VIRTUAL POWER PLANTS
LEVERAGING ENERGY FLEXIBILITY IN REGIONAL MARKETS

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ABSTRACT

In recent years, two trends determined power supply: sharp rise of decentralized generation and proliferation of renewable electricity generation, which both take place mainly in distribution networks. Virtual Power Plants (VPP) have therefore become increasingly importan, and regional market places might arise from this. Management of the Distribution System will increasingly need enhanced functionalities like Active Network Management (ANM), new processes and roles described below.

INTRODUCTION

The energy industry in Europe has been in a state of flux for years. Experts say that they are "in the middle of a new energy paradigm". Currently, four factors are particularly affecting the electricity sector: continuing market volatility, growing environmental awareness, the growing importance of sustainability in our culture, and the ever-increasing trend towards digitalization. Overall, the development is characterized by uncertainty and unpredictability.
An important prerequisite were the energy policy decisions of the previous years, which led to a sharp increase in decentralized and regenerative electricity generators, especially in distribution networks. Against this background, Virtual Power Plants (VPP) can play an important role in energy supply

THE CHANGING ENERGY SYSTEM

New tasks for Virtual Power Plants

In the last years the main focus of VPPs were aggregation of **Distributed Energy Resources (DER)**, which has slightly changed by adding thermal power plants and using district heat networks as storage. Current VPP's references reach further: Monitored and controlled via a Distributed Energy Management System (DEMS), VPPs now operate in conjunction with Demand Response. Additional requirements arise from construction of new neighbourhoods (e.g. smart city Aspern in Vienna) or microgrids, which are energetically partially self-sufficient, and by increasing flexibility in industry. Both interact with others and exchange flexibilities via VPP (Fig. 1).
A demand side management system ensures that power is consumed or stored when needed. Reaction of prosumers on market prices is called **Demand Response (DR)**. Industrial, commercial enterprises or households which stand for "demand", respond in real-time on production situations, power fluctuations and power market changes ("response"), which gives them additional revenues.
DR technology has been prevalent in the US for several years. Reusing this experience is a chance for upcoming pilots in Europe, especially for DSOs who have to initiate a DR program and users who need to agree to participate.

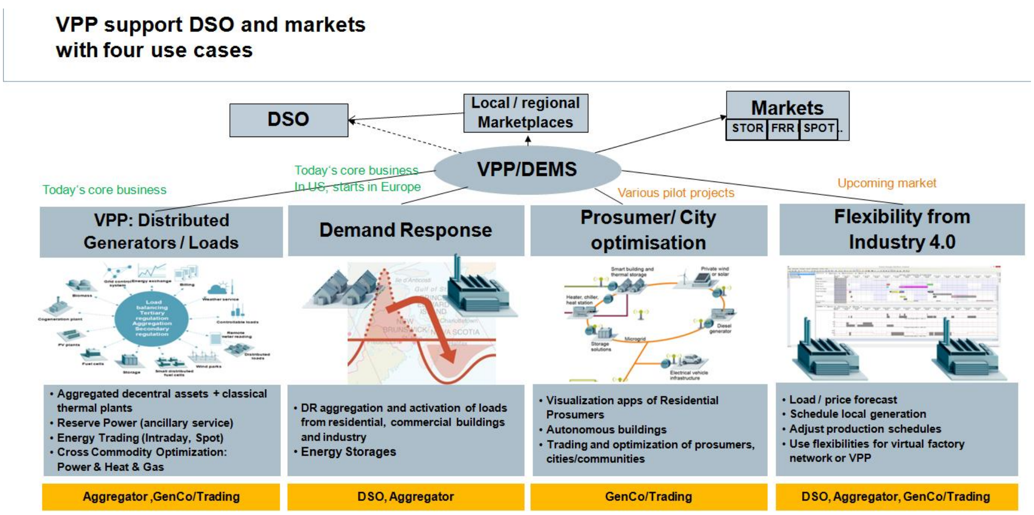

Fig. 1: Future VPP tasks: aggregate and offer flexibility to markets or DSO

The Increased Importance of Analytics

Localization of Forecasts

Today expected consumption is usually determined on the basis of statistical standard load profiles (SLP - approx. 30 for Germany, 8 profile classes for UK) in the household sector and special profiles for large customers. Due to the increase in smart meters and number of measuring points, large amounts of data are collected. The analysis of such data makes it possible to describe the system behaviour better and to predict it much more accurately.

However, in the future intelligent houses will not act like the sum of many individual profiles, but rather as a storage, as they will decide by themselves whether they supply energy to the market, or if they consume or store for themselves due to the price forecasts of the different market segments. Forecasts will be distributed by specialised companies or by DSOs which will offer them as a daily "newsletter"-service or customized to needs.

Increasing amounts of data as well as a dynamic market environment with a growing number of market participants, and thus a greater number of strategies, shorter decision-making periods and coupled markets, generate a process complexity that cannot be analysed timely by specialists anymore. Here, more powerful methods of machine learning and artificial intelligence, such as neural networks, provide assistance. These methods are not only predictive (predictive analytics) in the sense of Data Analytics, but they also provide concrete recommendations for action **(prescriptive analytics).**

It is obvious that the intensified data analysis for municipalities and DSOs will be the key to assess customers better and more individually, providing them with added value.

Short-term changes in the forecasts, actual values or log-outages of the pool participants as well as necessary portfolio adjustments by changing the markets and the necessary adaptation of the planning of the respective technical unit will take place in ever shorter cycles and several times a day within a VPP. Commercial and technical criteria must be considered, too.

However, it is unlikely that all market participants will create their own forecasting tools, but different players will use a common forecast for their decisions as a basis, which can lead to market movements (especially in small market segments).

With the new possibilities of "big data" being more regionalized, more often updated and accurate forecasts are possible.

Managing the Smart Distribution Grid (DG)

Active Network Management

Traditional approaches to network design have involved modelling worst case scenarios of minimum demand or maximum generation when assessing the impact of DG developers seeking to connect to the network. ([1]).

Having in mind the possible fluctuations in network stability and operation, it is important to know not only if and when problems (voltage violations, thermal violations) are likely to occur, but also if a DSO will be able to resolve them and which countermeasures can be applied. Modern techniques for network state estimation can calculate a realistic picture of the actual network conditions based on a limited number of real-time measurements. With fairly precise load and generation forecasting it is also possible to simulate the network state and subsequently required countermeasures over a period of time in near future e.g. 24 h, 48 h, 72 h. Volt/VAr Optimization tools can be used to deduce countermeasures that avoid critical network states.

The information of possible volatility can also be propagated to a TSO and other involved parties in the market as it affects their operations as well. So a TSO has an opportunity to obtain far more detailed information about the connected distribution networks than with its own forecasting system. Even with the best prognosis but without knowing detailed information about specific distribution networks it is becoming harder to anticipate and react to the events in transmission networks.

A semaphore model is used both as logical and visual presentation to convey the obtained network state information. The three discrete states reflect the state of the network and the DSO's ability to resolve the actual and anticipated volatility and provide the required information in order to enable the operator to react in time

With this so called **Active Network Management (ANM)** software - that Siemens has also developed -, fully automatic control of power networks can be realized. The basis for this is a load flow calculation near real-time. The ANM has access to a database that contains network structure or topology, as well as data about all components. The software records the current state of the power grid, identifies problems, finds optimal solutions and controls the network accordingly. For given energy feed-in and consumption, ANM calculates how the load flows spread over the network.

Due to modern computers a pure focus on limited hot spots resolving issues strictly on rule based approach is no longer needed. On the other hand a holistic and dynamic calculation based on variant scenarios allows the DSO much greater flexibility.

Grand Unified Scheme – Northern Powergrid (UK)

The distribution grid was supporting a high penetration of variable loads and generators (ca. 650 domestic participants included on time of use tariffs, 380 with heat pumps, 470 with solar photovoltaic (PV) panels and 160 electric vehicle (EV) users [2]) and further installation of such loads had the potential to exceed operational limits causing:

- voltage band violations and
- thermal overload of primary equipment.

With a multilevel hierarchical ANM solution (see Fig. 2) incorporating a central application system with a data warehouse and several autonomous substation controllers using a wide area communications system, the problem could be avoided. The Grand Unified Scheme brings together response and real-time thermal rating in a closed loop for optimal grid operation (e.g. 1,200 distribution

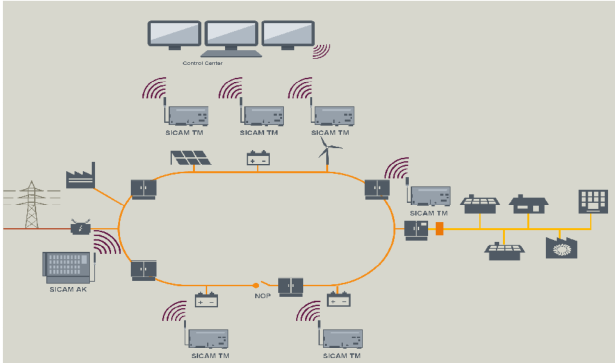

Fig. 2: ANM for Northern Powergrid

substations, 7 batteries, 6 controllable transformers).

Benefits of ANM

The ANM and flexible connection techniques explored in actual projects will form the basis for the technical requirements for the transition towards a DSO model and empower DSOs, to support TSO, control the Distribution network and issue actions to DERs directly connected.

Through real-time monitoring and control of the grid a DSO will be able to connect DER at lower costs and/or significantly earlier than traditional reinforcement would allow (**up to max 40% cheaper and 4 times faster** than classical DER integration). In a future smart grid, **VPP and ANM complement each other** perfectly.

Surgical Demand Response

VPP Demand Response uses a flexible load aggregation engine that allows aggregations to be defined by substation, feeder line, zip code, map interface or several other associations. This ‘surgical’ approach uses DR program resources more efficiently and allows utilities to ‘condition the load’ so that grid conditions are more favourable to safe and reliable operations. For example, DR can be configured to automatically execute DR events on loads serviced by specific substations or feeder lines when they are under operating stress and threaten reliability. Surgical DR gives utilities the ability to limit or avoid outages, restoration costs, and it contributes to longer, better performing assets.

LATEST DEVELOPMENTS

Electricity Markets

Ancillary Service Markets

In most European ancillary service markets, an availability and energy pricing model is established. For the trader, it is first of all important to be considered in the award. Therefore, the distribution of the offers made by all market participants is relatively low because everyone is trying to hit the market clearing price. After initial selection, activation is initiated by a merit order of energy prices. The distribution of activation offers is much bigger and reflects different strategies. In recent years, the market has changed: while a few years ago availability was adequately paid, the price paid today for some markets and offers in many time intervals is close to 0 EUR per MWh, which means that money is earned only via the energy price.

The ratio of the amount of activations to the average call size and duration is of great importance. If the distribution of the offers were taken into account in the tenders, there would be considerable potential for revenue. Neuronal networks show significant advantages over classical statistical methods in such market behaviour. The interest of the flexibility providers is still strong to participate in the regulatory energy markets.

Spot Markets - Intraday and Day-Ahead Trading

The spot markets Intraday and Day-Ahead have grown steadily since the beginning of the 2000s. Further growth is expected. On the other hand, prices tend to go downwards.

General Market Trends

Most of the European markets trend towards reducing minimum offer size and auction periods ([3], p. 67f). Gate closures will be closer to production time and market coupling will continue. Which means that more and more traders/ aggregators would like to participate in a greater “European” energy market. This might lead to an ever greater competition and for most of the participants increased flexibility for generation capacities and offers. This would lead to a more complex planning process and will generate more stress to the TSO and DSO as **traditional day ahead planning is no longer suitable**.

Regional Energy Markets

With a focus on local energy production, local/regional markets will arise to support this local for local idea (see Fig. 3.). Local residential or aggregators check their need and offer/ask for energy. The regional market place owner and/or aggregator bundles these requests and defines market prices. Surpluses or deficits are treated by the VPP, looking for compensation either in the market or in other VPP’s. DSOs might organize these regional markets. A sufficient volatility would be prerequisite to enable such market places. The **ENERA** project is a use case which will test such markets [4]. In case of grid congestions the DSO may use the regional market place to activate flexible DERs. DSO will also be responsible for balancing services in their area of responsibility if some DERs miss their production schedules and will be responsible for the settlement process. They will also support TSOs to help them manage grid congestions on transmission level.

So far only market changes have been considered, indicating an ever bigger market volume. One way to get out of the "Economy of Scale" for energy companies would be the **supply of additional services**. In this case an additional service in the form of diagnostics, load profile trimming or energy consulting etc. is offered on the basis of the present customer data in order to counteract the fall in prices. Again, VPP can help. The offers could be provided on the web, as a personalized newsletter or through remote interventions on the decentralized systems.

New Business Models and Roles

The agility in the energy sector becomes the imperative: a formerly "quiet" industry has to constantly reinvent itself and always question strategy. A possible reaction to this can be **new price and business models** for energy sales.

There are currently several approaches. Below a short outlook on major, possible developments is described:

Flat rate; the conversion of the energy supply is accompanied by a change in the market. For the current market a flat rate still sounds like future music, but the essence of our market economy is that new paths and concepts are being pursued. The advantage for the customers is clear: they neither have to worry about their consumption behaviour nor to restrict themselves; they also have the full cost control (at least as long as it remains below the limit). This business model would be an advantage for the entrepreneur as long as heavy users and low-end users are of importance.

A completely different model would be to offer a pure **"pay-per-use"** service, thus without "basic price" and the user would only pay for the energy he uses. For the customers, this would have the advantage that acquisition and some ongoing costs are eliminated and their flexibility increases. If "pay-per-use" is offered with a service offering for energy generators, energy contracting is already very close.

Asset Associated Metering would be another logical option. Here, leased assets with appropriate intelligent communication and measurement technology could enter the market itself and offer or ask for flexibility.

Many consider an analogy with telecommunications in the power industry. Due to the fluctuating availability of production from wind and PV systems, the average utilization of the electricity grid is decreasing. It is becoming more and more difficult to refinance the resulting capital-intensive infrastructure just by costs for consumed energy (per kWh). The route to higher basic or service prices is therefore presented. The current flat rate for different power classes and current quantities is a conceivable variant. However, this would lead to a change in energy consumption and thus a reduced interest in energy efficiency measures. DSO would lose any incentives to make consumption more flexible and thus to adapt to volatile production.

The grid operators have advantages because they can plan better how much energy will be consumed. In addition, there is a more equitable burden on the costs of grid expansion, since the basic utilization is more important (e.g. monthly fix costs and MW connection of certain size).

Sharing Ecosystem

This different information level leads to n-fold build-up of individual platforms in our current regulated environment. TSOs, DSOs, aggregators and pool operators often require the same information. If such could be shared, substantial process costs are likely to be eliminated, and the digitization would also allow the actors to be networked automatically. Also the more automated the markets are, the more participants we see, the more possibilities will arise that prosumers/industries managing a local cell might interact among each other selling/buying energy.

The individual local energy systems are autonomous, semi-autonomous or dependent cells which collect energy and exchange or act on energy. Such a peer-to-peer network will manage the energy exchange with technologies like Blockchain which will support them on their way for a shared economy (Fig. 4).

With Blockchain the participating players can act independently, autonomously and in a trustworthy manner or via a common platform (e.g. operated by DSO):

- Blockchain could be the key technology to connect the physical and digital world, thus enabling the integration of the distribution network into the flow of distributed information.
- Blockchain will allow trading by individuals (e.g. New York ISO Microgrid Project in Brooklyn, [5]).
- Better forecasts could lead to a much better exploitation of the local infrastructure. As a result, many balancing group tasks could be fully automated in the long term.
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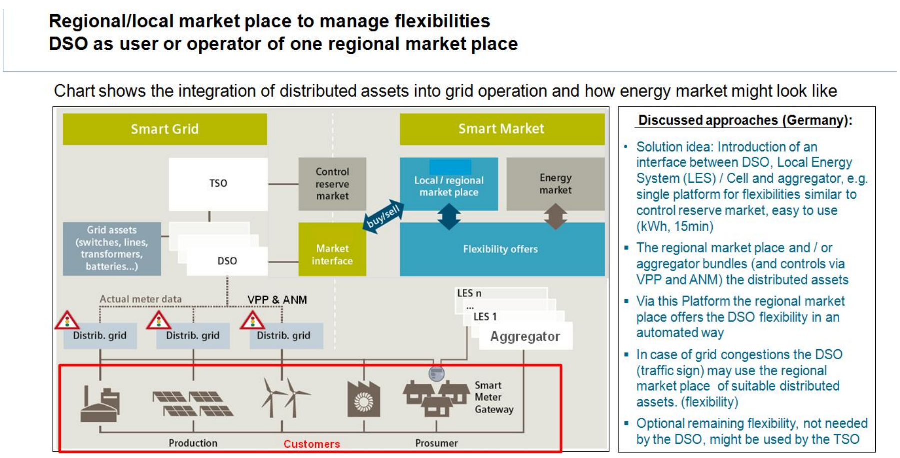

Fig. 3: Local for local: Organize, manage and solve energy needs locally, DSO to manage

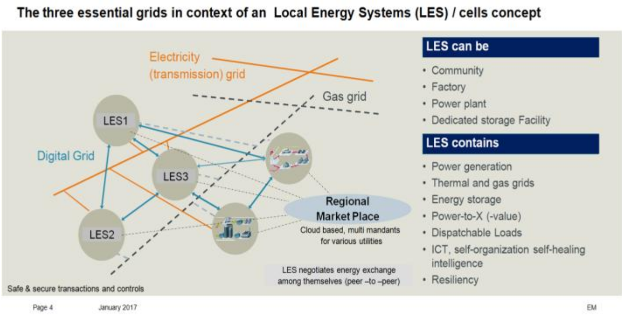

Fig. 4: High level sharing economy scenario for energy

Platform and Cloud as Base for IT Architecture [6]

As the number of integrated systems is increasing and more and more information must be available promptly, the question arises as to the architecture of such a system. This is where platforms show their benefits. These are either operated on premise or via cloud. In addition, there are several tools that are used from a common toolbox as shared applications in the Enterprise IT. They are available to classic SCADA systems as well as to VPPs. The platform integrates several business applications: e.g.: Meter Data Management, Data Hub, eCAR.

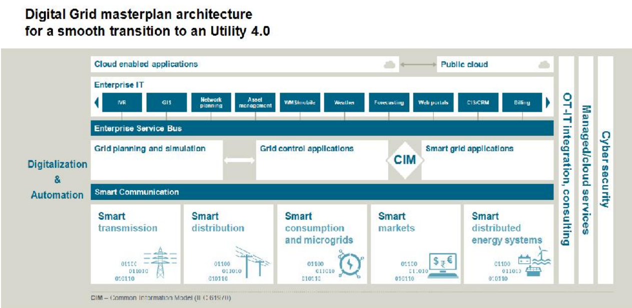

Fig. 5: Integrated platform to enable new business

New Tasks and Roles

New data from Prosumers on the one hand, and new market requirements on the other hand, cost-effective, secure data communication and billing, as well as the knowledge of network bottlenecks, enable further business opportunities. Number of participants active in the market will increase, and the volumes and periods traded will become more and more fragmented. The following trends are currently under discussion (excerpt):

A. DSO:

- Fully automated grid monitoring and control systems that proactively propose re-dispatch measures in the event of a network bottleneck - also considering actual smart meter data.
- Localized load forecasts and risk assessment of network operation**,** efficient O&M and ANM
- Automated DER integration and scheduling for DR

B. Aggregators

- Fully-automated action through smarter algorithms

C. Energy suppliers

- Efficiency monitoring by autonomous, self-determining systems including start/stop function
- Online condition monitoring per individual asset level, including agent-based recommendations for maintenance activities and trades within cloud.

D. Consumers / Prosumers

- Participation in (regional/local) markets
- Service offerings for entire energy supply chain.

Conclusions

Larger amounts of data and a dynamic market environment which has a growing number of participants and thus more strategies with shorter decision periods, generate a process complexity which can no longer be analysed by analysts. They need more efficient support of "smart data" and integrated systems. It is evident that enhanced data analysis for public utilities will be the key to assessing customers better and more individually as well as to provide increased added value for them.

This will change the DSO Role to that of an Energy Service Provider and integrator of Renewable IPPs using:

- Automated grid control, proactively proposing re-dispatch or other solutions in case of congestion
- Spatial load forecasting, circuit risk planning
- Automated DER deployment for DR
- Managing local market places to increase local production/participation in (local) markets
- Provision of service offerings for the entire energy supply chain

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