total load on a transformer level is measured by the DALi box.

Step III: Flex decision, make a flex Need decision

Primary goal is to devise a system which can run automatically without any human interaction. The decision module has been developed to decide whether flex is required. The basic logic of the decision is as following:

- If the maximum capacity of the transformer is less than the sum of the flexible and non-flexible load forecasts, then congestion is predicted and flex is needed.
- The second task of the decision module is to calculate how much the DSO is willing to pay to prevent the predicted congestions and how much risk is involved if the required flex cannot be delivered. This is defined by DSO as the proposed price and the sanction of the flex request.

The Flex Decision Module (FDM) determines both magnitude and the duration of the overloading based on the load forecast and transformer capacity. Subsequently, the overloading impact on the life expectancy of the congestion point asset can be estimated. The loss of life expectancy of the asset can be translated to a monetary value. Moreover, in case of severe congestion which would likely result in a temporary disconnection of customers, an extra risk factor is also considered. This risk is also translated to a monetary value. Both values together is the amount per Programma Time Unit (PTU) in the flex request. Details can be read in the CIRED paper "Flexibility for congestion management: an operational decision-making process, Paper No. 644".

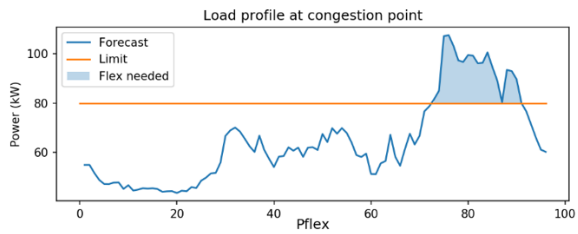

Figure 3: Congestion graph

Besides, a sanction price is determined, which should be paid by the aggregators in case they fail to deliver the requested flexibility. The sanction value is calculated by the difference between the settled flexibility price in the local market and the expected revenues an aggregator can achieve on other markets (e.g. imbalance) which operate on shorter time scales. In this way, the incentive to adhere to the promised flexibility profile is taken away.

Step IV: Messaging, sending Flex requests and receiving Flex offers

In case that flexibility is needed, the aggregators should be notified by the DSO. In order to notify the aggregators, a flexibility request is sent to them. This message contains how much flexibility is needed at what time. The connection between aggregator and congestion point is maintained in the GMS. Only those aggregators receive a flex request which are capable of solving the local congestion. The time is defined in PTU's (one value per 15 minutes, maximum of 96 values in one request).

The attribute named 'Power' provides the aggregator with the amount of required flexibility. This is exactly aligned with the USEF protocol. It is noticeable that in the current market design of USEF, the flex requests are generated in one direction: either increasing or decreasing the energy consumption. In order to prevent exceeding the limits, the trades are iterated until the grid is safe and required flexibility is settled. In order to cope with this potential overshoot (too much delivery that causes overload), a maximum and minimum volume should also be included in the flex request. The attributes 'PowerMin' and 'PowerMax' are used to indicate what the upper and lower boundaries of flexibility are. This will reduce the number of needed iterations. With respect to the fact that there are multiple actors (aggregators) connected to one congestion point, there can be more than one offer per request.

In addition, the DSO sends the 'SanctionPrice' attribute. This attribute indicates the penalty price that aggregators need to pay in case of failing to deliver the offered flexibility. Sending the penalty price as an attribute of the message rather than a standard penalty price setting can have a positive influence on the amount of available flexibility in the market. Variety of available flexibility resources will lead to better business case for flexibility owners who are willing to participate in the market and also provides the DSO with access to higher amount of flexibility. Every aggregator is allowed to send more than one offer, with a different combination of price and sanction price. The SanctionPrice is an addition to standard USEF.

Step V: Flex decision, making a flex order decision

After the system has sent out the need and price for flexibility, aggregators can submit offers as a response to supply the requested flexibility. If more than one aggregator submits a suitable offer, an evaluation and selection procedure is started to determine which offer(s) should be adopted. In this process an 'acceptance factor' (AF) is calculated for each flex offer., This acceptance factor is based on the price of the offer, the ratio of offered flex in compare to the requested flex, and the number of offered PTUs. The most reasonable offers will be selected by calculating the AFs and checking whether the offers comply with the maximum price and minimum sanction,. If the selected offer cannot completely solve the congestion problem, this process should be iteratively repeated for the remaining offers until the congestion is fully solved or no more suitable offers remain.

Step VI: flex settlement

The observed baseline is the base load profile which would happen if the aggregator did not deliver the flex. Since some flexible loads, such as EVs, are less predictable, this value allows the aggregators to specify what the baseline actually is. Delivered energy is the actual energy (positive or negative) that has been delivered by the aggregator.

The difference between the actual situation when aggregator takes no action (ObservedBaseline), and the actual delivered energy is defined as the delivered Flex. Briefly:

ObservedBaseline - DeliveredEnergy = DeliveredFlex

NetSettlement = sum (DeliveredFlex) – sum(Penalty)

The flex settlement message is also a standard USEF message which is sent every week from the DSO to the aggregators. The amount of the aggregator's invoice received by DSO should to be equal to the sum of the flex settlement messages.

CHALLENGES

From a historical point of view, DSOs are focused on grid stability and long term investments. Quick response to changes was not the main responsibility of a DSO. Most DSO organizations as well as the electricity grid, are hierarchical. Building a Grid Management System cannot be achieved without gathering the expertise of several specialists who are scattered in a hierarchical organization. Enexis has created cross-functional teams of specialists who are focused on all innovative aspects of smart grid development within the organization, which has been proved to be the key to efficiently carry out smart grid innovative projects. All the smart grid development projects are executed in agile/scrum teams. These teams create products for several projects. In this way, the expertise will be preserved in the team, even after ending the projects.

SCADA systems and other ICT components in the electricity grid have a very long lifespan. Replacements are quite costly and can have a high risk of failure. Those systems and components are not suitable for smart grid developments. The Enexis organization has opted for a dual approach. The SCADA system and the core of the electricity grid are subjected to slow changing components, since the main focus is to avoid the risk and ensure the stability of the grid. On the other hand, we are devising small scale but more agile systems, such as DALi and the GMS. These systems have a secure one direction communication with the SCADA system for receiving data. However, they cannot send the data back. Through this approach, Enexis can take advantage of both worlds in a secure way; The core components focus on stability and risk avoiding, and the smaller systems focus on flexibility and innovations.

NEXT STEPS

The power system keeps changing rapidly. In order to maintain our position as an excellent DSO, we need to obtain flexibility to use our assets efficiently. Profound insight of the loads behavior is essential. The GMS provides these insights and contains knowledge about where and when to obtain flexibility while it is also cost effective. This flexibility can be obtained through a flexibility market or can be unlocked via other approaches e.g, network tariffs, bilateral contracts or connection products like variable capacity. For all these kinds of mechanisms, a GMS system is required. Most of the modules are needed and can similarly follow the same steps as in the current system:

I. Receive measurements and various inputs.
II. Forecast the load or any other target value.
III. Make a decision.
IV. Send a message or communicate with another system.

All the modules of the GMS system are designed and built in a way that new or updated modules can easily be integrated to the system. There are several ideas to upgrade the current system.

The current system is developed based on an USEF market model. One of the ideas is to add extra protocols such as Open Smart Charging Protocol (OSCP) In this case, the output is not a flex request, but a load profile for a charging pole operator.

The second idea is to create a GMS to GMS communication. If one GMS system is not able to solve the local congestion, maybe there is a possibility to ask another neighborhood GMS system to deliver flex.

For the decision modules some kind of Artificial Intelligence algorithm that is self-learning and will optimize the decision also sounds like a logical step.

CONCLUSION

The energy market is required to be adjusted and adapt to the energy transition. To accelerate moving towards this important change, we have to go back to the mindset when electricity was new. As Thomas Edison said:

> “I have not failed. I’ve just found 10.000 ways that don’t work”.

Experiments and changes are necessary. However, failure in a productive electricity grid is not acceptable. Therefore, pilot studies and running innovative projects are essential.

Making use of new technologies, like BIGdata, decentralization, smart products and cheap sensors provide us with the opportunity to create a smart grid. This also means that ICT becomes a part of the core of an electricity grid. Creating multidisciplinary teams that understand new technologies as well as the electricity grid is essential. Through these approaches, Enexis has created a first version of a local Grid Management System. In 2019, the system will be tested and new functionality will be added. For Enexis, this is the next step in realizing a smart grid, and to stay in the top position of DSO’s in Europe.

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