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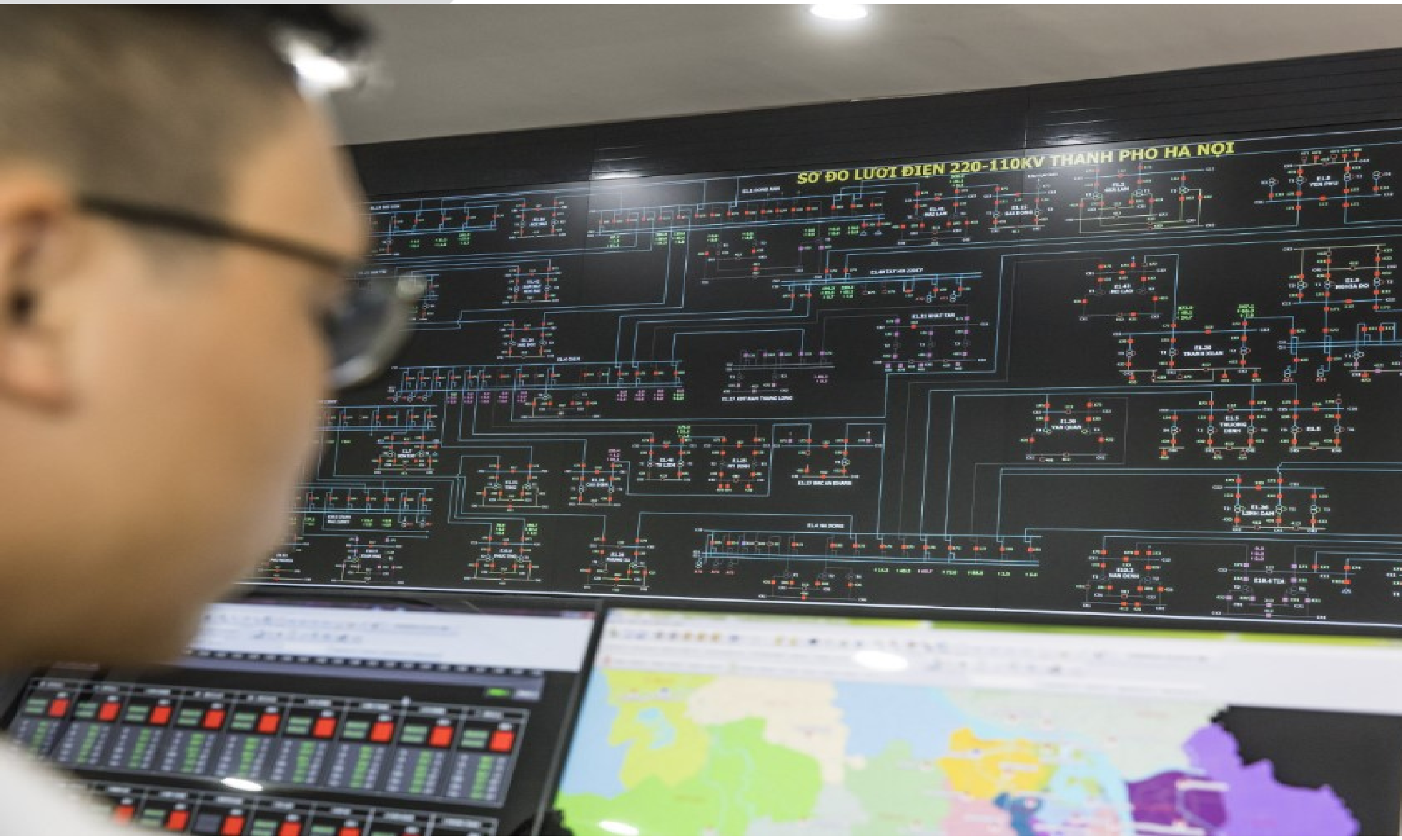

SGREEE-AA3: The Virtual Power Plant Technology and potential for application in Vietnam

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Viet Nam Smart Grid Community

As of
November 2021

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On behalf of the
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Development (BMZ)

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Abbreviations

API	Application Programming Interface
BDEW	Bundesverband der deutschen Energie- und Wasserwirtschaft Federal Association of the German Energy and Water Industries
CAMMESA	Compañía Administradora del Mercado Mayorista Eléctrico, Transmission System Operator of Argentina
CHP	Combined Heat Production
DER	Distributed Energy Resources
DSM	Demand Side Management
DSO	Distribution System Operator
EEG	Erneuerbare-Energien-Gesetz; German Law on Renewable Energy
EPEX	European Power Exchange
EU	European Union
EVN	Electricity of Vietnam
EUR	Euro
FIT	Feed-In-Tariff
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GW	Gigawatt
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IPP	Independent Power Producer
MoIT	Ministry of Industry and Trade, Vietnam
MW	Megawatt
PPA	Power Purchase Agreement
pv	photovoltaic
SCADA	Supervisory Control and Data Acquisition
TSO	Transmission System Operator
USD	US-Dollar
vRE	variable renewable energies
VPN	Virtual Private Network

Chapter 01

Introduction

1. Introduction

Internationally, the energy landscape is changing at a fast pace. Over the last decade, countries have opted to expand variable renewable energies and diversify their energy supply. The driving forces of this development are technological disruptions and the need to give an answer to the challenges of climate change.

The increasing proliferation of renewable energy plants and other distributed energy resources (DER) on a global scale raises concerns how to efficiently control and incorporate these assets into power systems. This is particularly important for solar and wind power plants whose weather-dependent feed-in challenges grid stability and system operational procedures.

Vietnam as well has started to diversify its energy supply, defining ambitious goals for expanding variable renewable energies. By the year 2030 Vietnam wants to achieve a share of 15-20% from renewable resources and has already massively added wind and in particular solar power plants to its generation portfolio.

As vRE shares grow in the power system, system integration challenges emerge progressively and new technologies and methodologies need to be applied. Internationally, the energy transition has given an impulse to the development of innovative vRE monitoring and control technologies. One such technology is the Virtual Power Plant which has emerged as a key solution to monitor, forecast and remote-control a large number of decentralized assets. The software thus effectively supports the smooth integration of renewable energies and other decentralized units in the power system. While the benefits of the Virtual Power Plant are increasingly acknowledged and demonstrated in operational applications, Vietnam so far does not have any experience with this technology.

On this background, the GIZ project "Smart Grids for Renewable Energy and Energy Efficiency" (SGREEE) which supports the Government of Vietnam in the implementation of its Smart Grid Roadmap, requested energy & meteo systems which forms part of an expert pool providing advice to SGREEE to provide a comprehensive introduction into the Virtual Power Plant technology and explore its possible deployment in Vietnam to address some of the challenges of the energy transition. The assignment has the title "Development of the Virtual Power Plant in Vietnam".

1.2 Reports under this assignment

This document is the final and complete report which compiles a series of studies on the Virtual Power Plant technology.

The tasks and the delivered reports under this assignment are as follows:

- Task 1: Review of Virtual Power Plant development in the world
- Task 2: Review of current Vietnamese power sector for the VPP application
- Task 3: Recommendations for current OCC of solar power plants in Vietnam
- Task 4: Overall design of VPP pilot phase
- Task 5: Detail Design of a VPP pilot phase in Vietnam

The tasks were bundled in three reports, one on Task 1, one on Task 2 and 3 and a report which addressed Tasks 4 and 5.

The second report on Task 2 and 3 also used information gathered in a support report contributed by the Institute of Energy which contains a thorough introduction into the Vietnamese electricity market and a technical description of the OCC and DERM software.

Apart from the above-mentioned Tasks under the Virtual Power Plant project, this report as well takes into account findings from activities which have been performed for SGREEE in other projects, in particular:

- Comments on the draft regulation for power forecasting in Vietnam
- ICT security in power systems. A brief case study on Germany and Austria.

This report is structured according to the three deliverables:

Task 1: After a general assessment of the need for Virtual Power Plants an introduction is given into the technological concept of the Virtual Power Plant. Then, possible business models and applications which turn this software into an instrument creating value for its user are presented. A brief chapter presents the most important international Virtual Power Plant markets and what is expected for their future development. Finally, user cases of Virtual Power Plants in Germany and Argentina serve to illustrate how this technology can be applied internationally for different purposes, contributing in every environment to the integration of distributed energy resources.

Task 2 & 3: A thorough introduction into the structure and development of the Vietnamese electricity sector with emphasis on the dynamic expansion of variable renewable energies is provided. The technological capabilities of different types of energy management software (Operational Control Centres, OCC) are assessed which are gaining ground among IPPs to centrally monitor and remote-control their assets to comply with grid requirements. The regulatory framework for the utilization of such software in Vietnam is reviewed. The report then compares the Virtual Power Plant technology with the OCC software already applied in Vietnam and proposes a VPP testing phase to more efficiently monitor and control real-time and future production of widespread rooftop pv systems for a better system integration.

Task 4 & 5: In its last part the report presents a general outline for the implementation of a VPP testing phase with a Vietnamese Power Companies as the main operator. The required steps to set up a VPP according to the needs of the Power Companies and connected to a selected number of rooftop pv systems in vRE hotspot areas in the South of Vietnam are described. The report suggests a period of 6 months to draw conclusions on the benefits of the VPP technology to better integrate power production from rooftop pv systems into the electricity supply.

The following report summarizes the entire material and findings on the Virtual Power Plant under the assignment ""Development of the Virtual Power Plant in Vietnam". The study compiles extensive know-how from energy & meteo systems in the Virtual Power Plant technology and experiences with international user cases from its customer base. The report is further enriched by multiple international publications and articles on the Virtual Power Plant technology.

Chapter

02

The Vietnamese power system and the surge of variable renewable energies

2. The Vietnamese power system and the surge of variable renewable energies

As mentioned in the introduction the Vietnamese power system is facing challenges to efficiently integrate the massive increase in renewable energies and is undertaking first steps to introduce or assess smart grid technologies to effectively control distributed and fluctuating feed-in. For this reason, this report begins with an analysis of the structure of the Vietnamese power sector, the situation of renewable energies and regulatory standards in place which are relevant for the application of control room software.

2.1 Structure and key players of the electricity sector

The Vietnamese electricity sector is dominated by the state-owned enterprise EVN. EVN is a vertically integrated utility, holding a monopoly on power transmission, distribution and retail to final consumers. EVN is managing all core infrastructure of the power sector, including transmission, and distribution grid systems, power metering systems and information technology systems serving the operation of the power system and the electricity market.

The structure of the Vietnamese power sector is shown in the Figure 1:

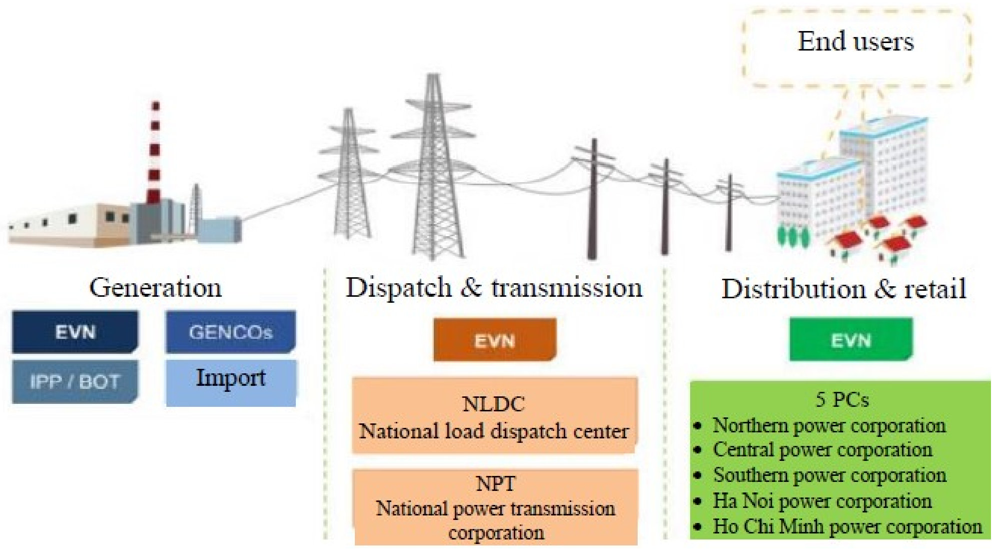

Figure 1: Structure of the Vietnamese power sector. Source: EVN

While EVN produces and supplies nearly 60 per cent of Vietnam´s electricity the generation has been opened to the private sector, allowing IPPs, privatized or partly privatized generation companies and Build-operate-transfer (BOT) projects to participate in the market. IPPs currently already contribute more than 30 per cent to the national electricity supply.

According to the grid code the transmission voltage level of Vietnam power system is 500-220 kV. The 500 kV power grid is considered the backbone of the Vietnamese power system with two circuits running throughout from the North to the South with a total length of over 1500 km. The grid with voltages under 110 kV is defined as distribution grid. The vast majority of the installed renewable energy plants are connected to the distribution grid.

The operation of the national transmission system on 500 kV level is managed by NLDC, a company affiliated to EVN. Part of NLDC´s organization are regional Dispatch Centers which control the 66 kV, 110 kV and 220 kV power network of the regional power system in the North, Center and South of Vietnam. The medium voltage grid is at voltages from 6kV to 35kV and is managed by local power companies.

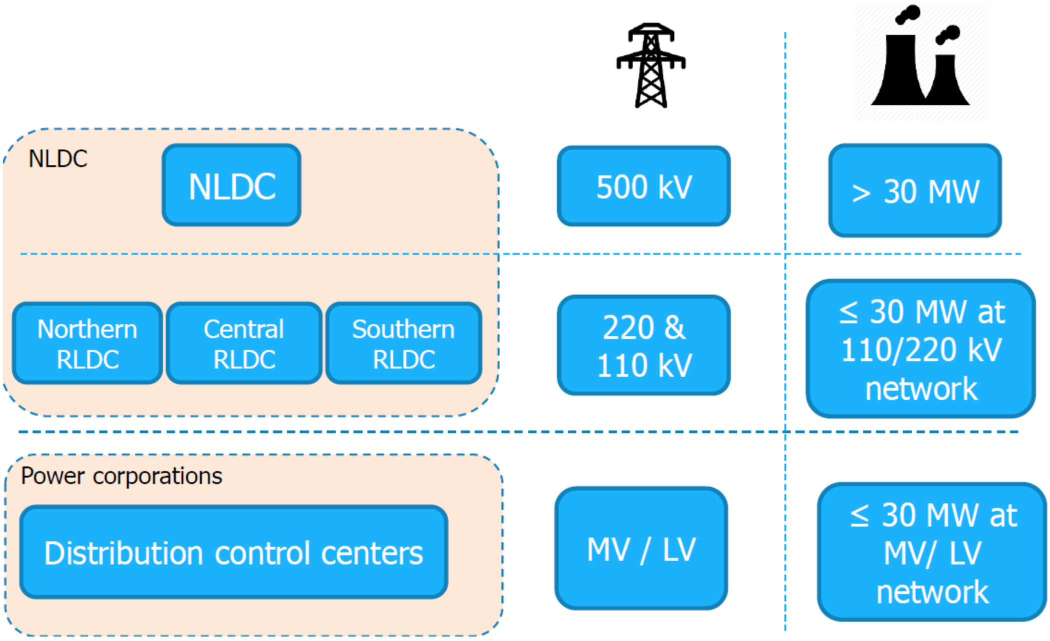

Figure 2: Responsibilities in the operation of the electricity grid. Source: EVN

Five EVN-owned Power Corporations are responsible for distribution and supply of electricity. These are the regionally organized North Power Corporation, Central Power Corporation, South Power Corporation, Hanoi Power Corporation, and Ho Chi Minh City Power Corporation.

The policy entity responsible for supervising and developing the power sector is the Ministry of Industry and Trade (MOIT). The Vietnamese government defines in national power development plans (PDP) to advance the sector, providing projections for growth in demand and mapping out the overall development of the power supply to meet demand in the next ten years.

Subordinate agencies of MOIT are the Electricity Regulatory Authority of Vietnam (ERAV) and the Electricity and Renewable Energy Authority (EREA). The 2005 created ERAV assumes the tasks of the regulator for the power sector, ensuring safe and stable electricity supply, supervising tariffs and supporting MOIT in law enforcement.

2.3 Power market

Vietnam is set to gradually unbundle its power supply and introduce a competitive wholesale electricity and retail market and has been making progress over the past years. As mandated in the 2005 Electricity Law a three-stage liberalization of the Vietnamese power sector along the value chain is being implemented. The three stages include the Vietnam Competitive Generation Market (VCGM), the Vietnam Wholesale Electricity Market (VWEM), and the Vietnam Competitive Retail Power Market (VCRM).

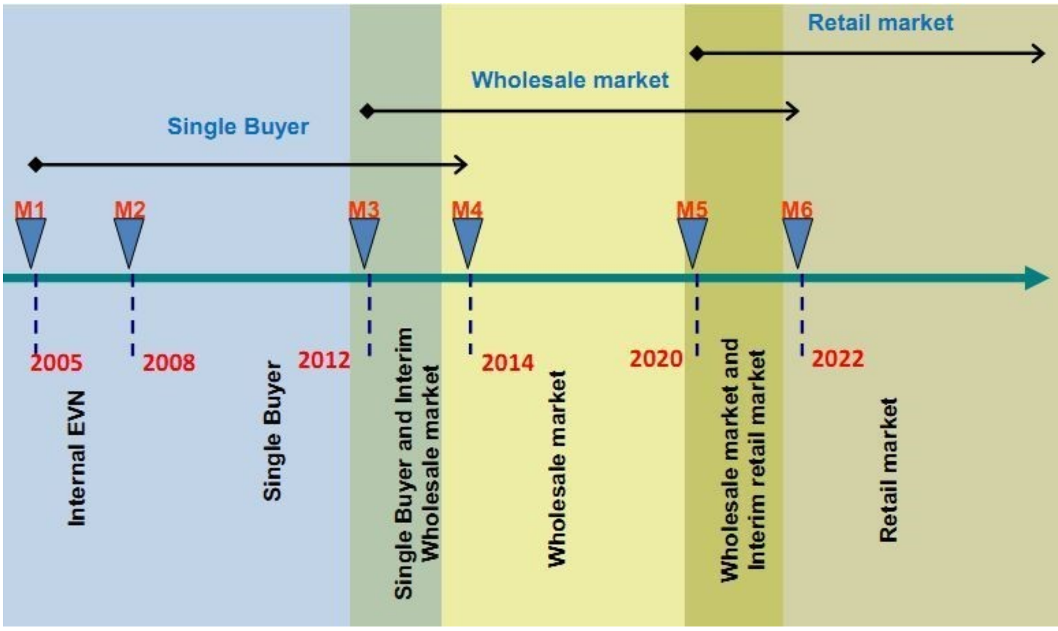

Figure 3: Development of the Vietnamese electricity market. Source: EVN

The VCGM was launched in 2012 and aimed at increasing competition between the generators by unbundling of the country's sole power distributor EVN´s generation function into three power generation corporations. The VCGM also introduced a cost-based electricity market with day-ahead bidding, operating largely according to market rules. In this phase, the Electric Power Trading Company acted as a single buyer, purchasing electricity from the generators and selling it to the Power Corporations.

After a pilot phase, the VWEM has come into operation in January 2019. The VWEM enabled the Power Corporations to directly purchase electricity from generators and sell the electricity to end users. The VWEM also allows for wholesalers to enter the market and contract with generators and then sell to Power Corporations. The VWEM market design also allows for the possibility of having so-called eligible customers (existing or new customer that is connected to the transmission grid and participates in the wholesale market) to contract directly with generators or freely choose any of the Power Corporation as their provider. All generators that own power plants with capacities above 30 MW are required to participate in the VCGM. Since additional exceptions apply only about 50% of the installed generation capacity participates in the VWEM.

The next stage of the power sector reform is the introduction of the VCRM which will complement the VWEM. The key goal of the VCM is to facilitate retail competition, allowing customers to choose their electricity provider. In addition, further new retailers will be enabled to enter the market.

2.4 Electricity generation and renewable energy

The backbone of the electricity supply in Vietnam are coal fired-plants and hydro power plants, followed by gas-fired plants. In the 10 years to 2019 the soaring growth of energy demand in Vietnam has been met to a significant degree by expanding coal-fired generation capacity as can be seen in Figure 4. However, the development and commissioning of fossil fuel plants struggled to keep pace with the rapidly growing appetite for electricity which was only (temporarily) interrupted in recent months due to the impact of the Corona pandemic.

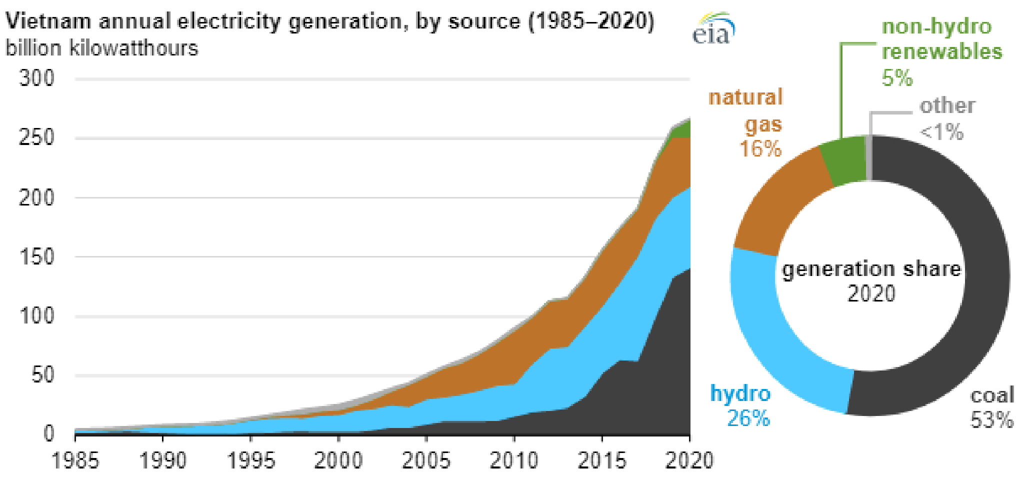

Figure 4: Development of electricity generation by technology. Source: EIA

As a consequence, private IPPs are expected to carry a large portion of the much-needed investment in the power generation sector, particularly in solar and wind power plants whose benefit is their quick development and construction time. They therefore are able to contribute in the short-term to the electricity supply.

Vietnam has recognized the importance of renewable energy and supported private investment by introducing and attractive Feed-in-Tariff (FiT). This triggered between 2018 and 2020 a massive growth in renewable energies, in particular solar power.

The vRE plants were only eligible for the FiT if they achieved commercial operation within certain time limits. Hence, already in 2019, a large number of utility-scale solar parks with a combined capacity of around 5 GW came online. In 2020 the FiT propelled the installation of rooftop pv systems with a combined capacity of 9.3 GW, creating an eight-fold increase in this plant segment by the end of December 2020 from only 378 Megawatts (MW) in 2019. It is noteworthy that 6 GW out of the 9.3 GW was built in the last month of 2020 when the FiT for solar rooftop was about to expire. As a result, rooftop pv systems accounted for a large share of the 14 GW which were added that year. In sum, more than 18 GW of solar capacity is currently installed in Vietnam which represents a huge share of the overall more than 71 GW of installed generation capacity.

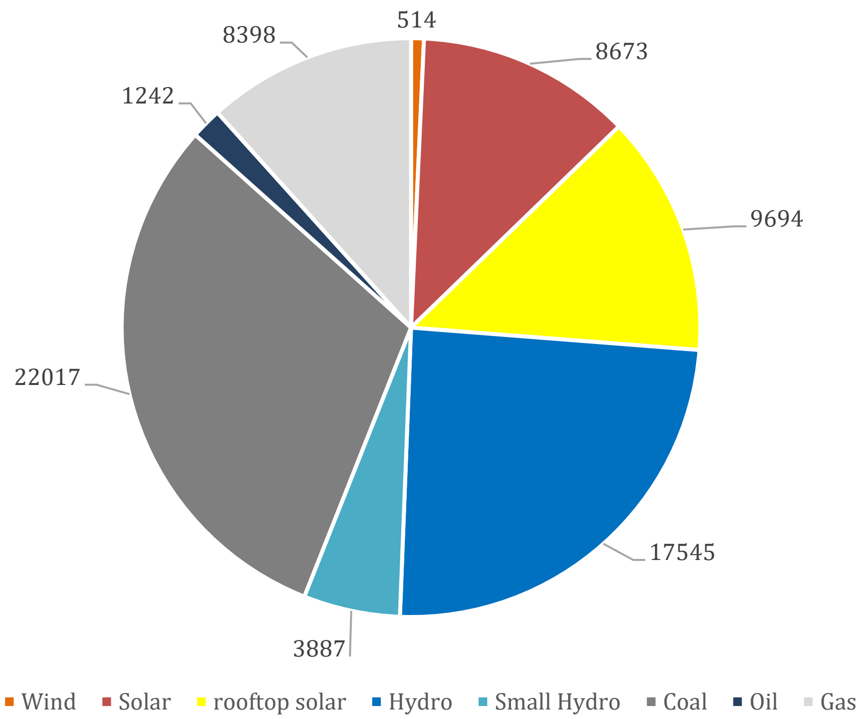

Figure 5: Installed capacity in MW by generation technology in Vietnam (2020)

This renewable energy capacity is distributed among more than 100 farms and 101,000 rooftop pv systems. In 2020, the overall installed capacity of the system grew at over 11%, owing in particular to the skyrocketing growth of rooftop pv plants. In addition, the Hai Duong 2 x 600 MW coal plant cluster and the Song Hau 1 phase 1 600 MW thermal power plant came into operation.

The FiT which applied to wind projects that are scheduled to enter commercial operations before November 2021 will be extended until the end of December 2023. Therefore, for the period 2021 to 2023 numerous wind power projects are expected to get commissioned.

The following figure shows a map of Vietnam illustrating the regional distribution of the operating and approved solar power plants.

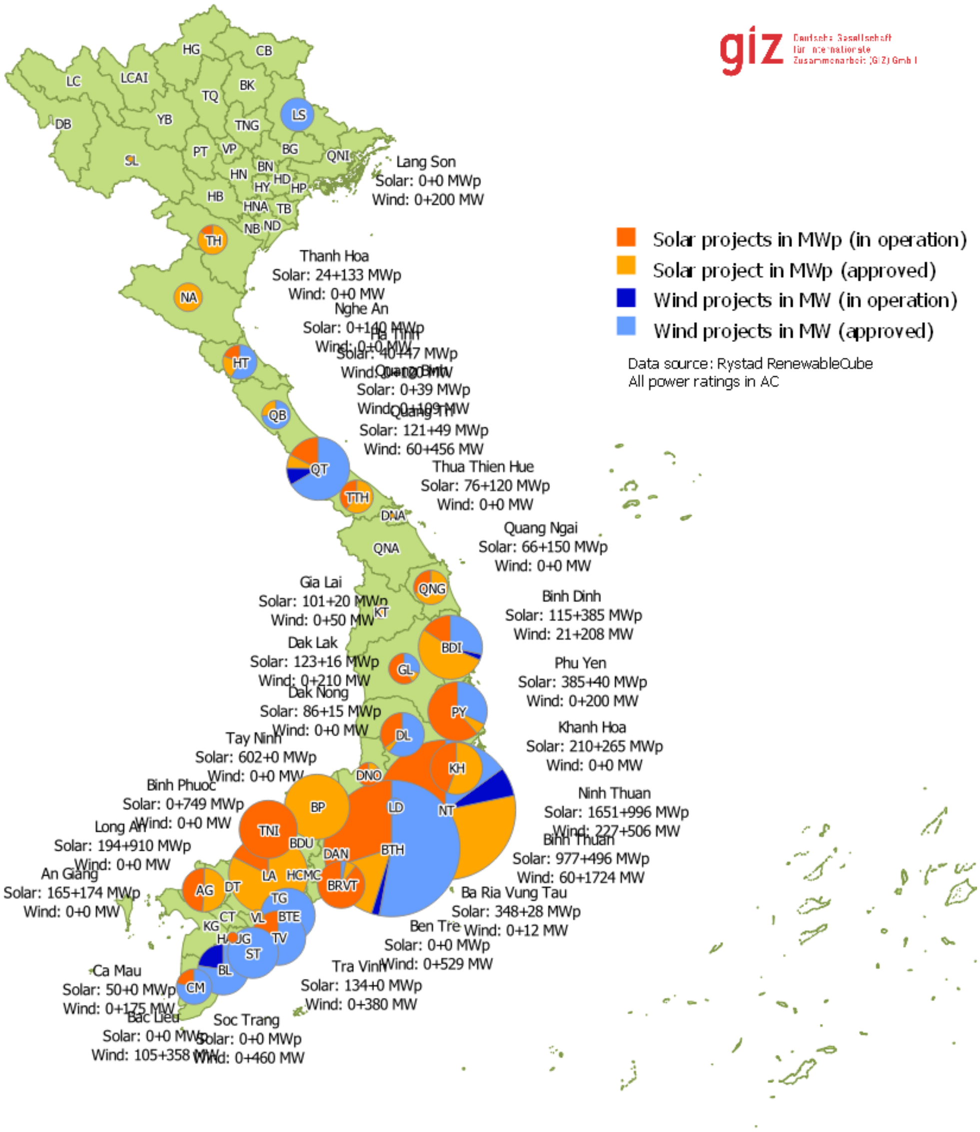

Figure 6: Distribution of operational and approved vRE projects. Source: SGREEE

The map shows the massive concentration of the installed solar and rooftop pv plants in the South of Vietnam where the best resources in terms of solar irradiation can be found. Since Vietnam´s most favorable wind resources are as well in the South of Vietnam the wind projects under development will be installed in the same area as the solar pv plants. The approved wind projects which are illustrated in the map reflect this development.

In sum it can be concluded that the Vietnamese power system is under a rapid transition, quickly adding renewable energies to the energy supply. The large-scale installation of solar and especially rooftop pv plants has contributed to a decentralization of the electricity supply. However, the aggregation of vRE generators in a single area of the far-stretched country is a rather unfavorable condition, bearing the risk of grid constraints and challenging traditional approaches in the operation of the power system.

2.5 PDP8: future generation mix and the path for renewables

In its draft Power Development Plan number 8 (PDP8) the Vietnamese government provides a preliminary guideline for the future development of the electricity supply and the contribution from different generation technologies to meet the increasing demand. Taking a look at the planned energy supply in 2030, it can be stated that coal-fired plants continue to play an important role and will be increased from 20,4 GW to 37,2 GW. The role of more flexible gas-fired plants will significantly increase, almost quadrupling the current capacity to 27 GW. The proportion of hydro power plants (and biotechnologies) is projected to gradually decline, owing to the fact that hydro resources have already been exploited to a large extent.

With regards to the plans for variable renewable energies it is remarkable that the expansion of solar energy will be significantly slowed, adding only 1,6 GW of new installed capacity. According to the PDP8 the development of variable renewable energies will in the next ten years rather focus on wind energy. It is foreseen that the installed wind power capacity which in 2020 only amounted to 600 MW will reach 15,2 GW. In sum, solar and wind power capacity will have a combined capacity of 42 GW which will increase their shares of the country's power plant portfolio from 25% in 2020 to 33% in 2030.

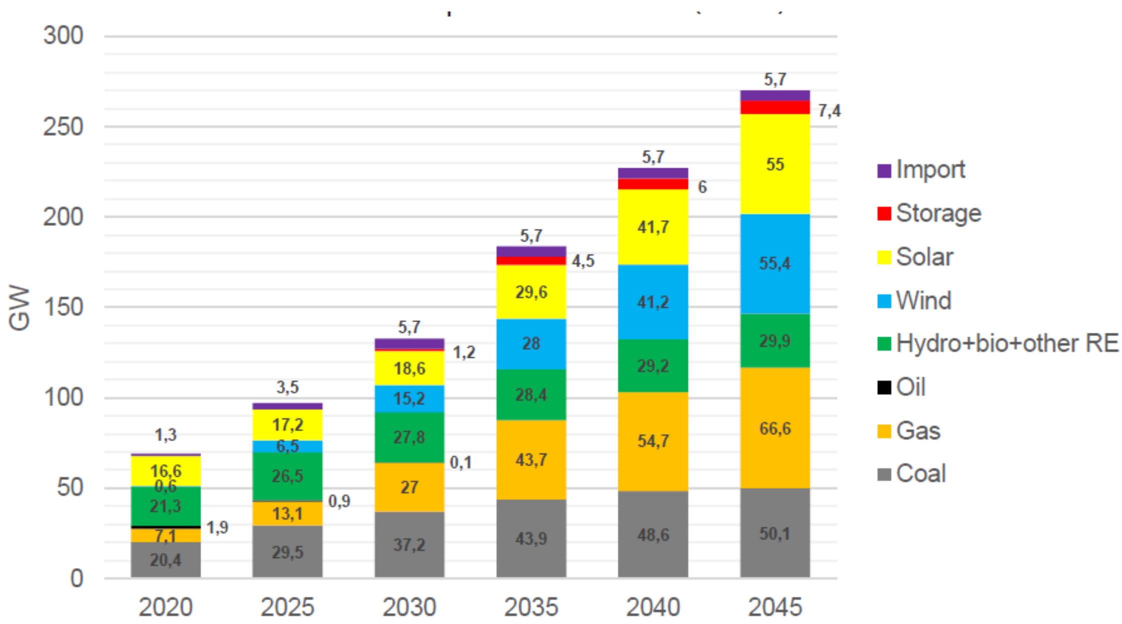

Figure 7: Future development of the generation mix according to the draft PDP8

2.6 Operational regime for vRE plants

Like many countries which started introducing a support scheme for renewables, Vietnam opted for a FiT mechanism. The Prime Minister Decision No 13/2020/QD-TTG from April 2020 encouraged the development of solar power in Vietnam. The regulation defined that EVN will purchase electricity from grid-connected solar and rooftop pv plants at a fixed price for a period of 20 years. The level of the tariff varies with the type of generator (ground-mounted, rooftop or floating solar plant). Rooftop pv plants can have a maximum capacity of 1 MW to be applicable for the FiT. The tariff was granted only to plants commissioned until 31st of December 2020 which led to the dynamic installation.

The FiT regime for wind power sets similar standards but offers different tariffs for wind onshore and offshore plants. As mentioned previously the applicability of the FiT has been extended, giving investors now time to start commercial operation until December 2023.

Since the entire solar and wind power production is purchased at a fixed price the vRE production is prioritized in the merit order of the dispatched power plants, provided that system stability is ensured. In case of excess generation NLDC first cuts the production from conventional power plants. For this purpose, NLDC operates an Automatic Generation Control (AGC) for frequency and Automatic Voltage Control (AVC) of larger plants with an installed capacity above 30 MW connected to 500 kV grid.

If despite this measure the oversupply in the system persists, NLDC will curtail as well the output from vRE plants. The required curtailment level for solar and rooftop pv production is determined by NLDC in its day-ahead planning process and submitted for execution to the Power Corporations. The Power Corporations send the curtailment quota to the Power Companies for cutting the production in their provinces. The Power Companies on their end give curtailment instructions (e.g., via phone) to the operators of the solar and in particular of the rooftop pv plants which are connected to the 22 kV voltage level of their grid. In the curtailment process only rooftop pv plants with a capacity of at least 200 kW will be considered by EVN in the curtailment process.

Due to grid limitations, vRE operators increasingly face curtailments of their plants. NLDC announced it will need to reduce the renewable energy output in 2021 by 1.3 billion kilowatt-hours because of oversupply and insufficient transmission capacity. However, the regulation does not contemplate compensation for the producers of solar and wind power if their plants are curtailed. This ultimately affects their revenue streams which may impact investor´s confidence which is crucial for the continuing expansion of vRE assets in Vietnam.

2.7 Power system challenges and smart grid solutions

The explosive growth of solar power which Vietnam witnessed in the past two years revealed the challenges to deal with the decentralization of the power supply. The Vietnamese power system is struggling with efficiently integrating the increasing share of solar and wind power and its fluctuating generation. The concentration of enormous numbers of solar power plants in the Southern provinces of Vietnam has caused power curtailments due to oversupply and local grid overload. The following map illustrates overload situations in the 500 kV lines connecting the North and South of Vietnam.

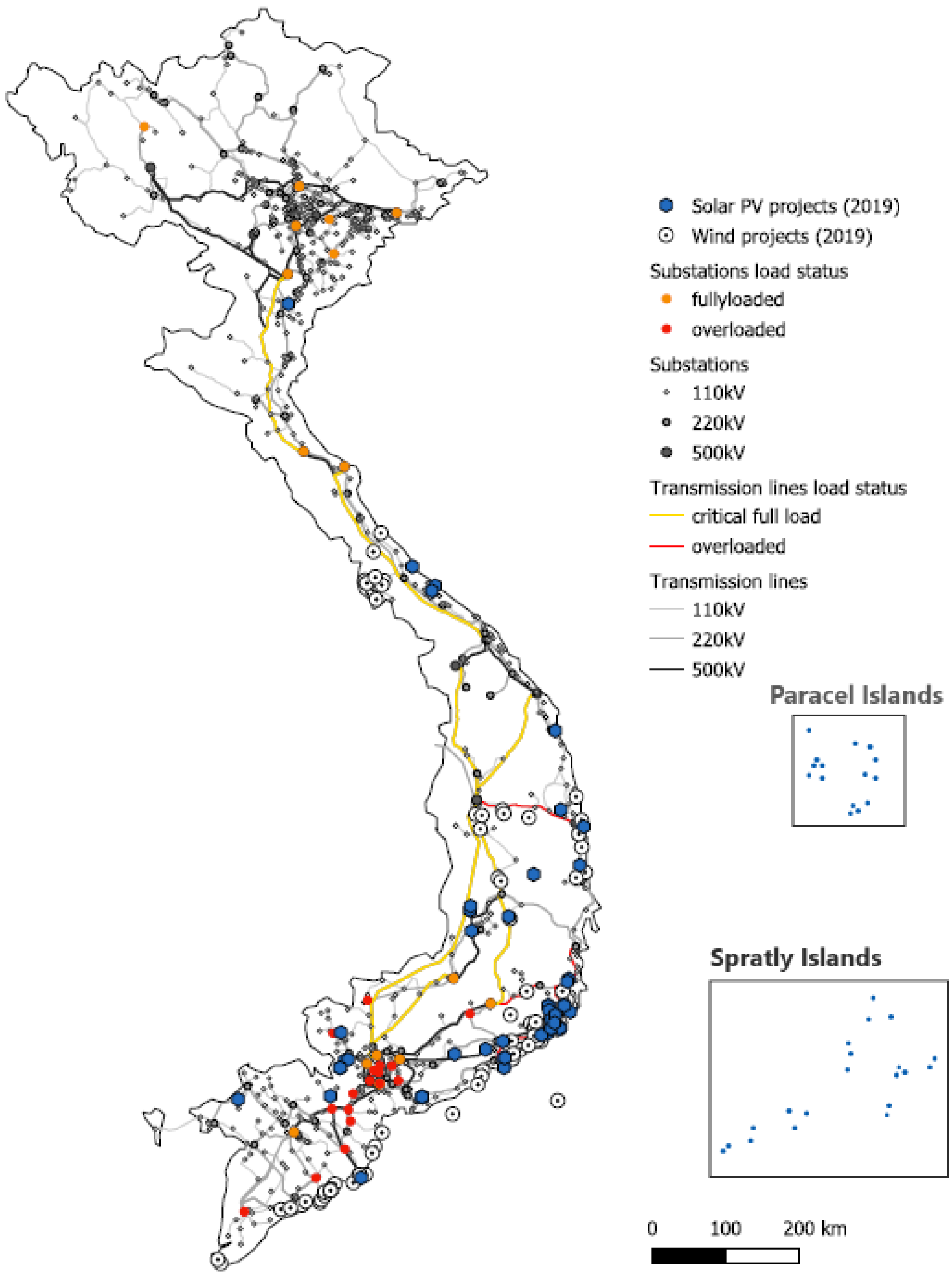

Figure 8: Power network and load status. Source: Fichtner

As expected, it can be observed that grid constraints match with the Southern vRE hotspot areas. In the provinces Ninh Thuan and Binh Thuan which have connected many solar power plants. 220 kV and 110 kV lines are frequently operated at full capacity during peak production times. In addition, 22 kV lines which first absorb rooftop pv production are often overloaded in areas where these plants have been installed in large numbers.

Apparently, Vietnam´s current network is not yet prepared for the massive connection of vRE which hampers the efficient integration of volatile vRE production. The country needs new transmission and distribution infrastructure to accommodate capacity additions and to transmit electricity to the load centers. Transmission grid expansion due to renewable energy growth is currently under way, but will take some time to complete.

While the extension of the grid is indispensable, the ongoing energy transition also calls for the adoption of modernized standards and technologies. This includes the adoption of smart grid technologies, enhanced use of DER units (such as rooftop pv systems), a system-wide digitalization and the automatization of the tasks for vRE integration.

A range of smart grid technologies and operational approaches which have been developed internationally can ease grid constraints and support with the system integration of vRE plants. These innovations are capable to turn a conventional grid into a smart grid. A smart grid is considered as a power grid infrastructure that uses modern communication technology to ensure continuous real-time balancing of flexible vRE generation and demand. The goal of smart grids is to optimally use available vRE generation and the grid's capacity. The higher the share of vRE generation, the more important becomes the intelligence of power grids for a successful energy transition. Different to the large planning and construction times for expanding the grid infrastructure, smart grid technologies have the benefit that they can be deployed in the short and medium term.

Intelligent software tools are a key component of smart grid solutions. They are increasingly used to address the diverse challenges resulting from the installation of large amounts of vRE generators on lower voltage levels. These also appear in Vietnam:

- First of all, smaller plants such as rooftop pv which are connected to lower voltage levels are invisible to NLDC. The system operator does not have any transparency regarding real-time production processes of these plants and their variation in different geographic areas of Vietnam. Even the Power Companies which manage the grid where the plants are connected are only able to retrieve production data with several hours of delay. The entire data of a day´s production schedule is only available the next day. This delay does not allow to operationally react on volatile generation.

- Second, the production from solar and wind power plants is weather-dependent which is why accurate generation forecasts are necessary to know in advance the variable extent of the electricity demand covered by renewable energy production. At this stage, professional forecasts in Vietnam are only provided for larger solar parks, leaving almost 10 GW of installed rooftop pv systems outside the prediction process. Only a comprehensive forecasting regime with high accuracy levels enables NLDC to dispatch the conventional plants to cover the residual load and to maintain the power system in balance.

- Third, the power system is challenged with the lack of control by NLDC or the regional system operators over the production output from small-scale systems. Therefore, vRE plants which are connected to lower voltage levels are not only invisible but cannot be efficiently remote-controlled, e.g., for the purpose of ensuring grid security. At present the plants which are connected to 22 kV level in Vietnam are only controlled manually.

- Fourth, it is not sufficient to exert control over individual plants. When faced with a large number of distributed vRE generators a solution is required to digitally aggregate the units to a controllable power pool with a relevant size. This is as well crucial for Vietnam where the number of power plants has dramatically increased in just two years. Today 53 per cent of the installed solar power capacity is distributed among 101.000 rooftop pv plants.

Intelligent software tools which have been developed to address these challenges which commonly appear in power systems with larger shares of vRE generation. They create visibility on production (and consumption) processes of different units in real-time, support power forecasting for vRE units, allow complex scheduling and dispatching operations and provide for control of vRE assets and other DER. The exact scope of capabilities varies with the goal and design of each software solution.

In the following this report presents and analyzes the Virtual Power Plant software which has emerged internationally as an intelligent software solution to support the integration of large numbers of vRE plants and other DER units into the power system.

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Chapter

03

Virtual Power Plant: a definition

3. Virtual Power Plant: a definition

The term Virtual Power Plant can be misleading. It does not mean that there is no real electricity generated or consumed. It rather refers to the fact that, in particular, small and decentralized energy units can be connected independently from their geographical location to a single controllable power pool.

There is not a single commonly accepted definition. We will define the Virtual Power Plant for this study as follows:

> *"A Virtual Power Plant is an aggregation of many decentralized energy plants that are monitored, coordinated and controlled via a central digital platform.*
>
> *Equipped with intelligent and robust control capabilities, the Virtual Power Plant acts as a single power plant, coordinating each individual unit that remains independent in ownership and operation.*
>
> *The Virtual Power Plant can be adapted to the framework of the energy supply system participates in power systems, allowing its users to manage and adjust the consumption and the - in many cases weather-dependent – generation processes of the power plant to changing market and grid situations."*

Hence, the Virtual Power Plant is not a plant in its original sense but a software created to digitally bundle and coordinate the operation of a large number of heterogenous distributed energy units, e.g., solar and wind power plants, biogas plants, conventional generators, storage devices and flexible load.

Chapter

04

The need for Virtual Power Plants

4. The need for Virtual Power Plants

Power systems on a global scale are undergoing an unprecedented transition. For decades, the energy supply was covered by the electricity generation provided by a few conventional power units. These large power plants are usually connected to the high voltage grid. These firm-capacity generators can be increased and decreased on demand by varying the input of the fossil energy source (e.g., coal, gas).

Usually, these large power plants are connected to the high voltage transmission lines which transport electricity, sometimes over large distances, before it is delivered via the distribution grid to the consumers. The grid networks were designed accordingly, providing the necessary infrastructure for this top-down approach to supply electricity.

Grid operators in these centrally organized energy systems are used to dispatch at the according to market needs. Dispatchable generators can be turned on or off, or can adjust their power output according to a defined level – both downward and upwards, within the technical limitations of the plants.

This conventional approach is challenged by the rise of variable and non-variable renewable energy resources. Especially solar and wind energy are expanding rapidly on a global scale to meet increasing demand and to replace conventional power units. One main driver of this development is the significant decrease in generation costs. In recent tenders in countries with a high irradiance, utility-scale solar projects have placed bids with less than 2 US-Cents/kWh, which undermines their economic competitiveness with fossil-fueled technologies.

The dynamic proliferation of power generation from renewable sources of energy across the globe poses a number of challenges to the existing power systems.

The main challenges are:

- **Capacity and number of distributed energy resources**

The power system needs to orchestrate the dispatch of the plants which participate in the energy supply. The energy transition, however, leads to a drastic increase of grid-connected renewable energy plants.

As an example, the following chart presents the impressive growth of variable renewable energy, especially solar and wind energy, in Germany. As can be seen at the end of 2019 there were 124.4 GW of vRE plants installed. This exceeds the installed capacity of conventional power plants which sum up to an installed capacity of around 104 MW (source: BDEW) and which has been stable over the past years.

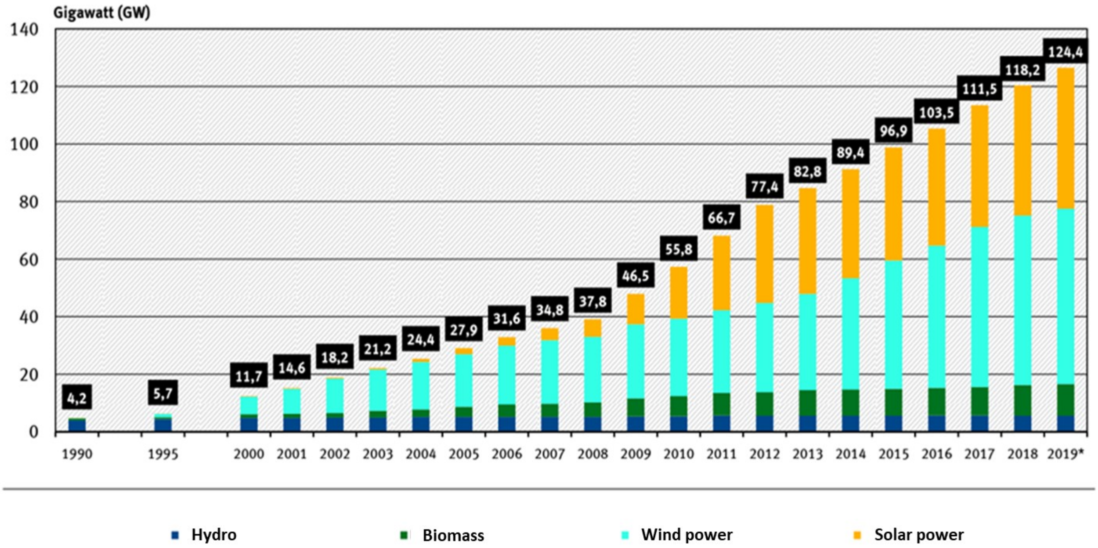

Figure 9: Expansion of renewable energy capacity in Germany (1990-2019). Source: BDEW

Since the installed capacity of the individual vRE plants is on average much smaller than the one of conventional plants, their numeric increase is even more significant. For instance, in Germany there are 1.8 million solar plants and almost 30,000 wind energy plants installed. The sheer number of vRE plants increases the complexity of managing the power system stability and a secure energy supply. However, in contrast to conventional power units, the grid operators in many cases face the challenge of not exerting any direct control over these distributed energy resources.

- **Different plant sizes and grid levels**

Another crucial issue of vRE expansion is that depending on the size of the plants they are connected to different grid levels. This ranges from low-voltage connection for small pv systems up to high voltage grid levels for wind onshore and offshore and utility-scale solar power plants. As a consequence, the impact of feed-in from solar and wind power plants on different grid levels needs to be taken into account. This refers particularly to avoiding overload situations for the existing grid infrastructure. For instance, the feed-in of vRE plants on low voltage grids can exceed the capacity levels of power lines and even lead to reverse power flows to upper voltage levels via substations. Hence, the grid operator faces the challenge of taking into account the variable penetration of grids by vRE plants and to react timely on critical situations which can occur locally or regionally.

- **Transparency on current production levels of vRE plants**

With widespread installation of solar and wind energy plants of different sizes the system operators lack control over their real-time production schedules. In many cases, TSOs do not have any transparency on the generation processes on DSO levels. However, this information is essential for carrying out grid operational procedures, for instance the intraday redispatch process which takes into account deviations from the day-ahead schedules.

- **Transparency on future production levels of vRE plants**

Power systems with an increasing share of variable renewable energy production need to anticipate future production levels which vary with weather conditions. Main market participants relying on power predictions are the system operators but, depending on the market design, also solar and wind plant operators and power traders. The Virtual Power Plant itself does not generate power forecasts, but integrates, analyses and combines them, thus leading to better results.

As outlined above, the decentralization of the of the power supply comes along with new challenges which require new solutions. In this respect, the Virtual Power Plant has emerged as a key technology to face those challenges. The software controls variable generation processes and efficiently bridges the gap to the demand side, tailoring production to grid and market situations. Virtual Power Plants are dynamic, delivering value in real time and anticipating future production schedules by integrating solar and wind power forecasts. They respond to the increased necessity of big data integration and analysis of the dynamic and manifold processes in a decentralized power system.

In the following chapter we will look more in detail at the valuable contribution of Virtual Power Plants to master the energy transition.

Chapter 05

Technical concept of Virtual Power Plants

5. Technical concept of Virtual Power Plants

There is no standard definition of a Virtual Power Plant and, therefore, not one single technical concept for a Virtual Power Plant. The common feature of Virtual Power Plants is their ability to connect a large number of different decentralized energy plants to form an effective network, which gains properties that otherwise only a single large plant has. The units which can be connected are primarily decentralized energy generation plants of any technology (solar, wind, biogas, hydro, but also conventional generators) and size (from a small rooftop pv plant to a large offshore wind parks) connected to any voltage level (DSO or TSO), but also consumers, storage facilities and grid infrastructure. Figure 10 illustrates this concept. In a Virtual Power Plant, the plants are connected with the aim to aggregate all information of the connected assets in the control room. It is important to note that Virtual Power Plant technology is predominantly offered and used as a Software-as-a-Service (SaaS) solution by specialized IT providers who set up the Virtual Power Plant according to the needs of the user.
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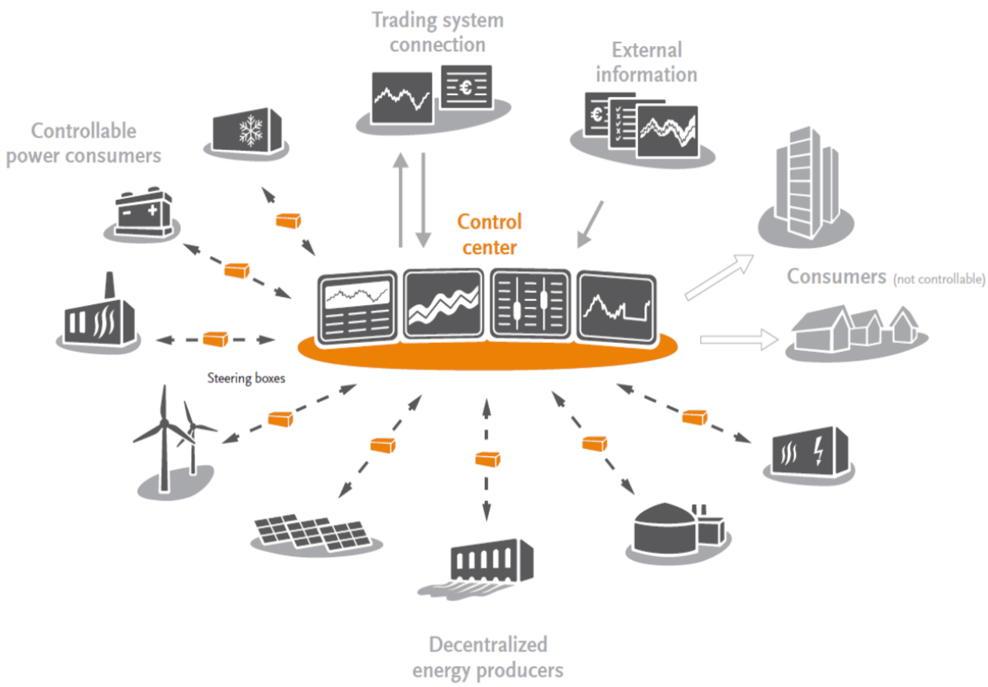

Figure 10: General concept of a Virtual Power Plant.
Source: energy & meteo systems

In chapter 5.1 different aspects concerning the connection of plants are presented while the core functions of the software are presented in the following chapters.

5.1 Real-time connection

A live data connection is a crucial requirement for the connection of plants and, thus, the functionality of a Virtual Power Plant. The generation data are imported in real-time via this connection, so that the individual status can be used for further processes at any time. In addition, schedules or setpoints can be sent to the plant. It is important that all plants, no matter what type, are connected to the Virtual Power Plant. This is a major challenge, since a wide variety of technologies can be used for such connections.

A basic requirement is the availability of data communication at the plant to be connected (normally via an internet connection). This can be achieved via a physical line or via mobile internet. Only in very remote locations data connection can pose a problem. Since communication takes place via the internet, certain security measures are indispensable. The standard is a Virtual Private Network (VPN) encryption. This represents a self-contained communication network. To establish the connection, key pairs are stored in the hardware of the plant's interface and in the Virtual Power Plant. Only with the knowledge of the key, data can be exchanged, so that no external access is possible.

Usually, a communication via VPN is sufficient for the use of a Virtual Power Plant. In certain special cases further security measures are necessary. For example, when providing ancillary services from system-critical plants, grid operators require a dedicated line directly to the plant.

Various models can be used to establish the connection. On the one hand, a single plant (wind farm, solar park, etc.) can be directly connected to the Virtual Power Plant as illustrated in the following figure.

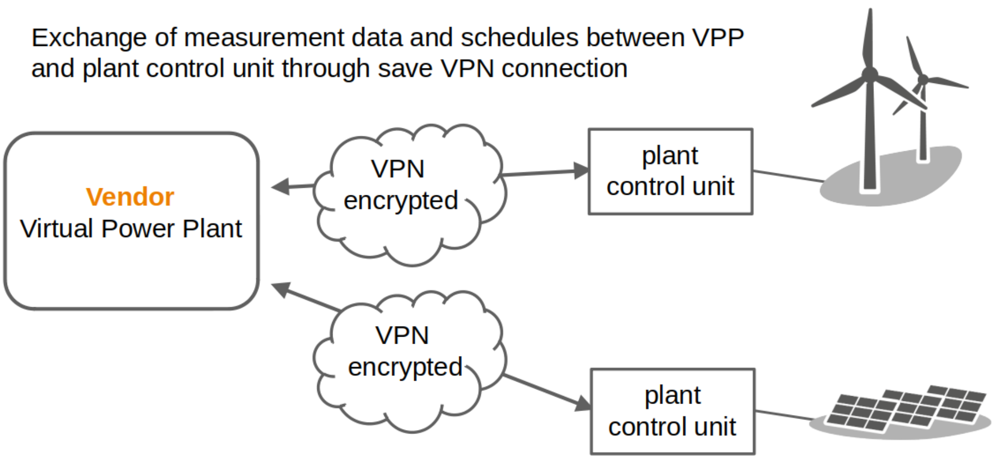

Figure 11: VPP directly connected to plants. Source: energy & meteo systems

On the other hand, the connection can also be made directly to a control room or another system that is already being used for technical operations management.

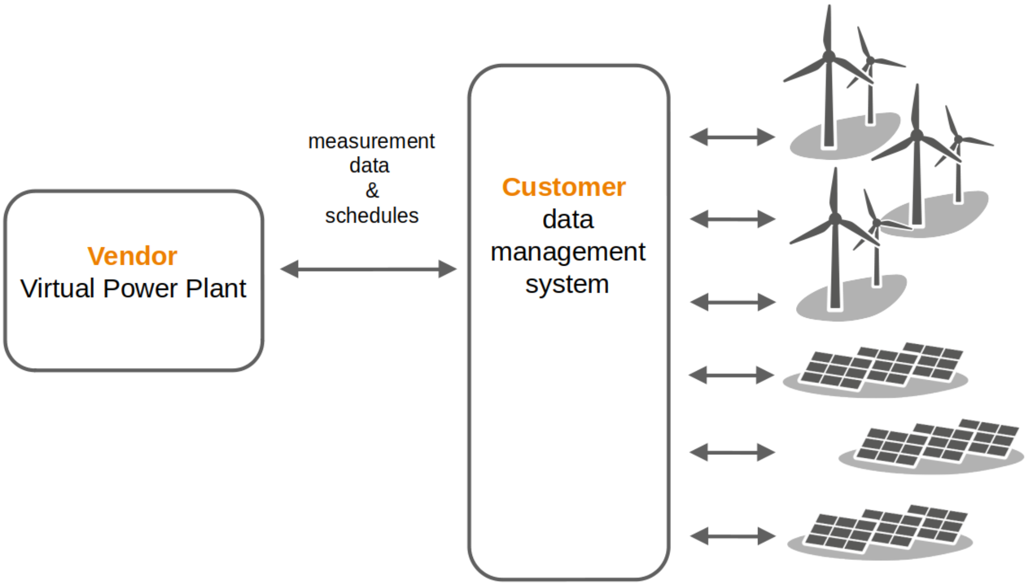

Figure 12: VPP connected to plants via existing data management system. Source: energy & meteo systems

For the connection of individual assets, the availability of the internet, of hardware for the establishment of a VPN connection and of a software interface that transfers the data (hereinafter referred to as interface) is a necessary basis. Modern wind farms usually fulfil these requirements. The manufacturers implement these interfaces directly in the Supervisory Control and Data Acquisition (SCADA) system or have their own central control room which can be connected to the Virtual Power Plant. The latter makes the inclusion of new plants in a Virtual Power Plant particularly easy, as they simply have to be connected by the manufacturer. Only in case of older wind energy assets these may have to be retrofitted. For solar plants, so-called data loggers are usually installed in the inverter, which enable the data to be made available. A router for VPN connection may have to be retrofitted for small plants, while such hardware is usually installed for large parks. For other types of plants (CHP, hydro, ...) it is less standardized. The larger the system, the more likely it is that interfaces are already available. For almost all types of assets, however, there is the possibility of retrofitting with third-party hardware.

There are efforts to create standards for interfaces related to Virtual Power Plants. One example is the standard VHPready. However, this standard has so far only been established in Germany for certain purposes (balancing power with biogas plants). For large plants the international IEC 104 protocol is often used, which was developed especially for large energy infrastructure. However, no uniform standard is foreseeable for all plants.

A good Virtual Power Plant software is therefore characterized by the fact that plants can be connected via all common interfaces. A wide variety of technologies, especially different protocols, are used in the interfaces. Therefore, these must be deposited in the Virtual Power Plant, and/or the possibility must be given to integrate new protocols as easy as possible.

In the process of plant connection, a VPN connection to the external hardware is usually established and then this connection is configured in the Virtual Power Plant. Afterwards the plausibility of the data is checked and a short test of the remote controllability is performed. Finally, the asset can be used in the Virtual Power Plant.

5.2 Integration of Measurements, Production Potentials, Forecasts and Schedules

The previous chapter described how live data are received from assets. These data, but also many other data, have to be managed as time series in the Virtual Power Plant. Therefore, the technical characteristics of the real plants have to be represented digitally in the Virtual Power Plant. Usually, plants are represented on the level of individual units, for example turbines of a wind energy plant, strings of a solar plant or CHPs of a biogas plant. Further technical details, such as technical boundary conditions, are only modelled in case of demand side management or connected storage systems. Furthermore, it needs to be modelled in the Virtual Power Plant how the individual assets like wind turbines are linked to higher level aggregates such as wind farms of grid connection points, which can then be considered as one unit.

Such a structure is imported via a master data database. There, further technical details are maintained, such as a tracking system for solar plants or the hub height of wind energy plants. Information about the location is fundamental for the forecast and for operational purposes. If remote control is possible, technical details of this solution are also maintained in the master data.

Once the plants have been modelled, they can be displayed in the Virtual Power Plant and processes can be set up for them. Different time series can be assigned to individual units. These are initially the measurements coming in via the data interfaces as described above. Depending on whether these are imported into the Virtual Power Plant at plant level or, for example, only aggregated for an entire park, they are assigned to the element and aggregated for the view at higher levels. Usually, not only one source of measurement data is available. For example, one set of real-time measurements can be taken directly from the turbines (i.e. through the SCADA system) and another one comes from the grid connection point (i.e. metering data). In addition, an official measurement is sometimes made available ex-post by the grid operator. While the real-time measurement data from the turbines are used for short-term processes, for example an adjustment of the forecast, the ex-post metering data are relevant for billing and long-term forecast training based on historic data.

Forecasts represent another essential time series in the Virtual Power Plant. They describe the expected production of a plant or the expected flexibility potential. For volatile decentralized generators, a power forecast based on numerical weather models is usually required, which can then be optimized with real-time data from the Virtual Power Plant. The forecast can, for example, be read in via files from external suppliers or the Virtual Power Plant is directly connected to a forecasting system. A forecast is usually available at park level. These are then aggregated to a portfolio level in the Virtual Power Plant.
It is also possible to combine forecasts from different suppliers. A Virtual Power Plant can perform historical evaluations of the forecast quality and on this basis weight each forecast to create an optimized combination forecast. In many cases forecasts also contain information about the uncertainty of the forecast. The Virtual Power Plant represents these with so-called uncertainty bands which indicate the spread.

In the control power sector, schedules and potentials are needed to plan the operation of the plants. These can be imported, for example, based on operator specifications. Alternatively, they can be calculated in the Virtual Power Plant based on various possible technical boundary conditions. For example, a schedule can be generated for an empty or fully loaded storage system.

Forecasts and schedules are influenced by non-availabilities of plants, for example during maintenance or a malfunction. Therefore, a Virtual Power Plant has the possibility to manage non-availabilities. These can be generated manually directly in the Virtual Power Plant or they can be read in via different interfaces. Such information can be entered via a synchronized web portal to which the operators of the plants have access. Alternatively, this information can be imported via a file import or via API (Application Programming Interface). Recently, another way has been established in Germany. The German Wind Energy Association has developed a uniform API interface for operational management software for wind turbines. These systems can be directly connected to the Virtual Power Plant and exchange non-availabilities.

Based on the forecasts, trading processes are carried out. In case the power output of plants needs to be adjusted as a result from the trading transactions, control schedules are generated and assigned to the plants. As a rule, different types of schedules are provided. Thus, a distinction is made between planned controls and controls that are actually carried out.

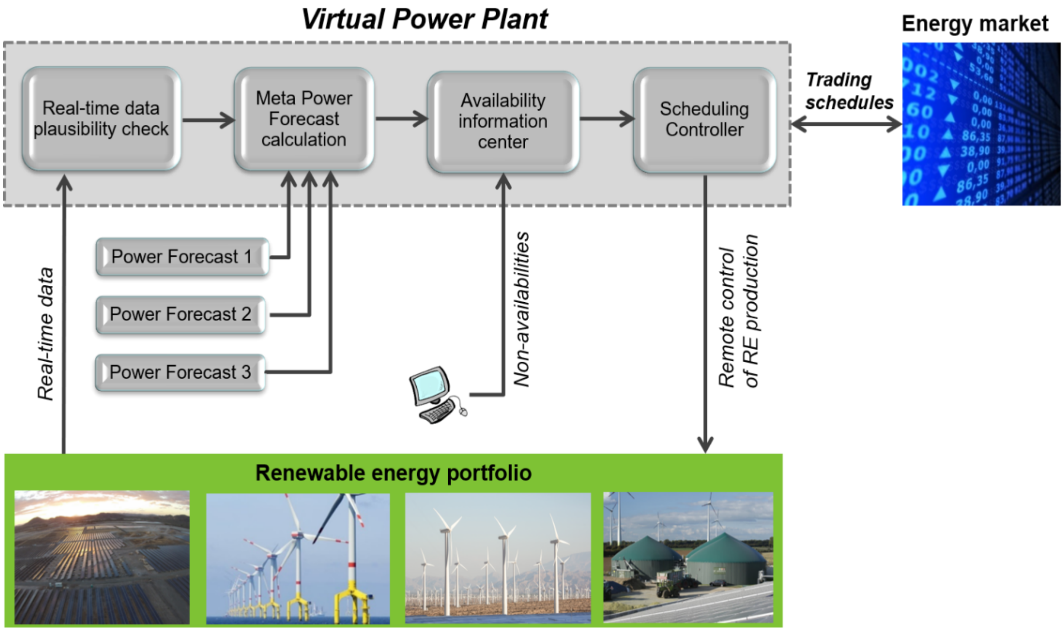

Figure 13: Illustration of data flow in case of trading renewables with Virtual Power Plant and power forecasts. Source: energy & meteo systems

5.3 Monitoring of data

One of the main functions of a Virtual Power Plant is to visualize the previously described information about assets and portfolios through adequately designed user-interfaces. Different information can be monitored, can contribute to decision-making in trading processes and can perform ex post analysis. Against this background, a Virtual Power Plant should be able to display data in any resolution and be able to display a period of a few minutes as well as over several weeks. Time series can be shown for any unit according to the modeling of the plants.

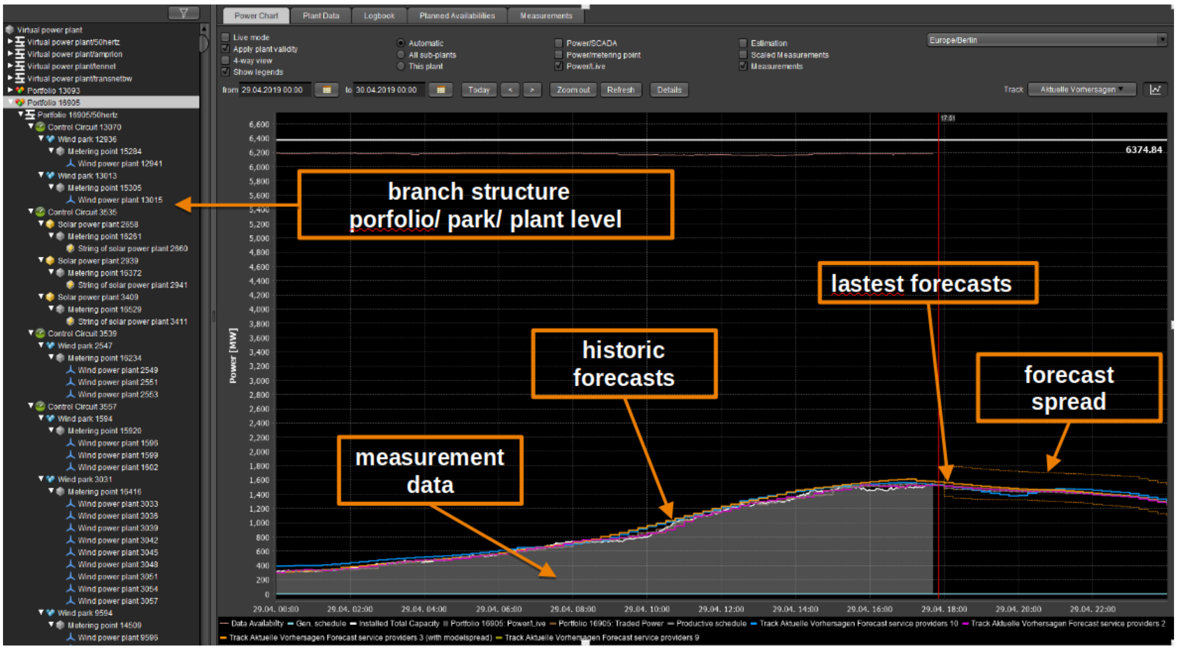

Figure 14: Monitoring view in a Virtual Power Plant. Source: energy & meteo systems

In addition to time series, a Virtual Power Plant can provide information on situational awareness. Thus, it can calculate and highlight deviations between certain time series. At the next higher escalation level, warnings can be issued if certain thresholds are exceeded or events occur, such as the failure of a live connection of plants. A communication center in the Virtual Power Plant with chat function, the possibility of shift handovers, etc. further increases the overview of processes.

For many processes historical evaluations are helpful. In addition to the purely visual evaluation in the timeseries view, a Virtual Power Plant provides further analysis functions, depending on its design. This is for example an analysis of the forecast quality. Various forecasts and forecast tracks (forecasts with a certain lead time) can be evaluated. Specific error measures are used for the above-mentioned combination factors of different prediction providers.

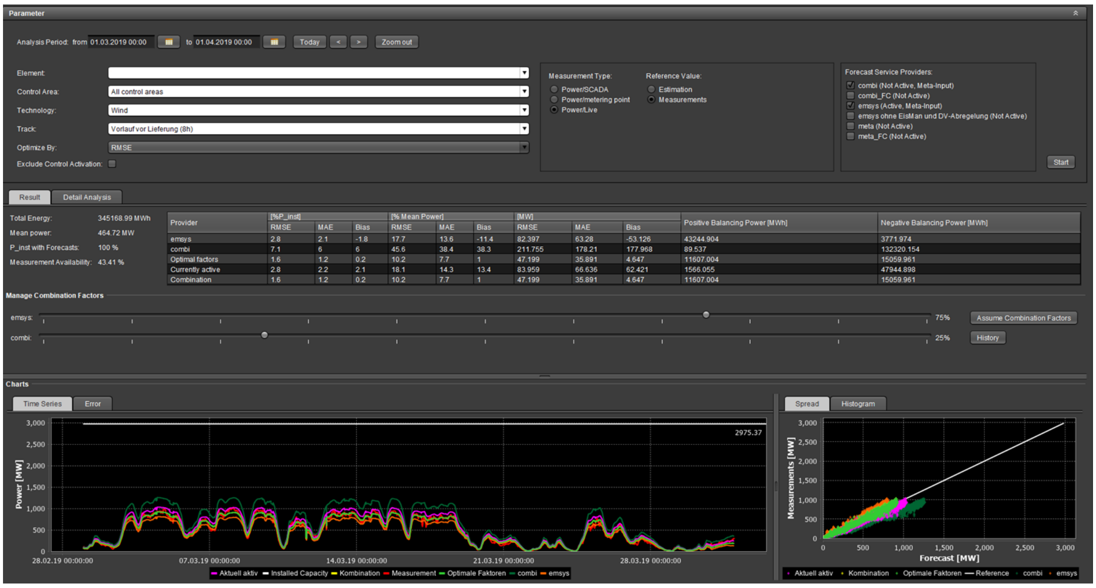

Figure 15: Evaluation of wind and solar power forecasts in a Virtual Power Plant. Source: energy & meteo systems

An analysis of the measured value availability and of measured value problems is helpful to identify defective interfaces. The Virtual Power Plant therefore has a logbook of the plant connections. On the other hand, it continuously checks the plausibility of measured values, for example for crude values or for deviations between a live SCADA measurement and a meter point measurement. It also checks whether control schedules are carried out correctly.

Finally, a Virtual Power Plant can also generate reports based on analyses. For example, it can calculate amounts of energy which have been curtailed for certain plants.

5.4 Trading Functionality

A central function of a Virtual Power Plant is to enable the trading of decentralized plants by aggregating them and selling their production on the market as one single unit. A Virtual Power Plant therefore has interfaces to power exchanges like the EPEX Spot (European Power Exchange) in Europe or similar power exchanges in other market systems. There are two possibilities to connect such a market place. An electricity exchange can be directly connected and trading processes are completely managed in the Virtual Power Plant. Otherwise, external customer-specific trading systems could be used and synchronized to the Virtual Power Plant.

The latter is suitable if, for example, other assets such as large power plants are traded that are not integrated in the Virtual Power Plant or other energy products are traded. In both cases it is important that bids and trading results are transmitted to the Virtual Power Plant almost in real time.

In the trading process, a Virtual Power Plant is able to calculate and display an open position still to be traded based on the latest forecasts and the quantities already traded. This is the central information for an electricity trader. Based on this information, new trades are placed and executed on the electricity trading places. The open position is determined separately for each trading interval (depending on the resolution of the market, e.g., 5 minutes, 15 minutes, 1hour, etc.) and recalculated after each forecast update and each bidding. This gives an electricity trader a dynamic overview of his last position on the market. The presentation is done visually as a time series and especially in tabular form, as this allows the values to be read more accurately. Every Virtual Power Plant should be able to display this basic function. Based on this, many other trading functions can be implemented.

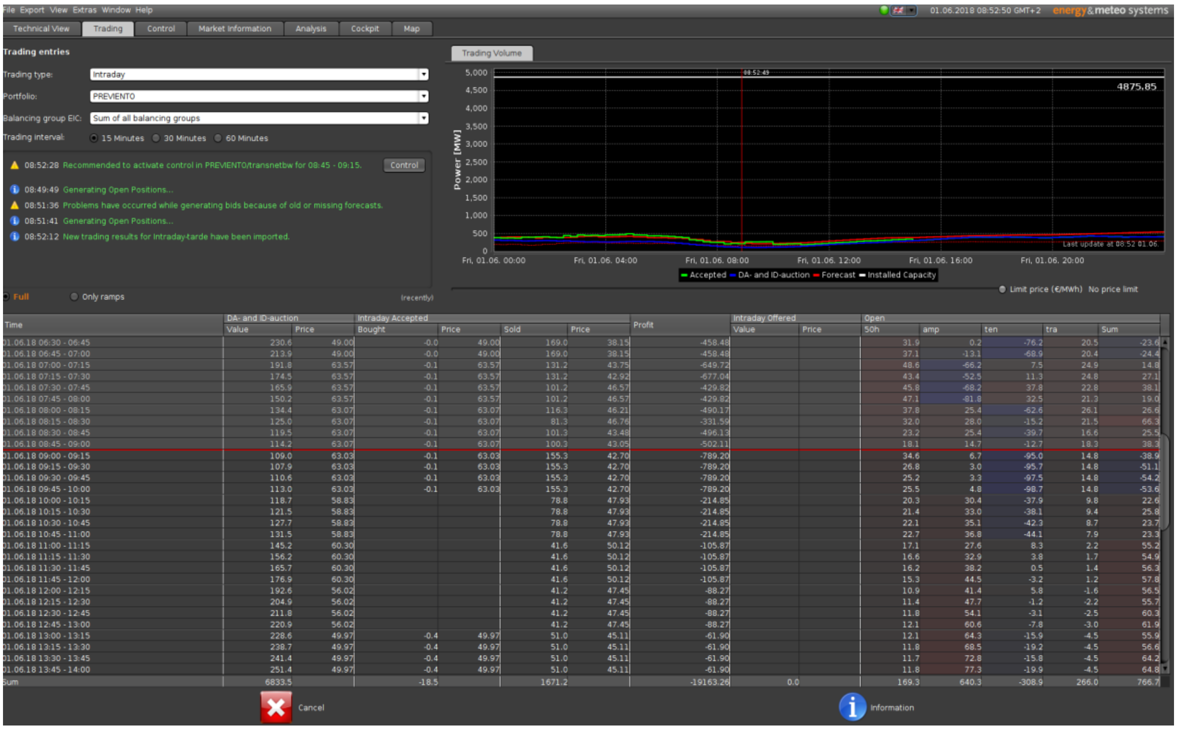

Figure 16: Trading view in a Virtual Power Plant. Source: energy & meteo systems

The basic function described above only refers to the volume risk in trading. In addition, however, there is the price risk. A Virtual Power Plant knows the individual plant prices and therefore determines open positions depending on the marginal price of the assets. Practically, this is done in steps. Quantities can then be placed on the power exchange in steps, with the Virtual Power Plant enabling the deposit of a marginal price for the execution of the bid. Based on this function, (automatic) trading strategies can also be executed in a Virtual Power Plant. The possibilities range from simple strategies, which automatically trade all open positions at certain time, to sophisticated functions, which trade only partial quantities at certain prices and times.

Furthermore, the Virtual Power Plant can support situational awareness in trading. It can visualize and evaluate market information. For example, trading results on the power exchange, open bids of other trading partners in the order book of continuous trading or control power calls. In the last step, the Virtual Power Plant allows historical evaluations of the quality of trading. As an example, the revenue of the intraday optimization against the pure day ahead trading can be calculated.

5.5 Remote-control of assets

The trading processes presented above may result in the necessity to reduce the power of plants or, if the potential is positive, to increase it. For instance, negative electricity prices occur in electricity markets, such as Germany and France, and indicate that too much energy is offered compared to what is asked for. If a plant only receives a feed-in premium, it makes sense to shut down a plant if the negative electricity price is below this premium. In addition, some markets even impose a penalty in case plant operators produce in case of negative market prices. This underlines the importance of exerting an effective remote-control of power plants.

The core function of the Virtual Power Plant is to ensure, independent of the application, a power production as given in the schedule or market position for a portfolio. A Virtual Power Plant tries to do this as accurate and efficient as possible by not only controlling the required number of decentralized plants but also by using exactly those plants which are best suited for this purpose.

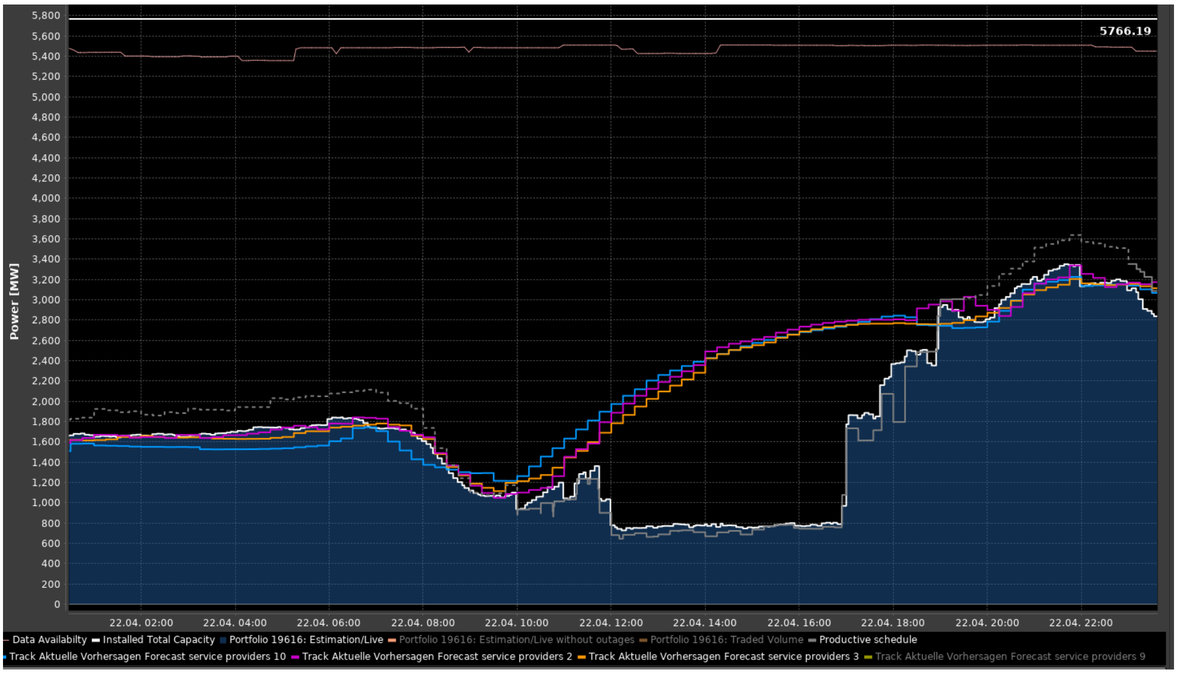

Figure 17: Portfolio schedule and control. Source: energy & meteo systems

In the application case of a market-based control, the basis for the further processes is the current trading status. For example, the traded volume may not be consistent with an updated production forecast. As a consequence, the output has to be adjusted via the Virtual Power Plant. In order to accurately determine a schedule from trading, the flexibility potential of each individual plant is used. To meet the schedule as efficiently as possible, the individual plants are sorted in a so-called merit order. The plant with the most economical marginal price is sorted at the beginning of this merit order and thus considered first for curtailment. Subsequently, further plants are added until the desired quantity of curtailed power is reached. If the forecast or the traded quantity changes, the Virtual Power Plant automatically adjusts the quantity to be controlled and thus the number of plants. The user does not have to worry about controlling individual plants. The user simply sets up a portfolio schedule and the Virtual Power Plant takes care of the implementation.

In the merit order the marginal plant price is the highest criterion. In the second step, further criteria are used which can influence the sequence or even exclude plants from a control. Such criteria are for example the technical availability of a plant, known control problems of the interface, priority requests by grid operators, a technical minimum limit, and any other criteria. When setting up a control and also the corresponding trading processes, these restrictions are automatically taken into account in the available potential.

Figure 18: Schedule and control of connected assets. Source: energy & meteo systems

If the Virtual Power Plant recognizes that plants do not react because of problems at the individual interface of the plant, further plants are automatically taken into account for control to ensure that the schedule is always met. However, it is also possible to set a limit price for the control. This ensures that only plants up to a certain limit price are considered. Here the user has to prioritize his criterion, the schedule loyalty or the cost for curtailing more plants.

Chapter

06

Applications of Virtual Power Plants

6. Applications of Virtual Power Plants

In renewable and digital energy systems the identification of new business models and new control tools for DER is of increasing importance for many market participants. The needs or business opportunities vary with regards to the impact which DER have on their traditional activities. This refers to every participant who actively needs to deal with vRE power generation in different stages along the value chain, spanning from generation via transmission, trading and distribution of electricity.

The Virtual Power Plant is in this respect a highly versatile technology which enables a wide range of possible applications creating value for a variety of users and on a macroeconomic level for the entire power system. This adaptability of the Virtual Power Plant allows as well its operation in different market environments.

As a digital, platform-based software the Virtual Power Plant aggregates DER, reduces complexity and offers services without the operator necessarily owning any of the connected units. By doing so, it meets the needs of a decentralized energy systems and contributes effectively to the integration of renewable energies.

In the following we will present the most common applications of the Virtual Power Plant which can be observed in international power markets:

- Virtual Power Plant as a control centre for DER
- Virtual Power Plant for Demand Side Management
- Virtual Power Plant for trading renewables and other DER
- Virtual Power Plant for providing ancillary services

6.1 Virtual Power Plant as a control center for DER

An example for a technical application of a Virtual Power Plant is its use as a control center for distributed energy resources.

The most important user group are the system operators. In countries throughout the world, they have been accustomed to managing their grid entirely with dispatchable plants. With the transition of their energy systems, they have to adjust IT infrastructure and operational processes in order to deal with the challenges of integrating DER. However, in many power systems which only recently started with expanding DER, the system operators are still used to manage their grid with conventional control room technologies.

Figure 19: Typical control room of a TSO. Source: energy & meteo systems

In many cases the existing IT technology does not allow to monitor in real-time the production from vRE sources on DSO levels. Hence, the system operators lack transparency regarding how much wind and solar energy is injected, precisely broken down to specific areas of the grid network. This information deficit can also include planned or ad-hoc production curtailments or complete outages of the parks due to e.g., maintenance work which is often not communicated on time. The incompleteness, inaccuracy or entire unavailability of real-time information on the behavior of DER is hence frequently a main concern of grid operators.

In addition, the IT tools in place do not enable the grid operator to efficiently remote-control a large number of DER. In many power systems with a centralized unit dispatch, the system operator still manually contacts the solar and wind plant operators, giving instructions e.g., to curtail power production in order to avoid grid congestions. What has proved to be a viable way of maintaining the stability of the grid in a centralized power supply becomes virtually impossible when dealing with a high number of DER.

Both challenges can be addressed by the Virtual Power Plant. The Virtual Power Plant allows monitoring of real-time production processes which can be dissolved according to specific areas of the grid network. The Virtual Power Plant also permits the grid operator to efficiently remote-control the feed-in-volume from wind and solar power plants. Furthermore, the software is able to curtail immediately the production regionally or from selected vRE plants in areas where grid congestions occur.

By integrating solar and wind power predictions in the Virtual Power Plant, the grid operator is able to anticipate as well future production volumes from these resources. Based on the power forecasts, the dispatch of power plants can be adjusted and possible bottlenecks at critical grid nodes detected in advance. In this way, the technology allows a more proactive and plan-based grid operation than reacting on an ad-hoc basis on the dynamic and weather-dependent generation schedules

A major concern is often the integration of the Virtual Power Plant in the control center of the system operator. Since Virtual Power Plants offer a variety of APIs as communication interfaces, they can most often be easily embedded into existing IT infrastructure, allowing a fluid exchange of data.

The control center application can also be a solution for Independent Power Producers (IPP) to monitor solar and wind energy production from an unlimited number of plants which may be dispersed in many countries. However, the Virtual Power Plant is commonly only in those cases required, where the IPP does not merely feed the generated energy into the grid but needs to actively control his production to avoid penalties or to trade it on short-term markets.

6.2 Virtual Power Plant for Demand Side Management

Another area of application for the Virtual Power Plant is Demand-Side-Management (DSM).

The term Demand-Side-Management (DSM), Load Management or Demand-Side-Response (DSR) is used to describe the management of demand for network-based services among customers in industry, trade and private households.

Historically it was primarily the supply side which reacted flexibly, actively adjusting the electricity production from conventional units to the existing demand. However, with an increasing share of renewable energies in electricity generation, this becomes more difficult. The volume of electricity production from wind and solar power plants is changing constantly with weather-conditions. As a consequence, the expansion of vRE leads to a higher variability on the supply side. The only way to actively control the supply from vRE plants is to curtail their production. In contrast to conventional units, the generation from vRE plants cannot be increased. As a consequence, there is an increasing need to provide more flexibility on the demand side.

Companies, for instance, who can manage their production processes with a high flexibility can adjust their electricity consumption to changing market and grid situations by cutting back on their production or falling back on previously stored energy. Common user cases for DSM applications are industrial consumers such as aluminum smelters, cooled warehouses or heat pump systems in private households which can be switched off for a certain time without affecting the work process. In such cases, it is defined in advance how long and which electrically operated devices may be switched off to stay within permitted operational ranges. Based on this defined flexibility criteria, the energy consumption process is mostly not avoided but postponed to a later period.

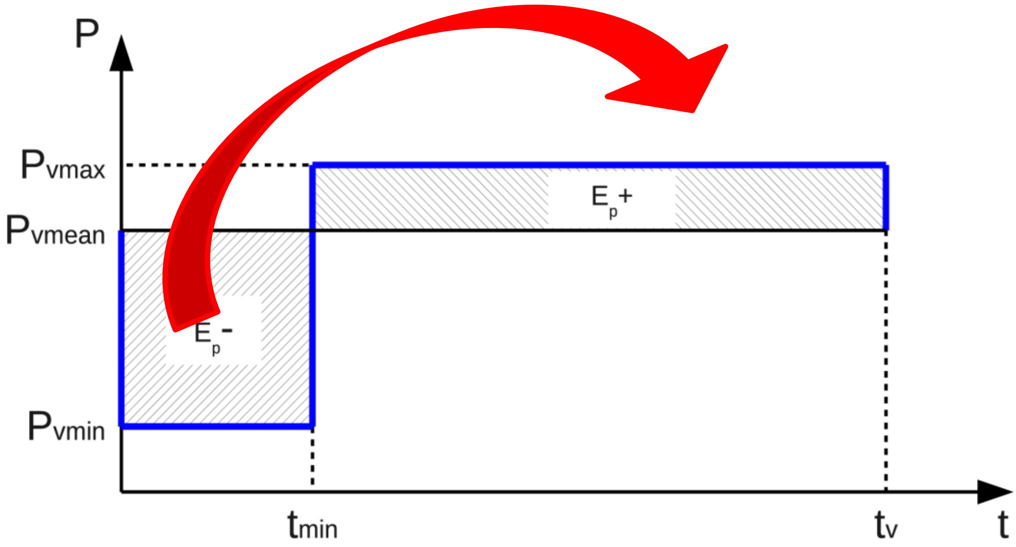

Figure 20: Basic concept of shifting demand in time in DSM application.

By doing so, energy consumers adjust for instance their electricity demand in the event of bottlenecks in power generation (e.g. the failure of a large power plant) or high demand for electrical energy (peak load at midday) or in the event of disruptions in network operation and the result of an underfrequency. Particularly, the consumers in DSM applications can react on volatile production from vRE. At times when vRE production is high consumers can increase the energy production. When the energy market turns this into corresponding price signals, the energy prices are low during these events. In turn, when there is a shortage of electricity supply companies are financially compensated for spontaneous load shedding. Depending on the market design, companies cannot only decrease energy costs with DSM but also open up access to a new source of revenue, marketing their flexible demand as ancillary service, on the spot market or on the market for disconnectable loads.

Digitalization opens up completely new possibilities for DSM applications and the Virtual Power Plant has emerged internationally as an ideal tool for adapting the demand for electricity to the generation of energy. The technology has the capability to integrate different market participants from the supply and demand side and orchestrate they processes in real-time. Thus, each connected unit contributes to an overall optimized operation of the entire portfolio.

The portfolios connected to a Virtual Power Plant can vary substantially. A portfolio may consist only of flexible consumers but can also be a power pool integrating vRE units, consumers and possibly also storage devices. The characteristics and operational limits of the connected units as well as the given environment in the respective power system define possible applications of a DSM solution coordinated by a Virtual Power Plant.

In order to set up a DSM application, a comprehensive set of data and information is required:

- plant data (installed capacity)
- real-time production data
- power forecasts for vRE plants
- real-time consumption data
- definition of flexibilities and operational limits from generators and consumers
- outages in generation and consumption

Depending on the application the Virtual Power Plant will respond to grid and market situations, constantly monitoring and offering the current and future flexibilities of the portfolio. Interfaces with the grid operator (e.g. for offering ancillary services) or the market (e.g. for trading flexibilities) allow a smooth interaction of the Virtual Power Plant with its environment.

In addition, Virtual Power Plants also provide unique technological skills to reduce forecasting errors in DSM applications. In case day-ahead power predictions for the wind and solar power production turn out to be inaccurate on the following day, they can be absorbed by the consumers of the portfolio. If, for instance, the forecasts were too low and more energy is produced, the Virtual Power Plant could give instructions to increase the load. If, on the other hand, the prediction was too high, the consumers were given signals to reduce the demand within the given limits. Hence, by compensating forecasting errors internally, the Virtual Power Plant helps to minimize penalties or balancing costs.

6.2.1 Excursion: The German market for disconnectable loads

The German regulatory authority as well as the energy market have reacted in many ways to respond to the massive expansion of vRE in the power system. This refers also to the rules for the market for disconnectable loads. The four transmission system operators (TSO) in Germany can give instructions to reduce load in order to compensate for a deficit in generation or in order to resolve a grid congestion. These rules are contained in the Regulation on agreements on disconnectable loads is in force since 2013.

The first version of the regulation defined the following rules:

- Connection to high or maximum voltage (110 kV or higher)
- At least 50 MW needed to be disconnectable
- Disconnectable capacity needed to be remotely activatable within 15 minutes or automatically within 1 second

In 2016 the regulation was amended, particularly concerning the following aspects:

- Extension of the circle of providers by including also units connected to medium voltage grid
- Only 5 MW need to be disconnectable
- Amendment includes new options for aggregating load to achieve the 5 MW limit

In addition, the tendering period was reduced from one month to one week.

The amendment clearly aimed at increasing the available potential on the demand side and support the usage of disconnectable loads in the industry to stabilize grid networks and the energy supply

6.3 Direct marketing of renewable energies and other DER

Another application for Virtual Power Plants is direct marketing of renewable energies and other distributed energy sources. This application is considered to be the most common use-case in Europe, especially in Germany which was the first-mover in introducing a direct marketing scheme. Since Virtual Power Plants are especially in Germany state-of-the art in marketing renewable energies, their rise is explained alongside the market development.

The direct marketing scheme has replaced former feed-in-tariff-based (FIT) regimes. The FIT proved to be a reliable and predictable payment to plant operators and led to high investments into renewable energy. In this model, the energy is fed into the grid and is paid according to the feed-in tariff by the DSO. The DSO transfers the energy to the power balancing groups of the TSOs, which then must sell it at the spot market (EPEX Spot).

In Germany, the direct marketing scheme was introduced in 2012 with the goal to achieve a more efficient integration of vRE generation in the market. The idea was to promote market sale of renewable power and hand over power balancing responsibility to the power market participants. The amendment of the German renewable energy law from 2014 obligated all newly commissioned power plants above 100 kW starting operations from 1st January 2016 to sell their power on the power market.

Out of Germany's current total installed capacity of 60.6 GW of wind energy plants and 47.95 GW of photovoltaic installations (Fraunhofer 2019), in October 2019, 57.9 GW of wind energy capacity and 13.6 GW of photovoltaic capacity participates in the market (50 Hertz et al. 2019: 1). For the rest of renewable power, which is primarily roof top solar, their respective TSOs are responsible for power trading in the market and for their power balancing.

The above market premium scheme led to the emergence of power aggregators in the German market. For a service fee, these aggregators trade the energy output for individual power producers. Thus, they often integrate many contracted vRE plants and create a portfolio whose aggregated production is traded on the power market. These power aggregations are balancing responsible for their generation, meaning that the produced and traded energy must be equal. In the German power market, there are currently more than 25 major power aggregators such as Statkraft, MVV, Vattenfall etc.

Direct marketers face the crucial challenge to efficiently trade the power generation of a portfolio which often consists of hundreds of regionally distributed wind and solar parks.

To fulfil this task, they need to

- monitor real-time production of the whole portfolio
- anticipate production based on power forecasts
- remote-control the electricity generation of their portfolio and adjust it to changing market situations

It is worthwhile noting that aggregators mostly do not operate the power plants and are not the plant owners. They focus entirely on trading the output. The Virtual Power Plant has emerged as a state-of-the-art technology used by aggregators to support their trading processes.

The first step consists in establishing a connection to each single plant in order to receive real-time measurement data and implement remote-controllability. As an external source, one or several solar and wind power predictions from forecast providers are integrated which provide information on the future production schedule of the vRE portfolio. Some Virtual Power Plants are able to create an optimized meta-forecast which takes into account the weaknesses and strengths of each single power forecast. Meta-forecasts are on average always more accurate than single forecasts and help aggregators further minimizing their balancing costs.

The software then takes into account outages due to e.g., maintenance of plants before calculating the future production schedule. These non-availabilities can be transmitted by the plant operators via a web-interface directly to the Virtual Power Plant (see once again Fig. 5 which illustrates the data flow within a Virtual Power Plant)

As a result of this process, the aggregator can then see the production schedule of his portfolio (and for single plants) and place his bids depending on the market situation. As mentioned earlier, a trading function within the Virtual Power Platform grants the aggregator direct access to spot markets for this purpose.

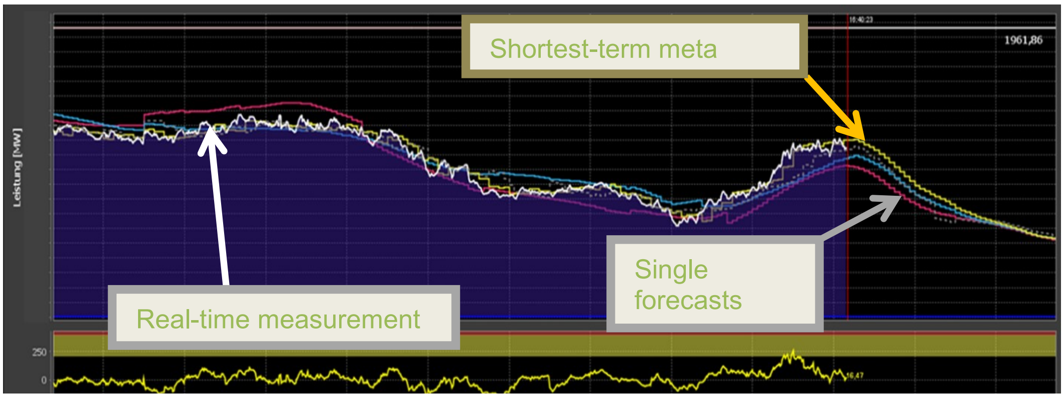

Figure 21: Monitoring view of VPP showing generation data (white line) and several forecasts (colored lines). Source: energy & meteo systems

In case of negative prices or grid bottlenecks, for instance, the aggregator can curtail within seconds the generation of his portfolio or selected plants to a desired limit.

The Virtual Power Plant also supports the aggregator in complying with his balancing responsibility. If due to a weather-event a short-term overproduction occurs which does not find an off-taker in the market, the aggregator can give the software an order to stick to the previously traded production schedule and curtail the excess energy.

Such interventions into the production schedule can be seen in chart below which shows the power output in kW from a power pool managed with a Virtual Power Plant. The upper constant line indicates the aggregated installed capacity. The white line marks the varying output level of the portfolio and the yellow line the meteorologically possible generation based on the latest power forecast.

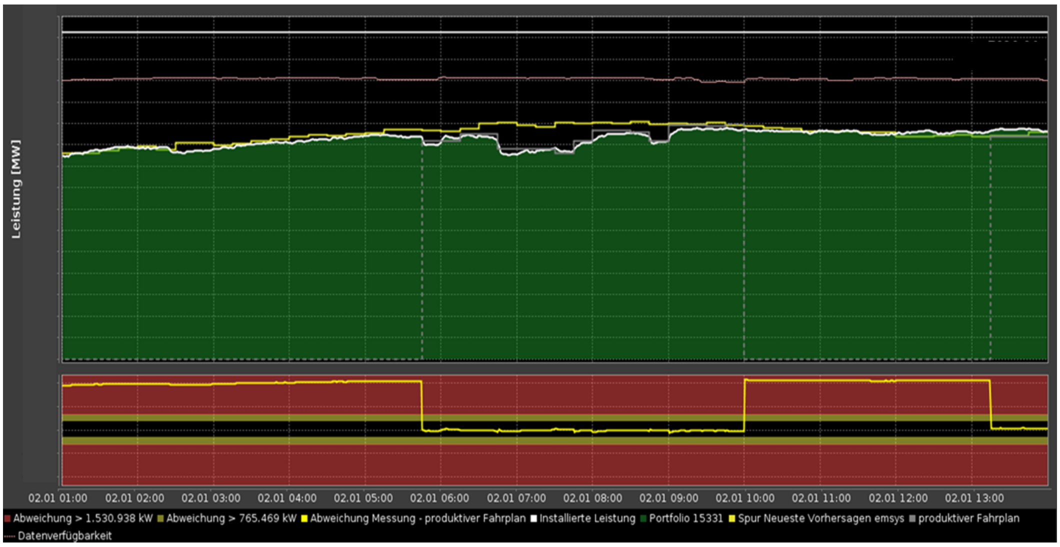

Figure 22 Curtailment schedule executed by Virtual Power Plant for a vRE portfolio
Source: energy & meteo systems

6.4 Providing ancillary services

Ancillary services are those services provided by generation, transmission and control equipment which are necessary to support the transmission of electric power from producer to off-taker. These services are required to ensure that the system operator meets his responsibilities in relation to the safe, secure and reliable operation of the interconnected power system.

Ancillary services are provided as mandatory services or based on a competitive market system. They comprise frequency and voltage stability, re-establishment of the power generation including black start capacity and the operational management of power plants and grid, e.g., grid congestion management by redispatching.

A crucial ancillary service is the provision of balancing power which helps maintaining frequency, voltage, and power load within certain limits and is therefore essential for the operation of a transmission or distribution system. To keep the frequency stable, balancing power of the operating reserve is used to balance the active power of the system on short time scales. Industrial loads as well provide balancing power, but it is mostly provided by generating units.

Historically, balancing power has been provided primarily by conventional power plants, as spinning reserve or supplemental reserve. With the increasing penetration levels of vRE, however, solar and wind plant operators also need to contribute to grid stability. It is essential to explore ways to control their power generation and mobilize their potential to contribute to system stability. This is also important with regard to the political decision of an increasing number of countries to phase out nuclear energy (e.g., Germany, Vietnam) or coal-fired plants (e.g., Germany, Chile).

A specific challenge of integrating vRE for the provision of system services is the high number and different – mostly weather-dependent - generation characteristics of distributed assets. Hence it is a crucial task to establish a smooth coordination between the grid operator and the variety of plant operators to ensure an efficient control over DER.

Wind farms and solar power plants have already been enabled to provide negative balancing power. Positive balancing power, however, could only be provided if vRE plants are curtailed and produce less energy than meteorologically possible. This would be uneconomic since a lot of potential renewable energy would not be produced. Notwithstanding, other distributed energy units, for instance biogas plants, can postpone at least partially postpone their energy production which enables them to provide as well positive balancing power.

In general, there are three types of balancing power with the following characteristics available for the TSO. The following example is based on the definitions of the German regulation.

- primary reserve to stabilize the grid within 30 seconds
- secondary reserve needs to be available within 5 minutes to its full extent
- minute reserve which replaces the secondary reserve needs to be provided within 7,5 minutes and is activated for at least 15 minutes at a constant level

If balancing power is to be provided to grid operators, the decentralized plants can as well be managed via a Virtual Power Plant. As with market-related controls, the aggregation in the Virtual Power Plant gives the ability to act as a full generation asset with a typical size, as normally size thresholds are implemented by grid operators (for example 1 MW minimum for being accepted to provide balancing power).

Within the processes the plants are addressed via the same interfaces of the data monitoring and market-based control, whereby higher safety requirements may apply (see chapter 6.1). Significant differences occur in the process. Decentralized plants have a certain flexibility potential, which can be used in positive or negative call-off direction for the provision of balancing power. It is, therefore, important that not only a plant schedule for the expected production is available, but also information about the future flexibility potential. If this potential is known from the individual plants, it can be aggregated in the Virtual Power Plant. It can then be made available to the grid operator. A typical balancing power process takes place in two steps. Plants have to be available in a certain period, but can run normally as planned. Only in case the grid operator needs more or less power the plants can get a request in a second step, which needs to be fulfilled immediately. Both steps are normally remunerated individually.

In Europe the needed power adjustment potential is usually requested by grid operators via auctions in which different types of control power are requested for different time blocks (e.g. weeks, days, hourly blocks). If the contract is awarded, a provider must ensure that he can provide power adjustments during this period, in accordance with the defined conditions (reaction time, minimum duration etc.)

In some countries grid operators insist that the technical capabilities must first be proven in a so-called pre-qualification process. Depending on the specific requirements, this can be necessary for the overall system and/or for each individual asset. A Virtual Power Plant maps this pre-qualification process and can perform it for each individual plant, as for example in Germany a double hump test. Once this pre-qualification was successful, the plants can be taken into account in the provision of balancing power.

Figure 23: Double hump test with wind parks. Source: energy & meteo systems

As described above, the potentials for providing balancing power of the individual plants are aggregated. Based on this information, the user offers the potential to the grid operator or the corresponding entity. Usually, not the entire potential is offered but a certain amount is kept as backup if some plants do not react accordingly.

During the activation period, the Virtual Power Plant receives direct power adjustment signals via an interface to the grid operators. Based on the quantity to be adjusted, the Virtual Power Plant calculates which plants need to be adjusted in terms of their capacity. Here again a merit order is used. The most economic plant is selected first and further sorting and filtering criteria are applied. For example, if one plant does not react, the next plant is immediately selected and the first plant is placed at the end of the merit order.

For monitoring purposes, the Virtual Power Plant also offers visualizations, as well as alarm functions if requests cannot be fulfilled. After completion of requests, a Virtual Power Plant offers possibilities to calculate volumes in order to generate invoices for plant operators or grid operators.

In numerous markets, the technology has already proven its efficiency in activating the potential of DER for providing system services. In Germany, vRE plants are today an established participant in the ancillary services market. In addition to biogas, biomass and wind turbines, lithium-ion batteries and industrial loads are already controlled operationally.

Their integration in the balancing power market has resulted in increasing the supply side which – along with a more dynamic short-term market which reduced trading blocks from 60 to 15 minutes – has led to a substantial drop in prices. So, while the feed-in from vRE has increased dynamically since 2011, balancing power is activated less frequently than before

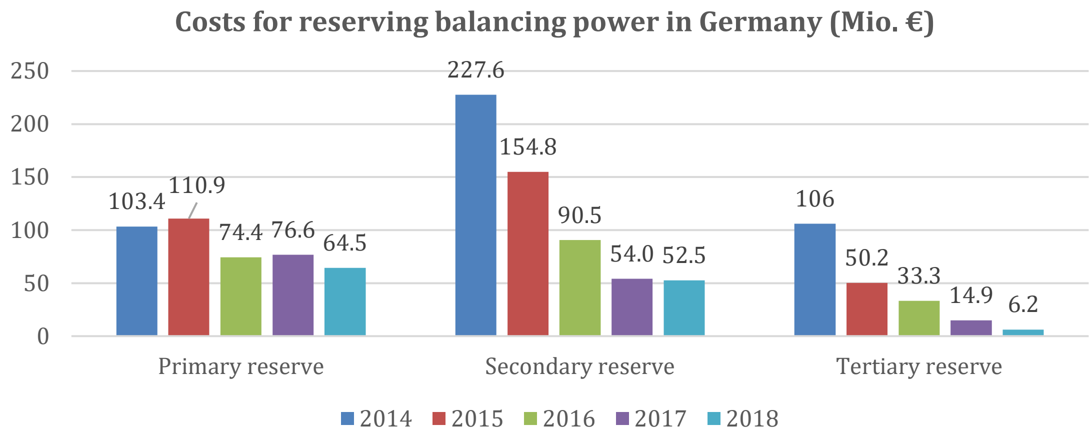

Figure 24: Cost development for reserving balancing power in Germany.
Source: energy & meteo systems, based on figures by BNetzA, Monitoringbericht 2019

Chapter 07

Applications of Virtual Power Plants

7. International market development

The Virtual Power Plant is a relatively young technology. The software was first tested in mostly non-commercial demonstration and research projects which mainly focused on connecting industrial consumers to activate and study their DSM potential. With the proliferation of vRE on a global scale the need for their aggregation and control created a new market for the technology. The capability of the Virtual Power Plant to absorb as well new technologies such as energy storage devices further fuels the demand.

In the following we provide a snapshot on the international Virtual Power Plant markets:

- **Europe**

The introduction and rapid expansion of renewable energies in many European countries sparked the need for a software to manage large amounts of DER assets. By introducing the direct marketing regime for renewable energies in 2012, Germany quickly emerged as a leading European Virtual Power Plant market. Aggregators required a software to control and trade their portfolios and the Virtual Power Plant quickly established as the state-of-the-art technology and today is the dominating technology. All of the market-leading aggregators listed in the figure employ a Virtual Power Plant software. Other European countries followed the German example with France introducing a direct marketing scheme in 2018 and Greece in the year 2020. In these countries as well, Virtual Power Plants are gaining importance even though some utilities tend to stick to existing control room technologies, trying to adjust them to the new tasks. As outlined in the following, the Virtual Power Plant is also used for offering ancillary services with different kinds of technologies (e.g. wind energy, biogas) to the system operator. Europe accounts presently for a very high market share owing to ambitious green energy targets and a large number of industry players.

- **USA**

The US market is today the second important market for Virtual Power Plants. Decline in the costs of solar PV and battery-based energy storage system are the factors which drive the Virtual Power Plant solution market in North America. Distributed energy, including rooftop solar, on-site batteries to store electricity are expected to grow to nearly 400 GW by 2025 which exceeds the current amount of coal or nuclear power capacity. Virtual Power Plants are bidding into wholesale electricity markets in California, New England and other areas. Applications do not only deal with the supply side, but also help manage demand, and ensure reliability of grid functions through load-shifting approaches. Pilot projects are proliferating and utilities are, if not yet pursuing the software, at least investing into or considering its purchase.

- **Asia-Pacific**

Asia-Pacific is expected to experience high growth rates in the global Virtual Power Plant market with a variety of applications reflecting the diversity of the countries. Main drivers of this development are a rapid industrialization in countries such as China and India, with rising energy demand and the expansion of vRE in the energy supply. The applications in these countries are likely to focus on load shifting solutions. Japan and South Korea, on the other hand, have already adopted liberalized market rules which will boost demand for Virtual

Power Plant software. In South Korea, the introduction of a direct marketing scheme for vRE is currently discussed. Japan is about to introduce a market for ancillary services in 2020 and a market premium model in 2021 which will automatically spur demand for control software solutions. Overall, it is forecasted that Asia-Pacific will achieve a significant share of the global Virtual Power Plant market in the upcoming years.

- **Australia**

In comparison to Europe, Australia started later with adopting renewable energies in its energy supply. The particularity of the Australian power market today is an extraordinarily high share of rooftop pv systems, often coupled with storage devices. The installed capacity of rooftop pv systems will achieve 12 GW at the end of 2020. Since rooftop pv systems need to provide schedules to the Australian power market, many energy providers have developed Virtual Power Plant platforms for their area to aggregate these resources. Another major concern is increasing grid constraints which lead to more frequent curtailments of vRE units which needs to be intelligently organized. Given these challenges, publicly financed Virtual Power Plant pilot demonstration projects have contributed to implementing and testing systems which digitally connect small-scale pv and storage systems and orchestrate their operation. The Australian Energy Market Commission also paved the way for Virtual Power Plants ruling that they can compete freely in the country's wholesale electricity market.

Difficulties remain to estimate the global market size of Virtual Power Plants. First, the Virtual Power Plant market is not very transparent. Virtual Power Plants are not a commodity and primarily supplied by few specialized providers. Second, the market volume would have to distinguish between mere software sales, the assets which they aggregate or the value they create for the user.

BIS Research provides the following numbers for the international market development for Virtual Power Plant. BIS Research does not provide information on its methodology but the figures suggest that the Virtual Power Plant and the connected assets are taken into account.

	2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**CAGR (2019-2024)**
North America	397	509	652	835	1,069	1,368	1.752	28,0%
Europe	360	448	563	708	888	1,115	1,400	25,6%
Asia Pacific	224	292	382	498	650	847	1,103	30,4%
Rest of World	87	105	126	150	178	211	248	18,7%
Total	1,066	1,355	1,723	2,190	2,785	3,541	4,503	27,1%

Figure 25: Global Virtual Power Plant Market (by region), 2018-2024, $Mio.
Source: BIS Research, Global Virtual Power Plant Market (2019)

Notwithstanding the methodology it can be concluded that Europe and North America are currently the leading markets. For the upcoming years it is expected that while these markets continue to grow the Asia Pacific region will pick up based on even higher growth rates.

Chapter 08

International case studies

8. International case studies

8.1 Germany

One of the leading Virtual Power Plant markets is Germany. Germany has a total installed power capacity 205.9 GW (Fraunhofer ISE 2019). Figure 1-1 below presents its technology mix, with wind and solar constituting around 51% of the total capacity. The German power transmission system is owned and operated by four Transmission system operators (TSOs) namely Amprion, TenneT, 50Hertz Transmission and Transnet BW. Further, there are 890 Distribution system operators (DSOs) in the country operating at high, medium and low voltages. The TSOs have a natural monopoly in their respective areas, but they as well as DSOs are regulated by the federal regulator which is called Bundesnetzagentur (Federal Network Agency).

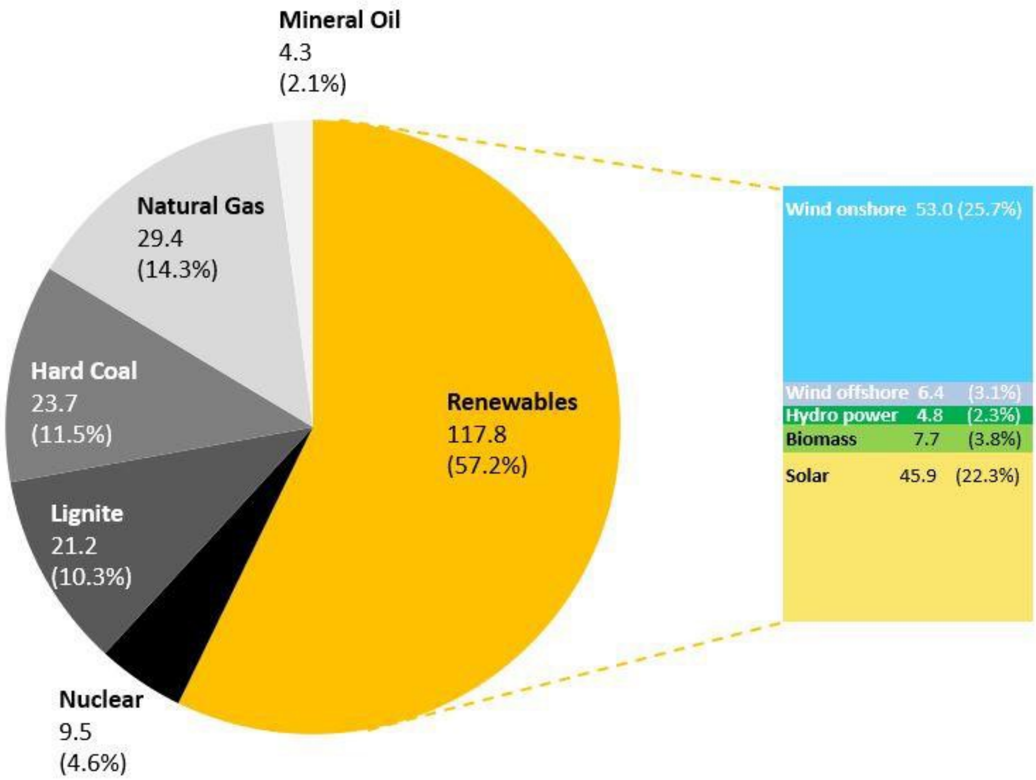

Figure 26: Energy mix In Germany. Source: BDEW

Until 2008, there was no obligation for renewable power plants in Germany to be remote controllable. EEG §6 dating from 2009 (Renewable Energy Sources Act) introduced the new obligation for renewable power plants to be remote controllable for all production units bigger than 100kW. Also, all existing power plants had to be retrofitted to meet this new requirement. The requirement from the law was the possibility to reduce active power feed-in and the possibility to measure the active power production in real time. At this point of time, not all manufacturers e.g. of wind farms had a solution to receive the signals and to reduce the active power feed-in yet. Neither an interface solution nor were all turbines capable in reducing their power production.

In the year 2009 the German Parliament issued the ordinance SDLWindV (ordinance regarding system services by wind parks). In this ordinance the obligation for new wind parks to provide ancillary services was introduced. This includes remote control of re-active power or the local control of re-active power as a function of the grid voltage, also known as Q(U).

From 2015 onwards the remote controllability by traders became an obligation for all parks that want to participate in the market premium model. Since 2016 all new renewable plants (with a capacity >100kW) have to participate in the market premium model, so they have to be remote controllable by their energy trader.

8.1.1 Virtual Power Plant user cases

8.1.1.1 Direct marketing of renewable energy

As outlined in the previous chapter, a direct marketing scheme replaced in 2012 the former FiT regime in Germany and in the following years also in other European countries. The aggregators or direct marketers have emerged as a new market participant which assume the responsibility to trade the power output of wind and solar plants against a fee paid by the plant owners. These aggregators are fully balancing responsible and need to pay balancing costs in case of deviations between forecast and actual production schedule.

In Germany, In the second quarter of 2020 the power production of renewable energy plants with an installed capacity of 81,675 MW was traded in the direct marketing model. Altogether, about 25 direct marketers share the total market volume. In order to match supply and demand in the best possible way, ways had to be found to make wind power generation controllable. Decisive factors were the Virtual Power Plant and power forecasts. For direct marketers, the Virtual Power Plant has evolved as the state-of-the-art technology to manage DER portfolios and successfully trade their electricity generation.

The list below shows the current TOP 5 direct marketers in Germany for different generation technologies. All of them use the Virtual Power Plant as technology platform for their business model. It is noteworthy mentioning that direct marketing has opened business opportunities for new market participants (e.g. Quadra Energy) which have reached a significant market share vis-à-vis the established utilities.

The largest direct marketer of renewable energy in Germany – and in Europe – is Statkraft. The public Norwegian energy company was among the first ones to enter in the new market premium model in 2012 which gave direct marketing a boost. Statkraft opted at a very early stage for the Virtual Power Plant technology provided by energy & meteo systems as a digital control center which connects the DER plants which mainly belong to 3rd parties. The technology enabled Statkraft to participate in the new market and become a market-leading aggregator.

Rank	Technology	Direct marketer	Status 1.01.2018	Status 31.12.2017	Wind	PV	Biomass / Biogas	Hydro
1	Wind	Statkraft Markets	9680	9825	8815	770	40	55
2		Quadra Energy	4880	3500	4800	74	3	3
3		MVV Energie	5900	7400	4400	1400		
4		EnBW	4505	4730	4100	250	40	110
5		EWE Trading	3765	2920	3480	45	240	
1	Solar	MVV Energie	5900	7400	4400	1400		
2		Next Kraftwerke	3090	2871	568	1222	1270	14
3		Sunnic Lighthouse	1700	1300	500	1200		
4		Wind Energy Tra-ding	4300	4300	3450	843	2	5
5		Statkraft Markets	9680	9825	8815	770	40	55
1	Biomass	Energy-2-Market	3543	3408	1198	633	1622	90
2		Next Kraftwerke	3090	2871	568	1222	1270	14
3		Baywa-Re / Clean Energy Sourcing	2135	3045	1565	121	445	
4		Lechwerke	400	390		47	254	58
5		EWE Trading	3765	2920	3480	45	240	
1	Hydro	Innogy	2117	1914	1391	156	184	385
2		Uniper	2408	1480	2278	3	7	120
3		EnBW	4505	4730	4100	250	40	110
4		Energy-2-Market	3543	3408	1198	633	1622	90
5		Vattenfall Energy Trading	3710	4410	3120	525		65

Figure 27: TOP 5 direct marketers for wind, solar, biomass and hydro power in Germany. Source: Energie & Management

Statkraft initiated its activities with a portfolio of 7,000 MW. In 2013, the aggregated portfolio managed by Statkraft´s Virtual Power Plant was bigger than any conventional power plant in Germany. In 2014 the remote-control of vRE assets by a direct marketer became mandatory. Two years later, a 3 MW storage system was added to the VPP. In the beginning of 2020, the company managed and traded a portfolio of 9,900 MW which consisted mainly of wind onshore parks. Currently the portfolio of Statkraft integrates 1,600 wind parks which produce 23,700 GWh. The Virtual Power Plant is currently the biggest European power plant and is exclusively renewable.

The Virtual Power Plant enables Statkraft to establish and maintain control of its entire portfolio and to quickly respond quickly to dynamically changing production levels and market situations.

8.1.1.2 Provision of ancillary services

As already mentioned, DER are now allowed to contribute ancillary services in the German power market. Statkraft was the first company in Germany to participate in the control energy market with a wind farm pool at the beginning of 2016. The technological platform for coordinating the wind farms is a Virtual Power Plant provided by energy & meteo systems. The Virtual Power Plant serves as transmission belt between system operator and wind farms. Managed by the Virtual Power Plant, the wind farms can offer negative minute reserve, as the power of the turbines can be automatically and precisely throttled.

The following chart illustrates how quickly and precisely the wind farms execute the digital instructions of the Virtual Power Plant. The chart shows the output level of a single wind farm with an installed capacity of 24 MW which is indicated by the constant horizontal line.

The white line which marks the upper end of the blue area indicates the production schedule. In this example, the Virtual Power Plant reduces the generation level to the desired output level of 6,2 MW, thus offering negative load to the power system.

Figure 28: Virtual Power Plant curtailing wind park to provide ancillary services to the system operator.

Source: energy & meteo systems

As can be observed on the time axis, the curtailment of the wind farm is carried out two times for a period of 15 minutes. On demand of the TSO, the curtailment is executed by the Virtual Power Plant within seconds and as quickly the wind farm returns to its meteorologically maximum output level.

The Virtual Power Plant can also integrate non-variable distributed energy resources in the balancing power market. A common user case in the German market are distributed biogas plants which provide their flexibility with a Virtual Power Plant. Biogas plants can provide secondary and tertiary reserve to the German system operators.

In the chart below taken from a Virtual Power Plant the power production of a pool of biogas plants is shown. The aggregated installed capacity of the biogas portfolio is 7,275 MW. In the given one-hour timeframe, the biogas plants run at a constant power output of 4 MW. The smaller charts below show the production schedule of the three single biogas plants.

Within the timeframe, the TSO needs negative load and requests the Virtual Power Plant to curtail the production of the connected assets. The combined output is throttled two times to a minimum level of 3 MW and one time to 3,5 MW. In comparison to the wind parks, the biogas plants react more slowly, showing the typical inertia of thermal power plants

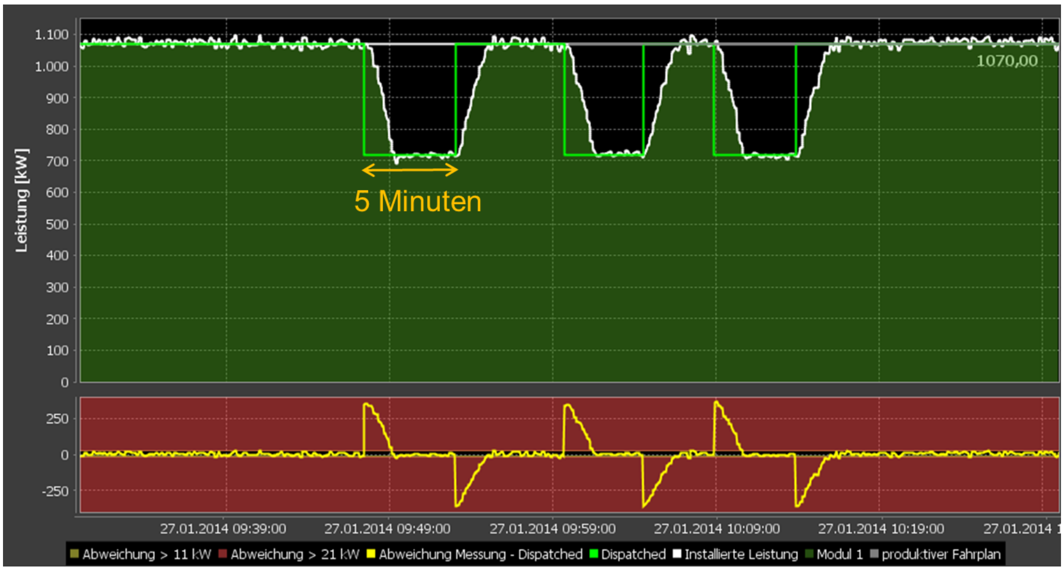

Figure 29: Virtual Power Plant curtailing biogas plants to provide ancillary services to the system operator. Source: energy & meteo systems

8.1.1.3 Demand Side Management

A variety of examples on a global scale have demonstrated the benefits of the Virtual Power Plant technology for implementing DSM projects.

In a model project in Cuxhaven region in the North of Germany, the eTelligence project tested a complex ICT-based system for balancing the fluctuation of wind energy, PV, biogas and CHP plants, which intelligently integrates electricity into the networks and into a regional market, while at the same time enabling the active involvement of consumers. For this goal, vRE producers were coupled with consumers who are suitable for storing electricity or who can flexibly adapt their electricity consumption to the generation process.

A Virtual Power Plant served to bundle the different market participants and implement the DSM project. On the generation side, biomass and wind onshore plants were added to the Virtual Power Plant portfolio. As flexible load, a cooled warehouse used for freezing food (e.g., fish) was connected to the software. The warehouse has to maintain a temperature level between minus 18 degrees and minus 24 degrees Celsius to procure that the food is preserved. This involves switching off the freezers and refrigerators for a certain period of time. The thermostats are adjusted beforehand so that they cool or freeze the food by remote control, they can remain switched off for about 1 to 2 hours before they have to be switched on again to protect the food from thawing. This flexibility range is considered in the algorithms of the software which then coordinates the operation of the cooled warehouse accordingly. In addition, the power pool was connected to a spot market, providing an opportunity for externally trading electricity and flexibility.

The following chart from energy & meteo systems´ Virtual Power Plant shows the power pool in the monitoring view. The green area shows the biomass plants which generate electricity at a constant level. On top in blue is the fluctuating production curve of the connected wind onshore plants. The grey area in the negative power scale indicates the load from the cooled warehouses.

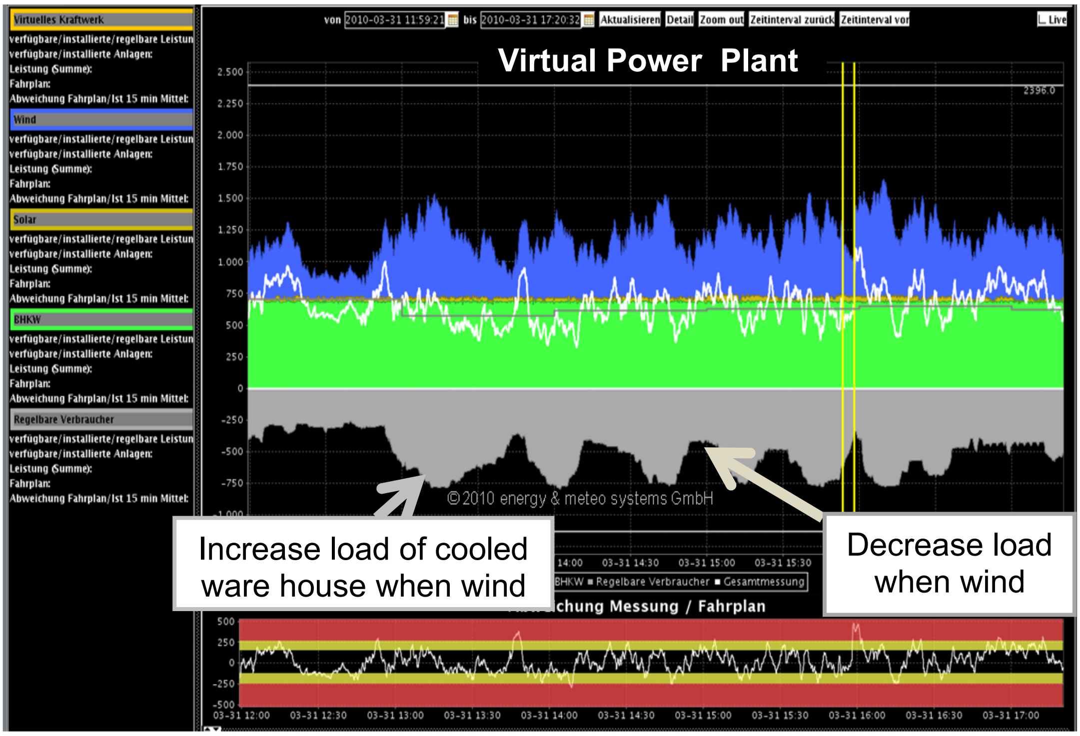

Figure 30: Virtual Power Plant curtailing biogas plants to provide ancillary services to the system operator.

Source: energy & meteo systems

Orchestrated by the Virtual Power Plant, the flexibility in energy consumption by the cooled warehouses can be balanced with the variable energy production from the wind onshore plants. At times when wind power production is high, the surplus can be used within the power pool.by increasing the load. The compressors are switched on and take advantage of the available energy, thus reducing external electricity supply at a later point of time. When the wind speed is lower and consequently the wind power production decreases, the Virtual Power Plant reacts by reducing the load of the cooled warehouses.

This coordination of supply and demand with the Virtual Power Plant has several positive impacts. First, the demand for external and more costly electricity supply can be reduced. Second, the power pool is able to jointly offer balancing power to the system operator. In addition, the balancing efforts prior to feeding into the grid result in alleviating the pressure on the public electricity network and contribute to avoiding grid congestions.

Another positive effect was the reduction of forecasting errors. When deviations between predicted and actual production schedule occur, these can be settled on the intraday spot market until 30 minutes before market closure. Imbalances which appear at a later stage cannot be traded anymore and are subject to imbalance settlement executed by the system operator.

The Virtual Power Plant was able to reduce these costly imbalances in the DMS project by compensating the deviations internally with the cooled warehouses. In case an unpredicted surplus of electricity production cannot be used by increasing the load, the Virtual Power Plant additionally offers the option to curtail the wind power plants to establish a match between forecast and production. The following chart shows the number of positive and negative deviations from the production schedule.

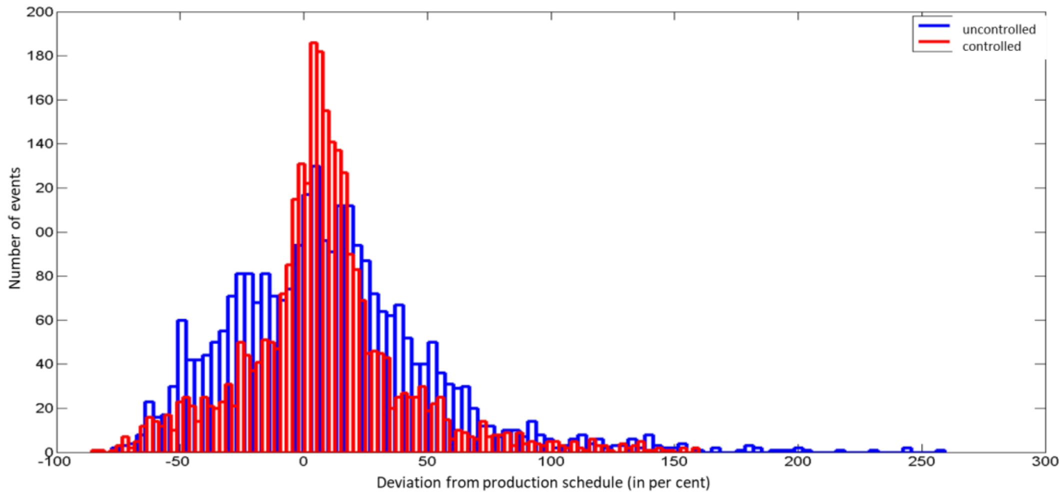

Figure 31: Positive effect of DSM application with Virtual Power Plant on power forecast errors. Source: energy & meteo systems

The distribution of these events Is given in blue for a system without Virtual Power Plant and in red coordinated by the Virtual Power Plant. As can be seen concerning the positive deviations, the software was able to avoid events with extremely high deviations completely. In addition, the number of events with medium to high deviations was significantly reduced.

8.2 Argentina

In this chapter, another user case of a Virtual Power Plant in Argentina will be presented. The Argentinian energy supply relies primarily on fossil fuels. The power sector is dominated by thermal power, which accounted for nearly 64% of the total installed capacity and 65% of the electricity generated in 2019. Being the third largest hydrocarbon producing country in Latin America, behind Mexico and Venezuela, the bulk of the generated electricity is based on natural gas and oil-fired plans. As non-variable renewable energy source, hydro power has historically contributed a significant share to the Argentinian energy mix. The following chart shows the electricity generation by source and the dominant share of the above-named technologies.

Since 2016, the Argentinian government pursues the goal to tap its abundant resources for generating solar and wind power. With the introduction of the RenovAR program Argentina initiated a series of auctions for solar, wind, small hydro, biogas and landfill gas projects. By 2019, 244 projects with a combined capacity of 6.300 MW have been awarded PPA contracts. As for the contract, the companies that were awarded sign a PPA with the Compañía

Administradora del Mercado Mayorista Eléctrico S.A. (CAMMESA).

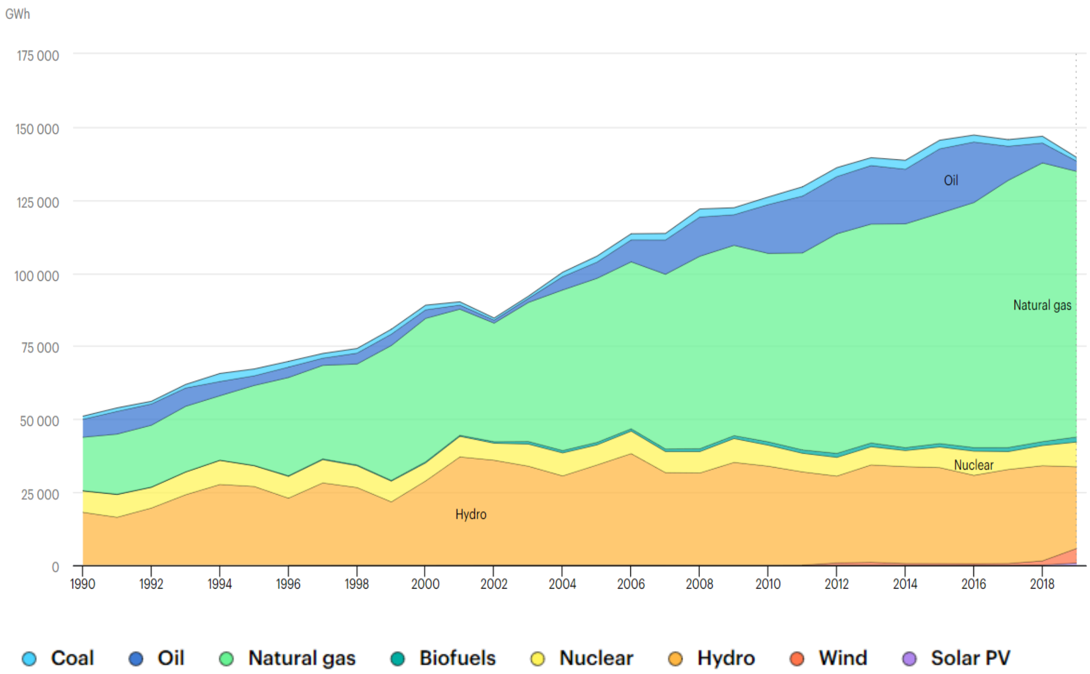

Figure 32: Electricity generation by source in Argentina, 1990-2019. Source: International Energy Agency

After their commissioning, the renewable energy plants will boost their share in Argentina's total electricity supply from 1,8 per cent in 2016 to about 18 percent by 2020. According to the Argentinian Ministry for Energy, on average two projects will become online per week in 2020.

	Year Tendered	Capacity (GW)			Minimum Price Awarded (US$/MWh)
		Auctioned	Offered	Awarded	
RenovAr Program				**4.8**	
Round 1	2016	1	6	1.1	49
Round 1.5	2016	0.6	2.5	1.3	46
Round 2	2017	1.2	9.4	2.0	37
Round 3	2019	0.4	0.4	0.3	53
Legacy PPA	**2016**	**-**	**-**	**0.5**	**59**
Private Corporate PPAs	**2017+**	**-**	**-**	**1.2**	**52**
Total		**3**	**18**	**6.5**	

Figure 33: Results of tender series for renewables in Argentina. Source: Argentinian Ministry for Energy (MINEM)

Given the abundant availability of land, most of the projects have utility-scale dimensions. The average size is more than 25 MW and taking into consideration that round 3 was dedicated to small-scale plants, the remainder plants often have an installed capacity between 50 and 100 MW. The vRE plants contributed significantly to the increase of the overall installed capacity in Argentina which rose from around 34 GW in January 2017 to 39,4 GW at the end of 2019.

The power plants are in general distributed in all federal states of Argentina but a typical concentration of the plants in areas with the highest resources can be observed as well. Solar parks are mostly installed in the Northeast of Argentina, whereas the majority of the wind parks is concentrated in the province of Patagonia.

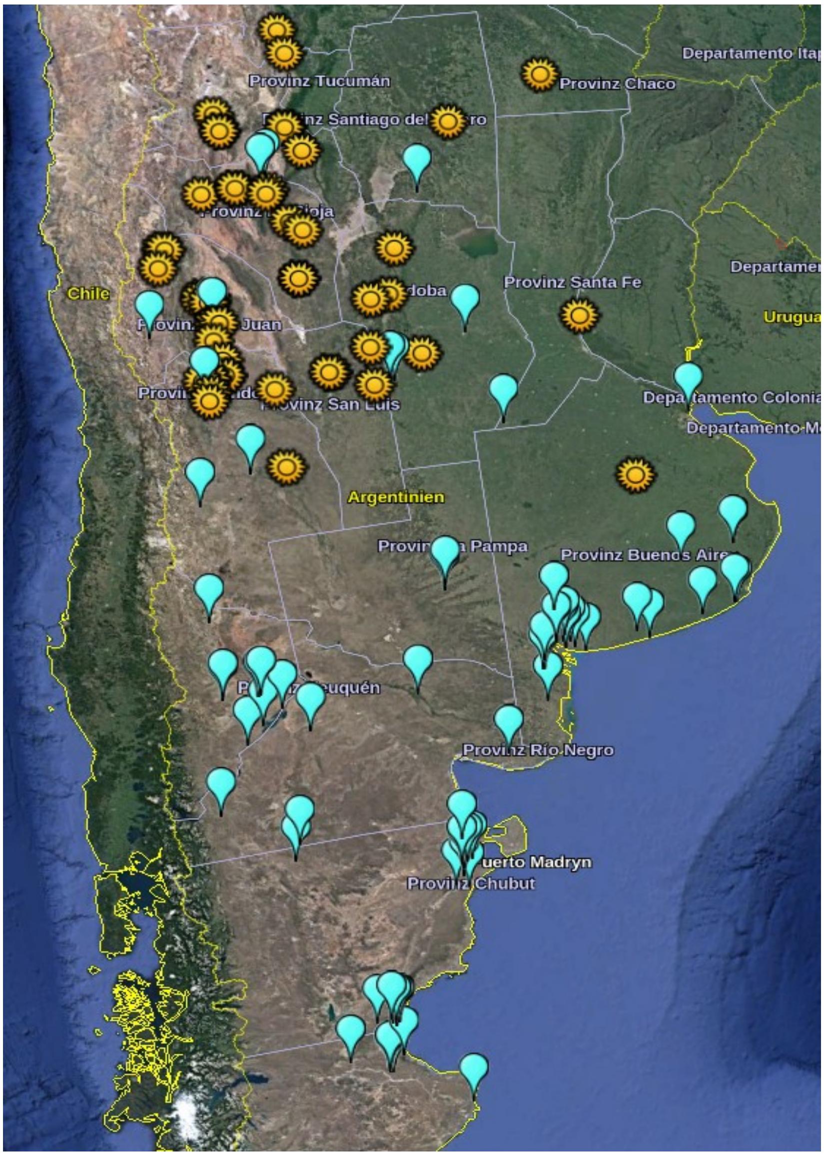

Figure 34: Geographical location of wind parks (in blue) and solar parks (sun icon). Source: energy & meteo systems

8.2.1 Virtual Power Plant as a vRE Control Room for the TSO

Following the installation and grid-connection of large-scale solar and wind parks the Argentinian system operator CAMMESA faced new challenges. CAMMESA was not used to dealing with a high number of distributed vRE plants and had to adjust its IT infrastructure and procedures to the new situation.

In particular, CAMMESA did not have a real-time monitoring and remote-control tool supporting it with the increasing number of solar and wind parks feeding into the grid and contributing to the energy supply. When grid congestions occur, the plant operators are called directly to give instructions to which level the output level should be curtailed. This approach works when you only need to control the feed-in from few vRE plants but becomes inadequate when a high number of plants need to be managed.

In Patagonia the situation became particularly challenging, since a high number of wind parks were installed in this Southern province which only has a weak grid infrastructure. The generated electricity needs to pass via a single substation and be evacuated via one transmission line towards the country´s main load centre in the Buenos Aires province.

In consideration of this situation energy & meteo systems initiated in 2019 with GIZ a Public Private Partnership (develoPPP) to provide support with its Virtual Power Plant. The develoPPP consists of two parts, a transfer of know-how on Virtual Power Plant technology and power forecasting to Argentina and a Virtual Power Plant pilot project to provide practical support to CAMMESA in dealing with fluctuating feed-in from vRE units.

For the pilot project, energy & meteo systems implemented a Virtual Power Plant and connected the wind farms in Patagonia to the systems. In addition, predictions for the wind farms were created and integrated into the software. In total, 27 wind farms with an installed capacity of 1,5 GW are now forecasted and connected to the Virtual Power Plant which will be operational until end of 2021. The connected wind power represents a significant market share since Argentina currently has 45 wind farms with 2,2 GW. Via a web client CAMMESA can access its digital control room at any time without needing a local installation of IT.

As a control room the Virtual Power Plant supports CAMMESA particularly in the following features:

- *Real-time monitoring*

The software receives live measurement data from the connected wind parks and thus allows CAMMESA a real-time monitoring of the assets as shown in the Figure 4. For data protection the parks are anonymized on the figure. On the left of the chart the connected wind farms are listed which can be selected individually or as a portfolio to see the current production status. As seen on Figure 4, CAMMESA in this case can monitor the real time generation which is given in grey and the latest forecast which is shown in orange.

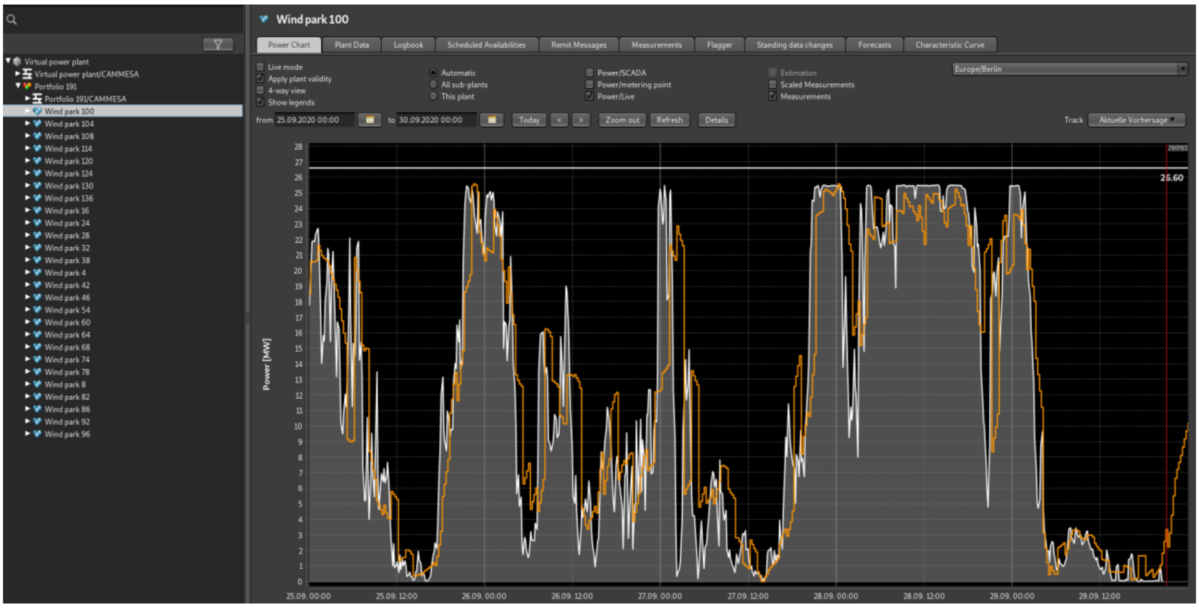

Figure 35: Screenshot of the monitoring view of the Virtual Power Plant.
Left: list of connected units. Graphic: grey = measurement, orange: latest forecast.
Source: energy & meteo systems

- *Forecast evaluation and combination:*

Additionally, CAMMESA can monitor future production schedules of the wind parks based on the forecasts provided and integrated by energy & meteo systems and monitor them against the measurement values. In case of having several forecast providers there is also the possibility of importing these forecasts, evaluating their accuracy and creating meta-forecasts as described in 3.4.

- *Data availability and scaling:*

In addition, the Virtual Power Plant allows CAMMESA to monitor the data availability of each park. The communication units installed in the generation units can sometimes fail to send the measurement data. In case no generation it can be checked if there is no generation or the data is missing. In case that data is missing, the monitoring view has the option of scaling up the available measurements to provide an estimation of what it is happening with the generation even though the communication units are not sending data.

- *Remote control of units:*

The Virtual Power Plant enables CAMMESA for the first time to remote-control wind parks without the need of calling the park operator. Here the power available to curtail is shown on the grey area and by double clicking at a time on the table on the right it is possible to assign a value of MW to be curtailed. A signal is sent to the wind park controlling unit and then the power is reduced.

In conclusion the Virtual Power Plant combined with power forecasts supports CAMMESA in its operational processes and a smoother integration of fluctuating wind energy into the Argentinian electricity grid.

Based on both solutions CAMMESA can now:

- monitor future production schedules, to plan dispatch and grid operation
- monitor real time generation versus plan (forecast)

- control remotely the generation units on real time
- monitor the data availability with an overview easy to manage even by big amounts of data and plants
- group the different decentralized units to operate them as a group which reduces the effort of monitoring and controlling so many smaller units.

Chapter

09

Conclusion on Virtual Power Plant technology

9. Conclusion on Virtual Power Plant technology

As we have seen the global transformation of power systems towards a low-carbon, decentralized energy supply has given rise to the Virtual Power Plant technology.

The Virtual Power Plant is capable of addressing the most crucial challenges which appear with the large-scale proliferation of variable renewable energies: they reduce complexity by aggregating a large number of assets and provide information on their current and future operational behaviour. With their remote-control function they contribute to efficiently coordinate their production schedules, adjusting it dynamically to changing grid and market situations. Therefore, they contribute to maintain control of the generation and consumption processes and thus of the overall stability of increasingly complex power systems which need to intelligently orchestrate a dynamically growing number of energy units.

The Virtual Power Plant is an IT platform which can be adapted to the specific needs of different user groups that have to deal with DER and often weather-dependent generators. It is up to the user groups – plant operators, grid operators, power traders, aggregators - to explore the full potential which this versatile technology offers for their respective tasks or business purposes.

Today, the Virtual Power Plant is already a mature technology with a proven track-record particularly in liberalized European countries and the United States. It is expected that the ongoing dynamic growth of vRE which can be observed on a global scale and the parallel increasing knowledge of the benefits of Virtual Power plants will further contribute to the proliferation of this technology.

The regulatory requirements for remote-control software in Vietnam, currently applied software solutions and how the Virtual Power Plant could be deployed to support the energy transition are the topics of the following chapters.

Chapter

10

Regulatory framework in Vietnam for the control of power plants

10. Regulatory requirements for the control of power plants

10.1 Main regulatory aspects

Prior to presenting the smart grid technologies deployed in Vietnam this chapter analyzes the regulatory framework for their application. As outlined in the previous chapters NLDC has the main responsibility for the integration of vRE production. Therefore, NLDC and the subordinate EVN organizations need to exert direct control over solar and wind power plants to incorporate them in the dispatch processes, including curtailments of the plants. In case a control room software is deployed by other entities (such as IPPs) to centralize control over a pool of aggregated vRE plants it needs to comply with the regulation issued by ERAV which is presented in the following.

The grid code defines in Article 42 of Circular 25 in detail the technical requirements of wind and solar power plants which must be capable, for instance, of adjusting generation of active power as commanded by the dispatch level in accordance with change of primary sources within 30 seconds. The distribution code (Circular 39) further details the technical requirements for plants connected to different voltage levels and its control system.

Circular No. 40/2014/TT-BCT issued on November 5th 2014 determines the organization of the dispatch process and the requirements for decentralized generators.

According to Article 52, NLDC controls the highest dispatching level of the national power system and gives the dispatching instructions to the regional dispatching levels, power plants under its control authority, 500 kV power stations and the operation managing units in the national power system.

The direct inferior operators of NLDC are:

a) Regional dispatchers;

b) Chief operators of large power plants under his/her control authority (on shift duty at power plant or control center of power plant);

c) Team leaders at power station with 500 kV voltage (on shift duty at power station or control center of power station).

At the underlying regional dispatching level, instructions are given to the provincial distribution dispatching level, power plant and power station with electrical equipment under its control authority and operation managing units in the regional power system (Article 53).

The dispatching hierarchy is further broken down to the levels the Provincial distribution dispatching level (Article 54) and the District distribution dispatching level (Article 55).

According to Article 50 the form of the dispatching instructions can be given via verbal instructions, signals to directly control the electrical equipment under their control or in writing.

In case of giving dispatching instructions via control signals, Article 51 determines that the SCADA/EMS, SCADA/DMS system transmitting the control signals must ensure the technical standards and management of operation as per the Regulation on transmission power system and the Regulation on distribution power system issued by the Ministry of Industry and Trade.

The Circular No. 40/2014 also relates to how the decentralized plants need to respond to dispatching orders. Article 60 and 61 refer to the subject of this report, the application of Operational Control Centers for a portfolio of assets. It determines that the power plant or power station must be monitored, controlled and their signals of status, measurement and protection must be collected from a control center (§ 3).

As a first step, the operation managing unit shall prepare the plan to establish the control center of power station or power plant without operator and formulate the procedures for inspection, monitoring and control of operation (§ 1).

The OCC is required to meet the technical requirements specified in the Regulation on transmission power system and the Regulation on distribution power system issued by the Ministry of Industry and Trade (§ 4).

Article 61 determines that the operation of a plant or station without operator is done from the OCC. Before commissioning a power plant or power station connected to an OCC it must meet two requirements. First, the operation managing unit must develop and issue the operation procedures of each plant or station to provide instructions for the operator at the OCC in the switching activities and breakdown troubleshooting (Art. 60, § 5). Second, the operation managing unit and the dispatching level with its control authority must develop and agree upon the procedures for a coordinated operation of each plant or station on shift duty to provide instructions for the operator in the switching activities and breakdown troubleshooting (Art. 60 § 6). The remote-control of the plants must be checked and periodically tested to ensure a reliable remote operation (Article 19).

In the regulation it is further specified in Article 61 how the operation of the OCC should be organized, which also includes local operational work at the plants. It is recommended, in case of necessity, to have additional staff at the plant or station to inspect and monitor the control from the OCC. In each shift at the OCC, the operation managing unit must assign at least two operators on shift duty, including one person assuming the title of Chief Operator or Team Leader. The operation managing unit of the OCC shall send its staff to the power plant or power station “to check the equipment on the spot, especially at the times of transmission or high-capacity generation”. Finally, in case of breakdown occurrence at the power plant or power station, the operation managing unit must notify immediately the dispatching level with control authority and send its operator and technician to the power plant or power station for breakdown troubleshooting in the shortest time. Article 46 of Circular 28/2014/TT-BCT defines in detail activities to be performed by the plant operator and staff at the Control Centre in case of failures.

It can be summarized that the regulation provides the option for IPPs with several power plants to centralize the control of their power plants via an OCC. At the same time, the regulation aims at maintaining the reliability and quality of operational processes by implementing a smooth interaction between the plants/power stations, the OCC and the Dispatching Unit. The main concern is to ensure a reliable control of the plants by the Dispatching Unit also in the event that an OCC as an intermediary IT infrastructure layer coordinates several plants.

Chapter

11

vRE control room software and their application in Vietnam

11. vRE control room software and their application in Vietnam

11.1 Operational Control Centre software

Given the regulatory possibility, some private IPPs have already started to use a software called Operational Control Centre (OCC) for their assets. The OCC centralizes monitoring and operation of all plants connected to it and ensures the safety and security of the plants. The staff at the OCC is able to remote-control the power plants. The benefit of OCCs for IPPs is that they do not need to have employees constantly on duty at each site which saves costs. These OCCs are deployed at the sites of plants which are located closely (centralized OCC) or are connected to geographically dispersed plants (distributed OCC).

Given the regulatory requirement described in the previous chapter, the Dispatch Centers still have the sole authority to exert control on the power output of the plants for system operational purposes. NLDC or the regional Dispatch Centers send control signals to the respective OCCs which are required to reliably forward them to the addressed connected plant(s).

At present, there are twelve OCCs installed in Vietnam which are either operated onsite at the plants or from a central control room. The existing OCCs are listed in the following table:

No.	**Name of OCC**	**Technology and capacity of power plants**	**Total capacity (MW)**
1	DHD	PV (59 MW) Hydro (352 MW)	411
2	Dau Tieng	PV (600 MW)	600
3	Solar Park	PV (200 MW)	200
4	PECC2	PV (114,5 MW)	114,5
5	Van Giao	PV (100 MW)	100
6	Cam Lam	PV (100 MW)	100
7	Bac Phuong	PV (71 MW) Wind (100 MW)	171
8	Loc Ninh	PV (550 MW)	550
9	Phu My	PV (330 MW)	330

10	Sesan 4	PV Hydro	472
11	Gelex	Wind (90 MW)	90
12	Ia Pet	Wind (200 MW)	200
		TOTAL CAPACITY	**2834 MW**

Figure 36: List of OCCs operating in Vietnam

In sum, there are currently 2834 MW connected in 12 OCCs. Some of the OCCs combine various technologies, solar and hydro (DHD, Sesan 4) or solar and wind power plants (Bac Phuong).

If we compare the share of solar parks controlled by OCCs with the overall installed capacity, we can observe that they represent a rather small share of the more than 5 GW installed large-scale solar parks which are installed in Vietnam. Furthermore, the bulk of it is made up by only one park, the 600 MW park OCC Dau Tieng. Given the increase of DER assets and the cost advantages of the OCC software versus a decentralized operational plant management it can be expected that the existing OCCs may be expanded in the future or that new OCCs will be installed.

In the following figure the layout of the software module of the PECC2-OCC system is illustrated. As can be seen, the system retrieves SCADA data from the plants to allow a comprehensive monitoring of the assets and to react timely in case of technical issues. This includes event and maintenance management, check-up, diagnostic and reporting.

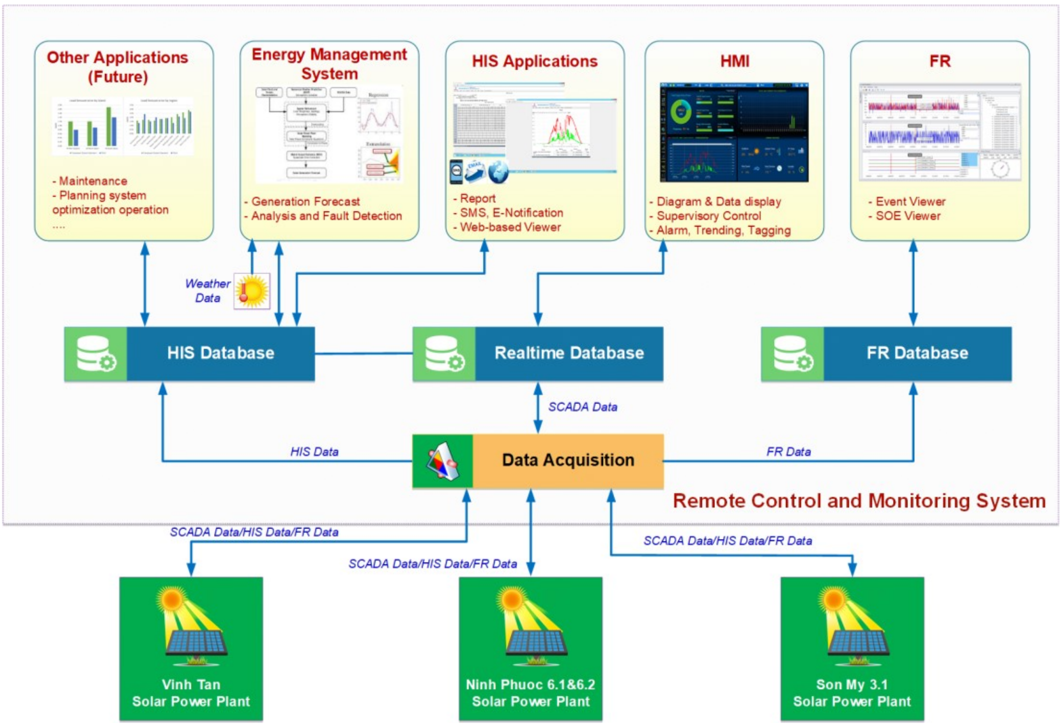

Figure 37: Software architecture of PECC2-OCC

The protocol used to connect the PECC2-OCC with SCADA systems at the Dispatch Centers complies with IEC 60870-5-104 which defines a universal communication standard allowing for communication and interoperability of different network control and telecontrol devices.

Even though the diagram mentions "generation forecasts" it is assumed that these are not created by the OCC but can only be optionally imported from an external source without further internal processing. In Vietnam, there is also no obligation for the OCC operator to provide power forecasts. Currently, the forecasting procedure is centrally organized with NLDC creating its own power forecasts and receiving as well predictions from external service providers. These centrally provided power forecasts as well cover the plants connected to the OCCs.

It can be concluded that the OCCs can be characterized as an Operation & Maintenance (O&M) software designed for the acquisition of real-time plant data for a comprehensive asset management but allowing as well to establish a communication link between Dispatch Centers and the single plants.

11.2 OCC for rooftop pv systems (DERM)

A major challenge resulting from the large-scale installation of rooftop pv plants is the lack of control over these plants. NLDC does not have any visibility or control about the current or future generation processes of these distributed pv plants and their overall impact on the power system.

To respond to these challenges, some plant operators are currently testing another software called DERM (Distributed Energy Management System). The pilot projects applying this software focus on connecting to the larger rooftop pv systems which are predominant in Vietnam. The idea behind the pilots is to prepare a large-scale roll-out of the technology in order to ensure an efficient monitoring and control of the large number of rooftop pv plants.

The DERM software was developed in order to support the plant owner or utilities with an integrated solution for monitoring and controlling of production and voltage of distributed renewable energy sources to meet local power network requirements and to curtail the connected plants upon request. The servers also calculate dispatched power flows as requested by the operators and grouping of distributed energy sources. The central system collaborates with an onsite system which serves for data acquisition and control of the connected units.

The technical capabilities clearly focus on a detailed control of the power output of the plants to ensure their support for grid stability. The main technical features are:

- Active power control and reactive power control
- Ramp rate control
- Power factor control
- Voltage control
- Frequency support
- Voltage regulation
- Startup/Shutdown plant control

In Figure 34 the layout of the software module of the DERM software is illustrated.

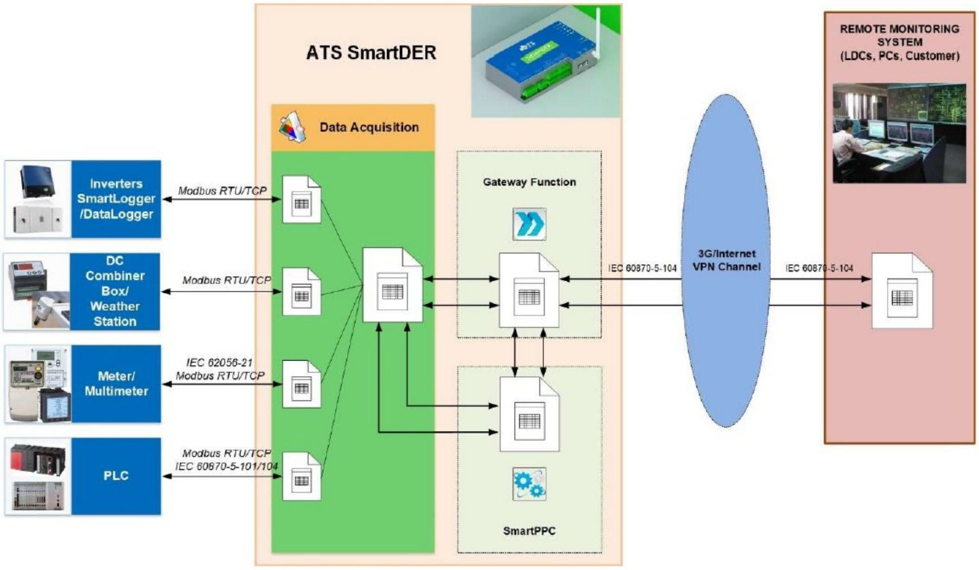

Figure 33: Software architecture of DERM software

In the user case of the DERM for rooftop pv plants in Vietnam the software needs to comply with the following requirements:

- Exchange information and receive dispatch orders from NLDC via AGC or direct schedule orders
- Monitoring and control system at dispatch at regional Dispatch Center
- Data collection, monitoring and control unit at the vRE station

Two projects are known which are currently tested:

- **DERM in the province Ninh Tuan** which monitors 5 larger rooftop pv plants with a combined capacity of 4310 kW. The plants are connected to the 22 kV electricity grid.
- **DERM in the province Quang Nam** with 7 larger rooftop pv plants with a combined capacity of 5000 kW which are as well connected to the 22 kV electricity grid

Normally, the curtailment of rooftop pv plants (connected to 22 kV) in Vietnam is carried out manually (closing and opening the disconnector by hand). This manual process is automatized by the DERMs which calculate and decide based on real-time conditions how much power will be curtailed at each rooftop pv plant or its individual inverters. When comparing this software with the previously presented OCC it appears that the DERM has more capabilities to actively respond to curtailment signals from NLDC by creating and distributing its own dispatch signals. The curtailment process executed by the DERM strictly follows technical requirements to achieve the desired curtailment level. Economic considerations, however, such as production costs of the plants or feed-in tariffs are not taken into account.

Regarding ICT infrastructure the DERM complies as well as the OCC with important international regulation such as the IEC 60870-5-104 for communication and interoperability of different network control and telecontrol devices. According to its technical specification the DERM applies an encrypted VPN communication for exchange of data and control signals.

The technical specification mentions as well that the DERM includes a software component to create solar power forecasts. This tool uses weather data from commercial websites to predict the future power output of the connected rooftop pv systems. This approach is considered to be very basic and not equivalent to the international state-of-the-art in power forecasting. The

DERM software therefore only allows a rough estimation of the future power output. The limited capability of the DERM´s forecasting tool is reflected by a statement which estimates its day-ahead power forecast error to be only a bit lower than 20%. By international standard, this value significantly exceeds the forecasting accuracy which can be achieved on average with professional forecasts for rooftop pv plants.

The international best practice is to create power forecasts professionally - mostly by contracting specialized forecast providers - and integrate them into the control room software. For comparison, professional power forecasts are based on several global weather models (whose service is subject to a fee), historic and live production data and use sophisticated software to convert these input date into precise predictions. As we have seen, an essential functionality of the Virtual Power Plant is - different to DERM - to integrate these high-quality forecasts and to manage and further optimize the forecast data for the connected plants.

In sum and concluding from the provided information it can be stated that the DERMs appears to be a suitable tool to create visibility over rooftop pv plants and gain control over their power production. However, the DERM technology does not seem to offer the possibility to integrate as well economic aspects in the dispatch schedule. Depending on the development of the Vietnamese market design this option may become crucial in the future. The forecasting capabilities of the DERM software appear to be limited and can only provide a rough guidance for operational decisions. In addition, inaccurate forecasting as well limits the capability of the DERM to offer flexibilities, for instance in case it is planned to add storage systems to the rooftop pv plants to reduce curtailments and to provide system operation services such as ancillary services or network load relief.

Chapter 12

A brief comparison of Virtual Power Plant, OCC and DERM

12. A brief comparison of Virtual Power Plant, OCC and DERM

Unfortunately, there was only limited information available on the technical capabilities of the OCCs and DERMs installed in Vietnam.

Regarding the OCCs, a basic description was only provided for PECC2 whereas no information was available on the technical setup of the other OCCs. From the available information on PECC2 it is concluded that the OCCs are mainly characterized as an O&M management software. Their main goal is to support IPPs with an efficient centralized operation of the plants while at the same time ensuring control of the Dispatch Centre over the connected plants. This control is important when grid congestions require curtailments of vRE generators by the Dispatch Centers.

It is assumed that the OCCs serve their current purpose as an O&M software for multiple plants. However, the OCC does not have any technical capabilities in terms of scheduling, dispatching or forecasting to actively support NLDC or other grid operators with vRE system integration If Vietnam introduces a more liberalized market model, requiring vRE asset owners to directly participate in the power market, the OCC will likely face its limits because it cannot perform trading activities for a vRE portfolio.

In contrast to the OCC, the technical features of the DERM show that this software was not designed for maintenance purposes but rather for monitoring and controlling connected plants. The capabilities allow the DERM to take its own decisions how signals can be executed among the portfolio based on real-time information. In this respect, the DERM allows a detailed live support to NLDC, creating visibility and controllability of the rooftop pv plants. However, the automatic forecasting module is considered very basic and does not provide professional vRE predictions which are essential for an accurate scheduling and dispatching process. The DERM strictly concentrates on technical control of the assets and is not capable of creating schedules – as well as the OCC – which also take into account economic aspects of the plants.

The Virtual Power Plant technology, by contrast, was specially geared towards scheduling, dispatching and remote-control applications of any sort of distributed energy unit. It is today an approved state-of-the-art technology for optimally integrating renewable energy production and flexibilities of consumers and storage systems into power markets. In liberalized and advanced renewable energy markets, such as in Germany, the VPP has emerged as a key solution for efficiently dealing with the massive decentralization of the power system and volatile energy production. Different to the OCC, the VPP was not designed to cover O&M software capabilities. As an example, the VPP does not source technical plant parameters for maintenance purposes. Comparing the VPP with the DERM it can be stated that there is more overlap between these technologies. The VPP as well contributes efficient support to grid operators by controlling the output parameters of the plants. But beyond this the VPP allows with its sophisticated prediction tool a forward-looking scheduling of the plants. This is particularly important for the main user groups of the Virtual Power Plant such as grid operators or aggregators of renewable energy portfolios who are responsible for an efficient vRE grid and market integration. In addition, in market-driven applications the capability of the VPP software to take economic aspects of each plant of the portfolio into consideration is crucial. In the following table a comparison of the three technologies is provided.

	Virtual Power Plant	OCC	DERM
Main purpose	Monitoring, scheduling and dispatching of large numbers of DER assets to respond to grid and market situations	Operation & Management of DER assets	Monitoring and technical control of solar power plants to respond to grid situations
Connectable assets	VPP can connect to renewable, conventional generators, storage systems and consumers	OCC can connect to renewable and conventional generators (assumption)	DERM can connect to renewable and conventional generators (assumption)
Number of assets	Unlimited in size and number	Unlimited in size and number (assumption)	Unlimited in size and number (assumption)
Technical plant management	Not designed for monitoring the technical status of the plant for maintenance purposes	Comprehensive capabilities to monitor technical status of connected plants for e.g., predictive maintenance	Not designed for monitoring the technical status of the plant for maintenance purposes
Power forecasts	Management and optimization of power forecasts for portfolio	No own forecasting capabilities	Basic forecasting module
Typical software operator	Aggregators, grid operators	Plant operators	Plant operators, grid operators
Ownership	Connects to any plant independent from ownership	Plant operators connect their own assets	Plant operators connect their own assets or grid operators connect plants feeding into the power network

	Virtual Power Plant	OCC	DERM
Monitoring	Monitoring of current and future production schedule of portfolio or single assets	Monitoring of current production schedule and technical parameters of multiple assets	Monitoring of current production schedule of portfolio or single assets. Limited capabilities to predict schedules.
Remote-control of assets	***VPP operator is an aggregator:*** Aggregator exerts control on portfolio based on economic considerations and can grant grid operator control over plants to activate ancillary services ***VPP operator is a grid operator/Dispatch Center:*** Grid operator can monitor current and future production schedules, predict grid congestions and curtail plants (i.e., remote control)	OCC enables Dispatch Centers direct control of connected plants	Plant operators execute with DERM control signals on behalf of the grid operator Grid operators directly control (smaller) solar plants via DERM
Smart distribution of curtailment signals	VPP can intelligently distribute curtailments among portfolio based on defined criteria (e.g., merit order costs of plants), plant availability and forecasts	OCC is not designed to execute complex curtailment procedures (assumption)	DERM can execute curtailments among connected plants based on technical requirements
Data exchange with external systems	VPP is designed to exchange data with many external systems such as data management systems, SCADA/O&M systems, control roof software or trading solutions with different technologies (API, web service, etc.)	OCC presumably restricted to exchange data with pre-defined external systems through IEC -104 protocol	DERM presumably concentrates on receiving signals from grid operator

Figure 349: Comparison of capabilities of Virtual Power Plant, OCC and DERM

As can be seen the software solutions VPP, OCC and DERM pursue different or only partially the same goals which is why there is only a limited match between the technical capabilities of the software solutions.

In the following chapter the report presents a possible VPP application for Vietnam which will further illustrate the unique skills of this technology.

Chapter 13

Deployment of the Virtual Power Plant in Vietnam

13. Deployment of the Virtual Power Plant in Vietnam

With the dynamically rising share of distributed electricity generation, an active management of these resources is indispensable in order to ensure operation of the electricity network towards the future. The remarkably speedy energy transition in Vietnam calls for action to accommodate existing system management procedures to decentralized and weather-dependent electricity production.

As described, the main deficits which NLDC and grid operators on lower voltage levels face are a lack of precise real-time production data and power forecasts for the entire vRE generation. This leads to inaccurate curtailment decisions and a loss of valuable clean energy production for the power system.

Additionally, the long top-down curtailment process from NLDC via Power Corporations and Power Companies down to the plant operator leaves potential for streamlining in order to live up to the quickly changing production volumes of vRE generators.

Centralizing vRE generation data and control over the plants with smart grid technologies is key for improving the status quo. In the following this report highlights the potential of the Virtual Power Plant to support the EVN entities in integrating vRE generation. Naturally, Virtual Power Plant software available on the market varies with regards to intelligence and scope of functionalities. The following description of a possible VPP application in Vietnam is based on a specific software which is widely applied in the German electricity market.

13.1 VPP application as a smart control room for vRE hotspots

13.1.1 Virtual Power Plant application and user groups

On the background of the current market design, it is suggested to deploy the Virtual Power Plant as a vRE control room to support operational processes in system management. The Virtual Power Plant could act as a centralized vRE management platform which directly connects to solar and wind power plants on the distribution level and provides valuable information on real-time production, availability and forecast data. These data can be shared with the grid operators on all voltage levels (NLDC, Power Corporations, Power Companies) to allow them monitoring of live production and predictions in the entire grid network or in specific sections of the grid for better decision-making. The centralization of monitoring and control would enable them to react precisely on local grid constraints due to high vRE feed, e.g., due to peak solar production at midday hours. International experience shows that an efficient power system control is only feasible if the DSO and TSO or alternatively the regional or national control center is equipped with real-time monitoring of all vRE plants.

A main purpose of the proposed Virtual Power Plant application is ensuring that the Power Companies are enabled to more efficiently execute curtailments required by NLDC among provinces and plants. It is therefore suggested that the Power Companies should be the main operator of the Virtual Power Plant, turning them into the sole connection point between NLDC and the regional Dispatch Centers on the one hand and distributed generators on the other hand. By directly retrieving live data from the vRE plants, the Virtual Power Plant visualizes the electricity production which can be grouped according to single provinces in their control area or defined grid sections. This allows the Power Companies to directly monitor and control feed-in processes in real-time. This represents a fundamental improvement in comparison to the current situation where production data are not available in real-time.

For a forward-looking operation of the grid, renewable energy forecasts can as well be integrated into the Virtual Power Plant. The forecasts could be provided by NLDC (when extended to smaller vRE plants) or a professional service provider could be contracted to supply the data. As mentioned previously, the Virtual Power Plant integrates a specific forecasting module designed to manage and analyze power predictions. In particular, real-time production data of the connected plants are used to carry out a short-term correction of the power forecast. This process results in very accurate short-term forecasts (up to 5 hours ahead) for vRE production.

Since the Virtual Power Plant has a very dynamic remote-control function, the production output can be adjusted according to grid operational objectives. Thus, the long curtailment process, spanning from the curtailment order by NLDC and its execution by the plant operator would be significantly reduced. With vRE plants digitally connected and controlled, the Power Companies do not need to rely on (manually) mobilizing plant operators to cut production. Curtailment orders by NLDC could be directly executed them.

To provide for maximum value for all stakeholders, the Virtual Power Plant should be accessible as well for other stakeholders, in particular NLDC and the regional Dispatch Centers. This can be realized by granting individual user rights to different user groups. For instance, Power Companies as the main operator could be granted comprehensive remote-control rights whereas NLDC´s and the regional Dispatch Centers´ user rights are limited to monitor production and forecast data.

Data flow and remote-control of vRE assets

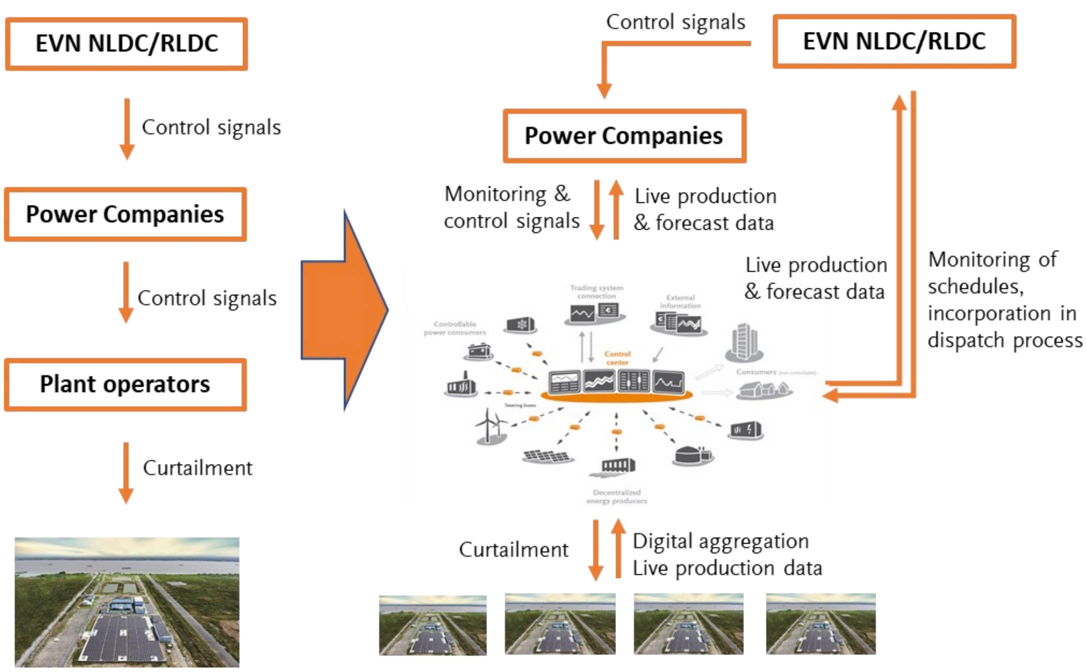

Figure 4035: Data flow and control of vRE plants and load in a possible VPP project in Vietnam. Left: current status. Right: with Virtual Power Plant as vRE platform

The benefit of implementing a Virtual Power Plant as vRE management platform for NLDC is to achieve more transparency on vRE production processes on the distribution level. Having access to real-time and forecast data on vRE production is crucial to obtain a more accurate day-ahead and intraday scheduling and dispatch process. NLDC is already aware of the importance of production from smaller vRE plants which now dominate the Vietnamese vRE portfolio. Currently NLDC is contracting a supplier of vRE power forecasts which now are extended towards rooftop pv plants.

With each Power Company having access to the VPP they for the first-time have access to monitoring, forecasting and remote-control capabilities for assets in their own control area. The energy management platform thus supports in different operational processes, such as short-term demand forecasting or load flow calculations.

While this application suggests to focus on rooftop pv plants in Vietnam there is of course the possibility to expand the size and functionality of the Virtual Power Plant. As described in chapter 5 there is not limit with regards to number, technology or size of the plants which can be connected. Therefore, it is as well feasible to add further technologies, for instance large solar and wind parks or even flexible consumers to balance their electricity need with fluctuating production.

13.1.2 Targeting vRE hotspots with a VPP

It is suggested that the Virtual Power Plant should first focus on providing support with incorporating the power output from rooftop pv systems. There are several reasons which justify this focus. First, rooftop pv plants have become the dominant generator type among all vRE technologies and segments and a main concern for system management. Second, there are no real-time production data for rooftop pv systems available in the power sector. Finally, the forecasting system does still not cover these generators. Combined, these challenges leave generation processes of rooftop pv systems largely in the dark which complicates their optimal integration in the energy supply.

The following map shows the distribution of the rooftop pv plants across provinces in Vietnam which is remarkably uneven:

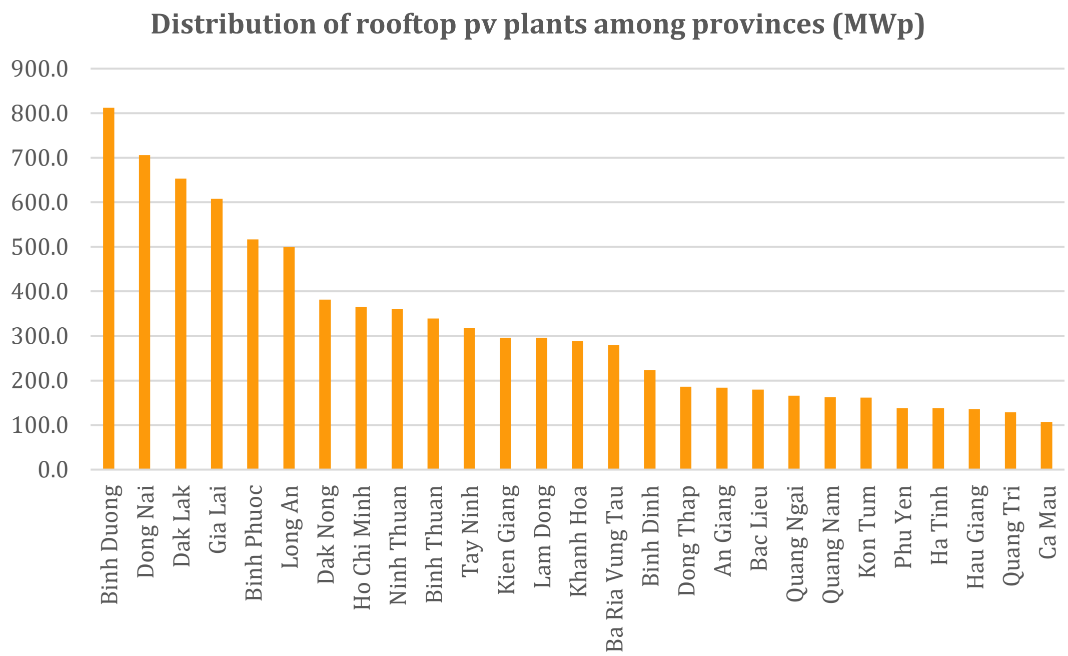

Figure 36: Distribution of rooftop pv systems in Vietnamese provinces.
Source: energy & meteo systems based on public data

Figure 37 shows 30 provinces out of 58 Vietnamese provinces and 5 municipalities with the largest share of rooftop pv systems in terms of installed capacity. About 89 per cent of the entire installed rooftop pv capacity is located in these provinces. All of the 30 provinces are located in the area Central and Southern Power Corporation where the highest solar irradiation can be found. The chart reflects the strong concentration of rooftop pv plants in view provinces of Vietnam. In addition, these provinces also accommodate solar farms with a combined capacity of 8,3 GW, representing 96 % of the total installed capacity of this plant segment.

Assigning the rooftop pv plants to the regional control areas of the Power Corporations it is obvious that most of the rooftop pv capacity is located in the SPC area (almost 6 GW), followed by CPC (3,2 GW) where rooftop pv systems are primarily located in the Southern provinces. By contrast, NPC only accommodates 476 MW of the installed rooftop pv capacity.

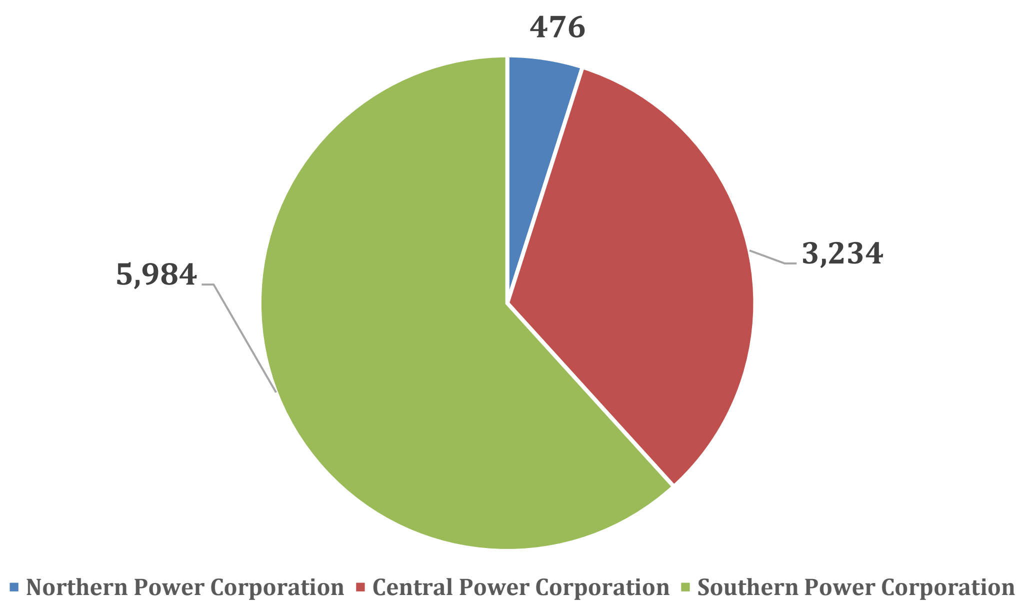

Figure 42: Distribution of installed rooftop pv capacity in control areas of Power Corporations

Source: energy & meteo systems based on public data

As a consequence, the VPP application should be initiated in the vRE hotspot areas in the South and South-Center of Vietnam where not only the installed capacity but also the capacity factor of rooftop pv systems is higher due to stronger solar irradiation.

13.1.3 Plant connection and creation of regional portfolios

With no limits to number or size of connected assets the VPP technology is highly scalable. However, for the implementation of a Virtual Power Plant a crucial step is a live data connection to the plants. The application of the full range of VPP services depends on a interface allowing a fluid data transfer in both directions and on the remote-controllability of the assets. This is mostly not an automatized process but requires support, e.g. from ICT experts from the software provider who have the expertise to connect a Virtual Power Plant to different generators of different manufacturers.

If a Virtual Power Plant is to be realized for an already existing plant portfolio a step-by-step approach is required to gradually connect the plants and achieve a critical size in the portfolio of the VPP.

The advantage of the rooftop pv portfolio in Vietnam is the large average size. In comparison for instance to Germany where many small-scale systems are installed, in Vietnam a plant size of 900 kW to 1 MW is most common. Consequently, a large share of the installed capacity can be attributed to this larger plant segment. This portfolio structure facilitates the setup of the Virtual Power Plant since a relatively small number of larger rooftop pv systems quickly amounts to a relevant share of the entire portfolio. This is illustrated in the following diagram which shows the distribution of rooftop pv plants according to plant size in the province of Gia Lai.

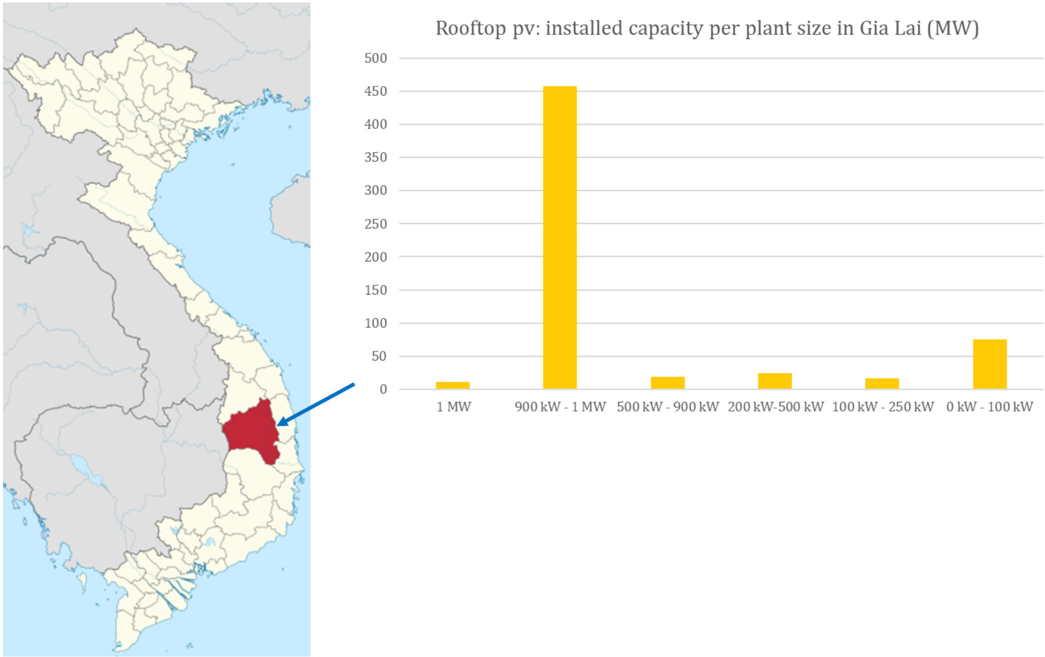

Figure 37: Distribution of rooftop pf plants according to plan size in the Vietnamese province Gia Lai
Source: energy & meteo systems based on public data

The total installed capacity of rooftop pv plants in this province is 604 MW out of which 458 MW is represented by 460 plants in the size range of 900 kW to 1 MW. By contrast, 2539 rooftop pv systems only account for 75 MW. The VPP can therefore benefit from focusing on connecting larger rooftop pv systems to quickly achieve a relevant portfolio size.

In the connection process, those rooftop pv systems should be prioritized which are located in particularly critical grid network sections and which frequently participate in curtailment processes. Since only rooftop pv systems with an installed capacity over 200 kW participate in curtailments, the connection to the Virtual Power Plant should be limited to plants above this size.

After the first larger rooftop pv systems are connected, the Virtual Power Plant continuously receives real-time production data from the assets. Knowing the total installed capacity in a certain area (province or entire control area of a Power Corporation) it is possible to upscale this choice of live measurements with the Virtual Power Plant to the size of the entire portfolio. The accuracy of this calculated real-time production estimate increases with the number of measurements from rooftop pv systems aggregated in the Virtual Power Plant.

In order to monitor rooftop pv production and allocate curtailments on a province level (or as well in grid sections which are frequently overloaded and need close monitoring) the Virtual Power Plant allows to group plants into regional sub portfolios. For instance, in a Virtual Power Plant Gia Lai the rooftop pv plants can be grouped in sub portfolios according to cities, zip codes or grid sections. The portfolio structure is highlighted on the left side in the following monitoring view of the Virtual Power Plant.

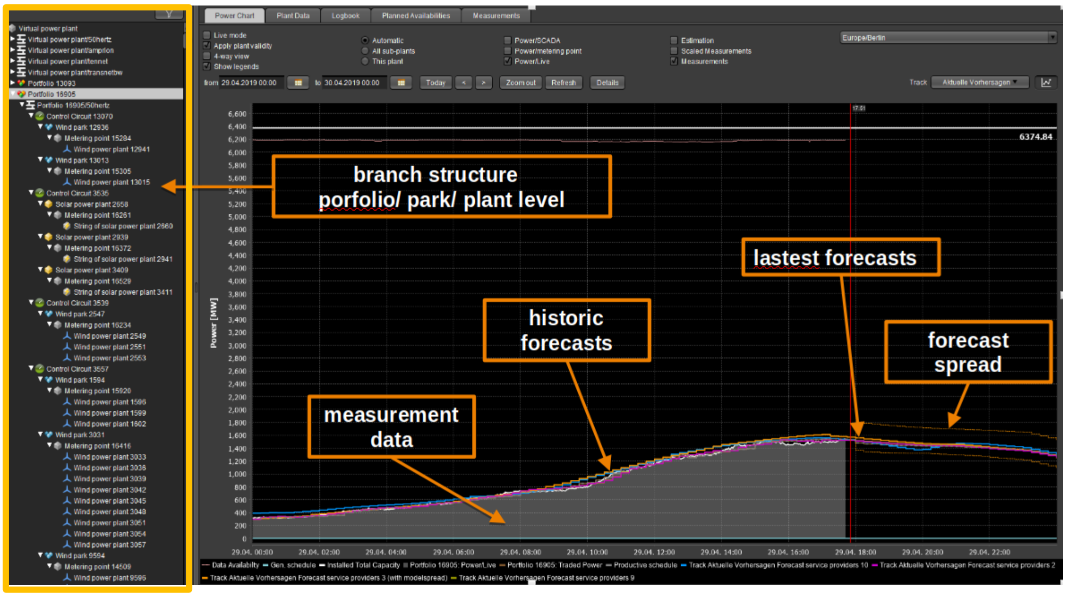

Figure 44: Monitoring view in a Virtual Power Plant. Source: energy & meteo systems

In this case, an example of sub portfolios is shown where the plants are not assigned geographically but according to connected type of technologies Plant (solar, wind). Here, specific geographical areas defined by the Power Companies could for example appear instead as sub-portfolios, bundling all the larger rooftop pv plants above 200 kW.

13.1.4 Integration of power forecasts, forecast upscaling and metaforecasts

The production of solar and wind power plants varies with weather conditions. Despite their relevant share in the Vietnamese power system there are until now no professionally created power forecasts available for the rooftop pv systems. Accurate power forecasts play a fundamental role for a foresighted incorporation of renewables in the electricity supply.

In contrast to OCC and DERM a strength of the Virtual Power Plant is its ability to integrate, analyze and improve externally generated power forecasts. An API interfaces allows the Virtual Power Plant user to constantly feed in updated power forecasts. The expected production schedule can thus be monitored along with real-time measurements as illustrated in the above Figure 18.

NLDC is about to extend the external forecasting service towards rooftop pv plants. However, since real-time production data from the plants are unavailable, they cannot be taken into account for a short-term forecasting process. This deficit can be remedied if the power forecasts are integrated into Virtual Power Plant. Its forecasting module then creates very accurate short-term forecasts, correcting the power forecasts with live data from the renewable energy generators.

Additionally, the Virtual Power Plant is able to support with creating meta-forecasts which optimally combine vRE power forecasts from different sources. The metaforecasting tool is soon applicable in Vietnam since NLDC is preparing a tender to contract a second power forecast provider in the near future. With two available predictions for rooftop pv systems, the Virtual Power Plant can analyze the performance of each provider by comparing historical forecast and production data. This results in a suggested weighing factors for each source of power forecasts to combine them in the metaforecast. The metaforecasts in general outperform the accuracy of single predictions and are therefore very valuable for system management and vRE integration. Figure 19 illustrates the metaforecasts in black in comparison to single forecast models, matching better with the measurements shown in grey.

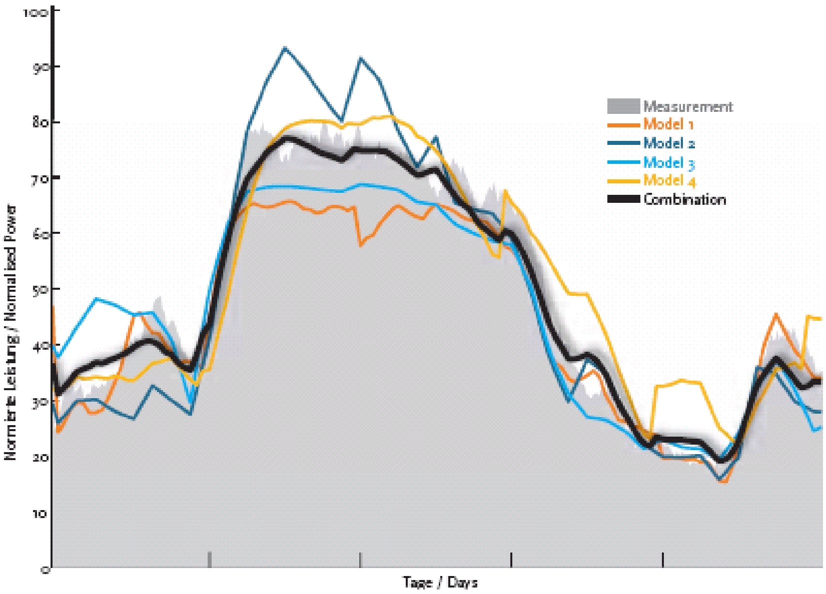

Figure 45: Accuracy of metaforecasts in comparison to single power forecasts. Source: energy & meteo systems

The power forecasting services which are being contracted do not cover the entire installed capacity of rooftop pv plants in Vietnam and as well not all of the rooftop pv plants connected to the Virtual Power Plant. Therefore, an upscaling of the power forecasts for selected plants to regional levels will be needed. This scaling can as well be carried out with the Virtual Power Plant to achieve power forecasts for the desired aggregation level. This enables to achieve power forecasts for rooftop pv production for areas with frequently overloaded power lines or selected Vietnamese provinces. An example for these tailor-made forecasts illustrated in the following chart which shows a 3-day-ahead prediction for the entire rooftop pv production in the province Gia Lai created. The installed capacity in Gia Lai is about 600 MW. The forecast was created by energy & meteo systems on the 1st of September 2021, covering a horizon from 1st until 3rd of September 2021 and can also be set up with a Virtual Power Plant.

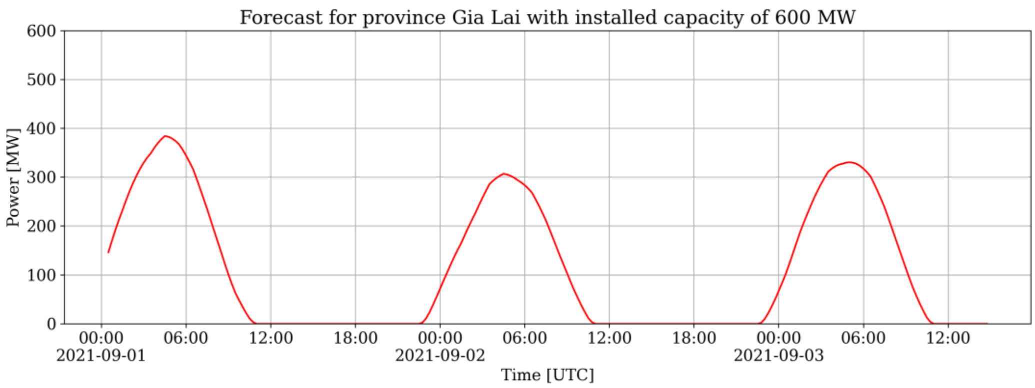

Figure 46: Power forecast for rooftop pv production in Gia Lai. Source: energy & meteo systems

With the Virtual Power Plant integrating and managing power forecasts, the prediction data can be shared among the different users. NLDC, regional Dispatch Centers, Power Corporations and Power Companies are able to monitor the expected feed-in schedule, allowing them to process this information in their operational processes, such as scheduling, dispatch and load flow calculations.

13.1.5 Scheduling rooftop pv production

In our suggested user case, the Power Company can now set up a portfolio schedule to comply with curtailments required by NLDC and the Virtual Power Plant takes care of the implementation. The Power Company as the main user of the Virtual Power Plant decides on criteria which influence the sequence of participating plants or even their exclusion from the process. Such criteria are for example the technical availability of a plant, a technical minimum limit, known control problems of the interface or economic parameters such as FiT. Any restriction is automatically taken into account in the available potential. If the Virtual Power Plant recognizes that plants do not react because of problems at the individual interface of the plant, further plants are automatically taken into account for control to ensure that the schedule is always met.

A curtailment schedule on a portfolio level is illustrated in the following dashboard view of a Virtual Power Plant. In this case, the production represented in the white line is entirely cut for a period of 18 hours. The orange line at the top indicates the production that would have been possible based on the power forecast.

Figure 387: Schedule and control of connected assets. Source: energy & meteo systems

The chart as well underpins the ability of the Virtual Power Plant to immediately and precisely implement scheduling orders of the user. This speedy reaction in combination with the grid operators exerting direct control over rooftop pv plants dramatically reduces the time needed to adjust the production output in the distribution grid. Thus, real-time scheduling and dispatching is enabled which is needed to adequately manage intermittent vRE production.

13.1.5 Main expected achievements

The deployment of the Virtual Power Plant technology as a vRE control room in Vietnam is expected to address main challenges the energy transition is posing to NLDC and distribution grid operators.

One challenge is the transparency gap on the distribution grid level. The software platform collects real-time production data of large-scale vRE resources which are increasingly penetrating the distribution grid. Power forecasts are analyzed and improved to achieve even higher accuracy levels. Plants can be clustered on a province level or according to grid sections which allows a focused feed-in management.

Used as a smart energy platform for different user groups, the Virtual Power Plant centralizes real-time, forecast and historic data, stimulating energy-data sharing across grid operators on all voltage levels. This represents a major achievement in comparison to the current situation where live data are not available and historical data are only recorded for one month. Sharing the same vRE control room is likely to promote as well the vertical collaboration between TSO and DSO levels, favoring a joint approach for the integration of renewables.

With the suggested application, NLDC obtains for the first-time visibility on the increasing volume of intermittent generation processes in the distribution grid which creates opportunities to manage the power network grid in a more flexible and efficient way.

The Power Companies are the suggested main operator of the energy management platform, including remote-control rights over vRE plants in the distribution grid. This bundling of competences allows a direct and more efficient curtailment process in comparison to the current status.

The energy management platform is also a valuable source of information for other purposes, such as grid planning, designing vRE support schemes or for further developing the regulatory framework.

Finally, digitalization efforts for a smarter management of network resources will also send a positive signal to the private sector that Vietnam is taking measures to better integrate vRE and to reduce curtailments.

13.2 Regulatory improvements: A direct marketing scheme to improve vRE integration and unlock more VPP potential

The Virtual Power Plant usually does not require much regulation apart from ICT security standards (see the following chapter) and the requirement to comply with remote-control tests of the TSO if participating in the ancillary services market.

The scope of possible applications for Virtual Power Plants is primarily determined by the market design. Taking into consideration the current design of the Vietnamese electricity market the use of the Virtual Power Plant Power as a vRE management platform is considered to have the most positive impact with respect to a more efficient integration of renewable energy in Vietnam.

However, the Virtual Power Plant is a versatile IT platform which can be applied by different users and for different purposes. This would require to further develop the electricity market and adjust vRE policy. Vietnam still relies on a FiT-based support scheme to promote investment in renewable energy. Due to the FiT regime the vRE plant operators simply feed in the entire meteorologically possible production without the need to actively integrate it into market processes.

Many vRE frontrunners with liberalized power markets have shifted from a FiT regime to a direct marketing scheme, requiring vRE plant operators to actively trade their electricity production. This step delegates responsibility from the grid operator to the plant owners, responding to the sharp increase in DER plants and power producers. Under the direct marketing scheme, plant operators are exposed to market risks and need to adjust their output to the electricity demand. For instance, in Germany all of the vRE plants with an installed capacity above 100 kW need to trade their production on the spot market. This policy reform successfully activated market mechanisms to support vRE integration efforts.

With the introduction of the direct marketing scheme in Germany the aggregators emerged as a new market participant who offers plant owners to take over the task of trading their electricity production. In Germany, aggregators rely on Virtual Power Plant technology to digitally bundle distributed vRE plants to a single portfolio which can be centrally monitored and controlled. Virtual Power Plants today are the undisputed state-of-the-art technology for trading renewable energy production in the German electricity market.

It is recommended that Vietnam should as well evaluate the introduction of this type of market mechanisms to involve plant owners in the efforts to optimally incorporate intermittent generators. This would unlock as well the market-driven potential of the Virtual Power Plant for integrating renewable energy.

Chapter

14

Cybersecurity issues for control room software

14. Cybersecurity issues for control room software

Concerns have been raised in Vietnam that a proliferation of the OCC model for operating decentralized assets could gradually create an intermediary IT layer between the Dispatch Centers and the power plants which could ultimately lead to IT security issues or a lack of control over the power plants.

Cybersecurity comprises different fields and perspectives that need to be considered. In particular, it is important to include organizational aspects as well as technical aspects.

Regarding the control of the plants, the provided information in both of these categories does not allow for an informed opinion if these worries are well-founded.

From a technical perspective it is assumed that it does not make a difference if further plants are controlled via OCCs if they have responded until now reliably to the control signals of NLDC. However, it must be ensured that NLDC maintains full transparency on the existing OCCs and their connected assets and that the applied OCC systems comply with defined minimum technical standards.

However, since the OCCs participate in the process of controlling the output of the plants, steps need to be taken to ensure highest IT cybersecurity standards. A massive expansion of OCCs and energy units digitally connected to them heightens the surface for cyberattacks. Therefore, it is crucial to mitigate the risks that will accompany the process of power sector digitalization.

The technical information provided for the OCC shows that for transfer of data and control signals a secure Virtual Private Network (VPN) is used. This is an essential step to ensure a safe data communication which is also applied between the VPP and connected assets.

However, on a global scale additional measures apply for VPP operators which should be considered as well for the operation of OCCs in Vietnam. Whereas Vietnam has enacted laws which rule general digital security there has not been an identification of critical infrastructure sectors and a specific cybersecurity regulation for the concerned companies.

Hence, as a reference, the German standard will be briefly described in the following and what consequences its application would have for the OCCs in Vietnam.

Germany has defined different sectors of critical infrastructure which need to be protected from digital attacks The German IT Security law enacted in 2015 defined for the first time the regulated sectors of critical infrastructure (CRITIS), such as energy, information technology and telecommunications, transportation and transport, health, water, nutrition, finance and insurance for which IT security requirements should apply. As can be seen, among these sectors is the energy industry.

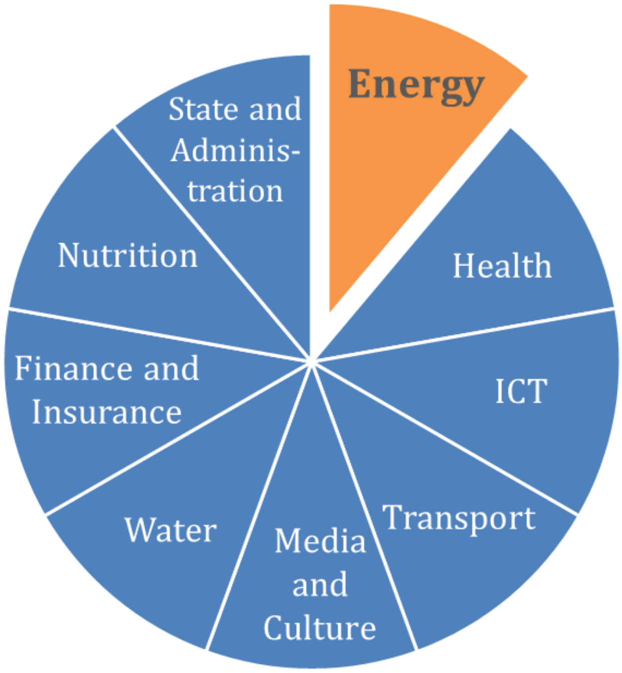

Figure 398: Areas defined as critical infrastructure in Germany

Who is considered an operator of critical infrastructures (CRITIS) is in turn regulated by the Ordinance for the Determination of Critical Infrastructures according to the Federal Office Information Security (BSI) Act (BSI-Kritisverordnung - BSI-KritisV). In the energy sector these are generating plants, network operators, storage facilities, central higher-level control systems and trading systems.

For the German electricity sector, defined criteria determine if an enterprise is considered to be critical infrastructure. For Virtual Power Plants a threshold value of 420 MW capacity has been defined. This value is determined based on the average electricity consumption per person and the number of people affected in case of an outage due to a cyberattack which should not exceed 250.000 people.

Each CRITIS operator must take appropriate organisational and technical precautions to avoid disruptions to the availability, integrity, authenticity and confidentiality of its information technology systems, components or processes that are critical to the functioning of the critical infrastructures it operates in accordance with the "state of the art". A key requirement is to implement an Information and Security Management System (ISMS) for the establishment of procedures and that serve to permanently define, manage, control, maintain and continuously improve information security. A broadly applied and accepted is ISMS standard is ISO/IEC 27001. Additional obligations might be applicable for certain areas, e.g. ISO/IEC 27019 for control room systems. The ISO 27001 certification scheme contains a very large number of specific details to set up and maintain an ISMS in a risk-based approach.

According to §8a BSIG, KRITIS operators must prove every two years that they meet the relevant requirements. Testing can be carried out by accredited auditors and is accompanied by BSI staff in individual cases.

In Germany aggregators control large portfolios of DER assets whose combined capacity exceeds in most cases the threshold value of 420 MW. This is illustrated in Figure 23 which lists the five biggest aggregators for different generation technologies and the size of their controlled portfolio. With the exception of one aggregator, all of them bundle plants with a combined capacity that significantly exceeds 420 MW.

Rank	Technology	Direct marketer	Status 1.01.2018	Status 31.12.2017	Wind	PV	Biomass / Biogas	Hydro
1	Wind	Statkraft Markets	9680	9825	8815	770	40	55
2		Quadra Energy	4880	3500	4800	74	3	3
3		MVV Energie	5900	7400	4400	1400		
4		EnBW	4505	4730	4100	250	40	110
5		EWE Trading	3765	2920	3480	45	240	
1	Solar	MVV Energie	5900	7400	4400	1400		
2		Next Kraftwerke	3090	2871	568	1222	1270	14
3		Sunnic Lighthouse	1700	1300	500	1200		
4		Wind Energy Tra-ding	4300	4300	3450	843	2	5
5		Statkraft Markets	9680	9825	8815	770	40	55
1	Biomass	Energy-2-Market	3543	3408	1198	633	1622	90
2		Next Kraftwerke	3090	2871	568	1222	1270	14
3		Baywa-Re / Clean Energy Sourcing	2135	3045	1565	121	445	
4		Lechwerke	400	390		47	254	58
5		EWE Trading	3765	2920	3480	45	240	
1	Hydro	Innogy	2117	1914	1391	156	184	385
2		Uniper	2408	1480	2278	3	7	120
3		EnBW	4505	4730	4100	250	40	110
4		Energy-2-Market	3543	3408	1198	633	1622	90
5		Vattenfall Energy Trading	3710	4410	3120	525		65

Figure 409: Overview of largest renewable energy aggregators in Germany.
Source: Energie und Management

Hence the bundling of energy units via an IT infrastructure such as the VPP has explicitly been mentioned in the regulation as forming part of critical infrastructure. As a consequence, the VPP operators need to comply with the regulation and implement an ISMS.

Applying this approach in Vietnam and assuming a similar threshold value would mean the OCCs Dau Tieng (600 MW), Loc Ninh (550 MW) and Sesan 4 (472 MW) would be regarded as critical infrastructure and would have to implement an ISMS. The remaining OCCs would not be affected by the CRITIS regulation. Concerning the DERM technology both pilot systems in Ninh Tuan (4310 kW) and Quang Nam (5000 kW) would neither be considered as critical infrastructure.

However, taking into account the impressive pace of renewable energy expansion boosted by private investment in the past three years it is very likely that the number and size of OCC and DERM systems – which currently are only tested in rather small-scale pilot projects - or other control software solutions such as the VPP will increase rapidly. Hence it is recommended to not only ensure a technical functionality of the OCC system and the use of safe VPN connections to execute dispatch orders as it is defined in the current regulation. Rather, it is recommended to evaluate as well the introduction of an ISMS requirement for larger power control systems in order to ensure availability, integrity, confidentiality and authenticity of the information and to counteract cyberattack risks.

Chapter

15

Concept for an operational testing phase of the Virtual Power Plant in Vietnam

15. Concept for an operational testing phase of the Virtual Power Plant in Vietnam

15.1 Goal of VPP project: improve visibility and control over vRE generation

The overall goal of the testing phase is an assessment of the Virtual Power Plant technology and its added value for grid operators in efficiently dealing with fluctuating power production in its operational processes.

A key improvement that the proposed testing phase aims at is making vRE production processes at the distribution level more transparent and controllable. Therefore, this report suggests the deployment of the Virtual Power Plant technology as a central control room for vRE hotspots in Vietnam. The Virtual Power Plant has internationally emerged as a versatile RE control room platform which – combined with power forecasts, rooftop pv forecasts and grid-load forecasts – can be used by different market participants for their purposes

The Virtual Power Plant is able to digitally connect large numbers of DER assets to a single portfolio which can be centrally monitored, dispatched and remote-controlled. A live data connection to the plants allows to retrieve real-time production data. Power forecasts can be integrated which are analyzed and optimized by the Virtual Power Plant on different aggregation levels. As an example, the grid operators can cluster vRE plants in specific grid sections which are frequently overloaded to closely monitor feed-in schedules.

Based on the requirements of the user, the electricity production can be adjusted for single assets, defined sub portfolios or the entire portfolio. Thus, the Virtual Power Plant allows to precisely integrate large scale numbers of decentralized assets according to the needs of the power network or market.

In consideration of the current challenges in Vietnam it is proposed to use the Virtual Power Plant as a common data hub for grid operators on different voltage levels. By connecting to solar power plants, in particular to the dominating larger rooftop pv plants with a capacity of about 1 MW, the software can raise, process and share real-time data with NLDC, Power Corporations and Power Companies. If external vRE power forecasts already available to NLDC or especially contracted predictions covering smaller vRE assets are integrated, the Virtual Power Plant also provides an outlook on future weather-dependent schedules. Thus, for the first time, a continuously updated stream of live and forecast production data is centrally available and can be shared with grid operators in Vietnam.

Additionally, the Virtual Power Plant also allows grid operators a better control over renewable energy generation. With a direct connection to the vRE plants in place, the Virtual Power Plant allows grid operators to directly adjust production schedules based on the data analysis tools provided by the software. This significantly reduces the length and complexity of the curtailment process currently in place and the required reaction time. With the Virtual Power Plant, grid operators are enabled to take data-based decisions and put them into action without the need to involve the plant operators.

We can therefore summarize the following focal points of the testing phase:

- Real-time monitoring of vRE production on lower voltage levels covering in particular feed-in from solar farms and rooftop pv systems
- Forecast-based visibility of future vRE production and consideration in day-ahead dispatch and intraday redispatch processes.
- Allocation of feed-in processes to defined grid areas (impacted by grid congestions)
- Testing of remote-control function of vRE assets

It is suggested that access to the Virtual Power Plant should be granted to grid operators on all voltage levels to share the vRE data on the distribution level. Since Power Corporations need to implement curtailment requests within their control area, they could have extended user rights including the possibility to remote control vRE assets on a province level. If needed, the underlying Power Companies may also be granted remote-control rights for their respective provinces in case there is beyond the curtailment process additional demand to control the plants, e.g., to solve local grid overloads.

Since the Virtual Power Plant allows a fluent communication with its surrounding via interfaces (e.g., APIs) it can also be embedded in existing IT infrastructure of the grid operators. Measurement and forecast data which have been integrated and processed by the Virtual Power Plant can also be exported to other IT systems for further processing.

Another advantage is that Virtual Power Plant technology is mostly offered as a Software as a Service (SaaS) solution which is why the technology can be provided for a limited period of time without the need to locally install any software.

Until now Vietnam does not have any experience in the internationally emerging Virtual Power Plant technology. The testing phase is therefore considered an ideal starting point to evaluate the technical performance, assess different applications and produce key learnings with the perspective of stimulating innovation and technology transfer.

15.2 Scope of the VPP testing phase

Given the massive installation of rather large rooftop pv systems during 2020 in Vietnam which are not covered by the current forecasting system and which are not efficiently remote-controlled it is suggested to focus in particular on these plants in the Virtual Power Plant project.

As suggested above, the application of the VPP as vRE management platform should focus on vRE hotspots in the CPC or SPC area where the integration of (rooftop) solar production is increasingly challenging. A specific province or grid section can be suggested by CPC or SPC in collaboration with the affected Power Company and the Virtual Power Plant technology provider energy & meteo systems.

As outlined in the previous VPP report, a peculiarity in Vietnam is the dominating role of larger rooftop pv plants with an installed capacity of close to 1 MW. For example, in the province Gia Lai 460 plants in the size range of 900 kW to 1 MW account for 458 MW out of 604 MW of total installed capacity. By contrast, 2539 rooftop pv systems only account for only 75 MW. This is different to the size distribution in many other countries such as Germany where most rooftop pv are mainly up to 10 kW. The advantage of larger rooftop pv systems is that less plants need to be connected to the Virtual Power Plant to achieve a relevant share of the overall installed capacity. This is an important point since the connection of plants to the VPP is not an automatized process but requires mostly case-to-case solutions and the support of ICT experts. This expert advice will also be contributed by energy & meteo systems.

The number of plants which can be selected to participate in the VPP testing phase therefore depends primarily on the effort required for connecting them. In case the vRE plants need to be connected manually to the VPP, the effort is larger and the number of assets must therefore be limited to a reasonable extent. The basic concept of a VPN-secured connection between vRE plants and the Virtual Power Plant is illustrated in Figure 1.

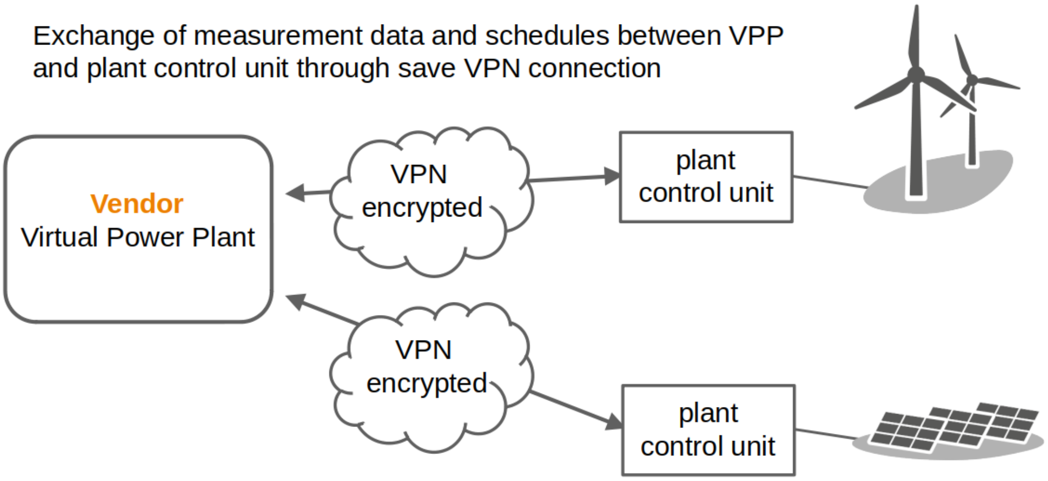

Figure 50: Connection between VPP and individual plants via VPN connection. Source: energy & meteo systems

However, even in case a smaller number of rooftop pv systems will be connected to the Virtual Power Plant the retrieved live data can be a valuable starting points for a founded analysis of solar production on different aggregation levels. The Virtual Power Plant is for instance able to upscale real-time data from a few connected plants and thus provide an estimation of the production of the entire installed capacity in a defined region. This “nowcasting” of rooftop pv production provides grid operators with production values for the current point of time which is essential information for short-term adjustments in operational processes.

As an additional data source, energy & meteo systems can also provide access to real-time measurements from inverters installed in Vietnam. These live measurements of hundreds of solar inverters can be gathered and additionally integrated into the VPP. This approach would enable an even more detailed monitoring of rooftop production and represent a broader data base for upscaling processes.

It is suggested to complement the real-time measurements with power forecasts in order to create visibility with regards to expected production volumes. The predictions can be supplied as well by energy & meteo systems and integrated into the VPP. By correcting the weather-based power forecasts with real-time measurements the VPP is able to carry out a short-term forecasting process. The short-term rooftop pv forecasts resulting from this optimization process are significantly more accurate for the next hours of the prediction horizon.

Beyond monitoring real-time measurements and forecasts the testing of the remote-control function is considered a crucial element of the VPP project. It is up to the Power Corporation as the suggested main VPP operator to define a case where the dynamic plant control capabilities of the VPP can be tested to assess the responsiveness to NLDC´s curtailment signals. This would as well create the basis for a comparison of the current curtailment procedure with more data-based curtailment decisions and shorter curtailment routes enabled by the Virtual Power Plant.

15.3 VPP implementation process

Setting up an individual Virtual Power Plant requires a close cooperation between the VPP provider and the user of the software. The size of the portfolio, the effort to connect the plants to the VPP and the scope of customization mainly determine the time which is needed to supply the grid operators in Vietnam with a ready-to-use system which meets their requirements.

In the following the main steps are presented which form part of the implementation process of a Virtual Power Plant.

15.3.1 Planning, coordination and development

a. Virtual Power Plant

At the beginning of the project the Virtual Power Plant will be presented in a workshop / web conference in order to define with NLDC, the Power Corporation of the selected vRE hotspot and subordinate Power Companies the goals of the Virtual Power Plant testing phase. In the process of goal definition, the operational needs of the grid operators are raised and assessed (need assessment). The specific user case and derived requirements for the Virtual Power Plant are clarified and documented.

In a first VPP demo the Vietnamese partners are then familiarized with the functionalities and overall capabilities of the software. In case the Vietnamese partners require essential modifications, a separate workshop for these particular functionalities will be arranged.

It is suggested that both sides nominate project managers who will be the main contact person throughout the project and coordinate processes internally with the respective staff. Frequent videoconferences are carried out where the project progress is discussed and next steps are agreed.

Main aspects which need to be discussed include:

- Definition of the number of users
- Definition of user rights for staff of the grid operators
- Selection of the vRE plants to be connected
- Technical data of the parks (technology, installed capacity etc.)
- Definition of clusters to which the solar and wind plants should be connected in the Virtual Power Plant (e.g., grid-oriented clusters, regional clusters, technology-oriented clusters)
- Individual software configuration

In chapter 3.2 the implementation process for the VPP is presented in more detail.

b. Optional: solar and wind power forecasts

energy & meteo systems operates its own forecasting systems for solar and wind power which today cover almost 500 GW of installed capacity on a global scale for grid operators, traders and plant operators. energy & meteo systems has as well longstanding experience in forecasting rooftop pv plants. In a separate project, these rooftop pv forecasts are currently under preparation. Therefore, the rooftop pv forecasts can also be used for the VPP project in case they cover the selected plants.

In case the plants are not covered by the power forecasting project, the rooftop pv forecasts can be created specifically for this VPP project. Data which need to be contributed by the grid operators are the standing of the plants plus historical measurements to train the power forecasting module. At least one year of historic production data is used - if available - for training the power forecasting system. A template will be provided to the Vietnamese partners for supplying the measurement data.

The solar power forecasts will then be set up by energy & meteo systems. Part of the work is selecting global weather models of different meteorological service providers whose meteorological forecasting accuracy shows the best performance. energy & meteo systems has access to the most important international weather models. The selected weather models are weighted to produce an optimized combination forecast.

As mentioned previously, live production measurements can be used for a short-term optimization of the power forecasts which significantly improves the accuracy of the predictions in the first hours after delivery.

It is crucial to complement the VPP project with vRE power forecasts, since visibility of future power production is essential information for grid operators to timely schedule the dispatch of the vRE plants.

15.3.2 Implementation process for the Virtual Power Plant

The Virtual Power Plant will be set up in close collaboration between the grid operators and energy & meteo systems. The process includes the following steps.

1. Creation of a catalogue of requirements

Initially, a detailed list of requirements for the use of the VPP with the selected generation plants is developed in close cooperation between energy & meteo systems and the Power Corporation. This set of requirements is the basis for the customization and for configuring the VPP, for the connection of the plants and for the test of the entire system prior to commissioning. If during the implementation phase or during the practical operation of the VPP it could prove useful to modify specific aspects of the requirement specification, then energy & meteo systems carries this out as part of the customization and maintenance.

2. Setup of the Virtual Power Plant

- License to use the VPP

As mentioned earlier, the VPP technology will be provided as a SaaS solution. energy & meteo systems provides a license (non-exclusive, non-transferable) to use the VPP software during the testing phase.

- Setup of the VPP software and access for NLDC

energy & meteo systems installs the specific VPP for the Power Corporation on a server of energy & meteo systems. The Power Corporation, NLDC and Power Companies obtain authentications for up to 10 users to access to VPP through client software. energy & meteo systems defines together with its Vietnamese partners the desired users and their rights. Thereby, it can be ensured that only selected staff has complete user rights including remote-control of the plants.

- Parametrization / configuration of plants

energy & meteo systems configures the plants in the VPP system together with Power Corporation. Templates will be provided to collect the required standing data of the plants which will be connected to the VPP. Staff of the Power Corporation, NLDC and Power Companies will be trained in web conferences in working with their individual VPP.

- Communication and plant connection

energy & meteo systems sets up the communication between the vRE plants and the VPP, if necessary, and can also provide some advice how the connection can be realized, if required. However, energy & meteo systems does not bear costs for required hardware installations or communication infrastructure. Hence, if additional communication equipment is necessary, the purchase, installation and operation will not be covered by energy & meteo systems.

- Metering data management incl. data checks and checks of metering points

Available metering data can be imported by energy & meteo systems into the VPP. The data range and periods of missing data can be checked easily in a first step. Furthermore, the correct metering points can be found by automated checks for unassigned data. The data of the metering points can directly be plotted in order to check the automatic proposal manually. A check of plausibility whether the data fits to other data in the database (e.g., installed power) will be conducted.

- Generation of meta-prediction

If power forecasts are provided by NLDC and/or power forecasts are created by energy & meteo systems these can be integrated into the VPP. If it is agreed to put a focus on rooftop pv systems, forecasts for these plants can be created by energy & meteo systems and integrated into the VPP to visualize real-time and future production schedules. If at least two sources of power forecasts are available, a combination forecasts based on optimal weighting of individual forecasts can be created. This combination forecast is on average more accurate than single forecasts and will be used by the VPP. The weighting factors of power forecasts can be calculated automatically with the evaluation function of the VPP.
For that purpose, historical forecasting data is used to find the best weighting factors. The Virtual Power Plant user can run this analysis for a defined forecasting period. Alternatively, the weighting factors can also be pre-determined manually.

- Extensive analysis function

In the analysis section, the availability of metering and real-time data can be plotted graphically or numerally. Gaps of data or delay in data export can reliably be identified. Plants with data rated as incorrect, can be reviewed at this point, in order to be settled. An overview of all controllable plants including provider information is available.

- Creation of schedules

Day-ahead and intraday schedules are created daily by the VPP considering the available forecasts and the status reports of the plants. Status reports such as outage information or maintenance schedules are received automatically and processed, e.g., from an external web portal. For remote control schedules, e.g., to curtail the plant production, the VPP also considers plant specific restrictions such as minimum production limits.

- Remote control: limitation or curtailment schedules from external systems

The VPP can consider the limitation schedules describing a request for remote control for certain assets from an external system, e.g. the trading system or a portfolio management system. This schedule can be updated anytime (i.e., in case of alteration in intraday prices).

- Remote control: Limitation / curtailment in a defined order

In case of a change in production initiated by the VPP for a portfolio or group of assets, the order in which individual plants are selected can be pre-defined in the VPP. This can be conducted by numeration or setting of costs (e.g., marginal or operational costs). If a selected plant is not available, e.g., due to unexpected outages or communication problems, the VPP automatically chooses alternative plants according to the pre-defined order.

- Testing of the VPP system (software und plant control)

After the set up and configuration of the VPP system (software and connection to the plants) the entire system will be tested based on a catalogue of requirements. Within an extensive practical test of all components including the connected plants will be carried out, further readjustments will be executed. After successful testing, the VPP system is available for operational use.

- Training and documentation

energy & meteo systems will provide online training sessions for employees of the Vietnamese partners in operating, maintaining and configuring the VPP system.

15.3.3 Testing phase: VPP hosting and operation

Since the VPP is provided as a SaaS solution, energy & meteo systems will take care of hosting the system during the testing phase. The provided technical support is described in the following.

- Redundant Servers

The VPP system is operated redundantly in two different computing centers which are independent and separated in terms of network and power supply, i.e. in case of failure of individual servers or individual network connections as well as power failure, the VPP remains operational.

- Users

energy & meteo systems will register up to 20 users for NLDC. Up to 10 users can work on the system simultaneously.

- Online monitoring of the software by energy & meteo systems

energy & meteo systems sets up an automatic monitoring system with logging that generates warnings and alarms when software, hardware or communication errors occur. The messages are sent to the internal support of energy & meteo systems and evaluated. Detected errors in the system are corrected as soon as possible.

- Online monitoring of plant connections by energy & meteo systems

energy & meteo systems sets up a logging in order to generate warnings and alarms in case of errors in the plant connection. These messages will be sent to a support defined by the Power Corporation. For each plant different contact persons for different problem reports can be specified.

- Maintenance and Support

energy & meteo systems maintains the VPP system on a regular basis and provides updates of the system. Employees of energy & meteo systems are available as a contact.

It is estimated that based on a 12 months period the testing phase will cover a period of about 6 months. The main goal of the testing phase is that the grid operators get familiar with the VPP technology and its benefits for real-time monitoring and localizing feed-in processes in certain grid areas and, if required, remote-controlling the production of vRE assets. As mentioned earlier it is suggested to particularly focus on larger rooftop pv systems in areas with increasing grid constraints.

energy & meteo systems will not only be available for technical hosting but also discussing with the Power Corporation, NLDC and Power Companies in frequent meetings the application of the VPP for grid operational processes.

15.4 Assessment and final report

At the end of the testing phase a report will be created by energy & meteo systems in collaboration with the grid operators which summarizes the main results and experiences from the testing phase of the Virtual Power Plant.

The report will highlight the experiences of energy & meteo systems in setting up the first Virtual Power Plant in the Vietnamese power system. This may include topics such as plant connection process, forecasting accuracy or required software adjustments to satisfy the needs of grid operators in Vietnam.

Second, the report should present the perspective of the grid operators and their experience as first-time users of the Virtual Power Plant technology in Vietnam. This may reflect on the added value of disposing of real-time production and forecast data as well as a direct remote-control of vRE plants for system operational processes. In particular the availability of accurate short-term forecasts should be assessed and how grid operation can benefit from these data. The conclusions may also include possible adjustments of intraday operational processes (e.g., redispatch) to pull maximum value out of these short-term predictions. Possible efficiency gains and increased collaboration between grid operators on different voltage levels may be conclusions and experiences the grid operators can as well elaborate on.

Eventually, the report will also contain recommendations for ERAV and policy makers how the regulatory framework could be adjusted to support the application of the VPP technology in Vietnam. The main results will also be presented and discussed with key stakeholders of the Vietnamese power sector in a final workshop

15.5 Project schedule

It is suggested the testing phase should cover a period of at least one year, including the time required for setting up the Virtual Power Plant according to the requirements of the Power Corporation. The estimated time for implementing the Virtual Power Plant is 3-6 months.

In the following Figure 46 a draft timeline is presented for the VPP testing phase.

	2021			2022								
Project Activities	October	November	December	January	February	March	April	May	June	July	August	September
Phase 1: kick-off workshop												
○ Definition of requirements for VPP ○ Selection of plants to be connected ○ Agreement on project coordination												
Phase 2: Set up of individual VPP												
○ Setup of VPP software												
○ Connection of vRE plants and integration of standing data in VPP												
○ Metering data management												
○ Integration of power forecasts												
○ Testing of VPP and training of staff												
Phase 3: Operational testing phase												
○ Testing of VPP by Power Corporation ○ VPP hosting and support by emsys ○ Continuous exchange between emsys and Power Corporation												
Phase 4: Evaluation												
○ Joint evaluation of VPP testing phase by Power Corporation and emsys ○ Creation of report on testing phase												

Figure 5141: Schedule for Virtual Power Plant testing project

The initial setup of the Virtual Power Plant and integrating the standing data of the rooftop pv plants to create a digital twin of the real plants is usually carried out rather quickly.

The most time-consuming task in the set-up process is establishing a real-time connection with the plants. The period depends mainly on the number of assets which should be connected and if any additional hardware is required to establish a live data connection. Apart, the scope of customization desired by the Power Corporations will influence the project timeline.

Chapter

16

Conclusion on the potential for Virtual Power Plants in Vietnam

16. Conclusion on the potential for Virtual Power Plants in Vietnam

The Vietnamese power system is undergoing a massive transition. Private investment has spurred the large-scale installation of renewable energies of different technologies and sizes. The public utility EVN and its grid operating unit NLDC are tasked with integrating massively increasing distributed electricity production into the power system while ensuring at the same time the reliability of the energy supply. Hence, plant operators are required to respond quickly to the control signals which are sent by NLDC or underlying dispatching units.

The regulation allows private plant operators the option to centralize the control of multiple assets in case the control room reliably participates in dispatching processes, forwarding control signals to single connected units.

While the expansion grid infrastructure has been initiated, the deployment of smart energy software can support already in the short and medium term a more efficient use of the existing networks. So far, some private plant operators have installed Operational Control Centers (OCC) which are connected to a small number of medium to large scale solar parks. These OCCs can be characterized as an O&M software which allows IPPs to centralize the management of vRE plants. At the same time, they need to reliably react to control signals by grid operators. It is assumed that a further proliferation of this software does not pose a threat to the control of vRE plants by NLDC or the regional dispatch centers. While the technical setup is sufficient for the current requirements to adjust on demand the output level of certain plants, its benefit for a better integration of vRE into the power system appears to be limited. The DERM technology is more advanced, integrating as well complex scheduling and dispatching capabilities. However, this system lacks the intelligence to manage vRE forecasts and include them in foresighted scheduling.

The VPP as described in this report, by contrast, was specifically designed to deal with distributed weather-dependent generation and integrates comprehensive forecasting, scheduling and dispatching capabilities. As a versatile IT platform, it can support various stakeholders in the power system with their individual challenges resulting from vRE production and feed-in. The proposed user case of the Virtual Power Plant as an energy management platform for vRE hotspots in Vietnam aims at addressing vRE integration challenges: a lack of live and prediction data and a lack of control over production processes which results in an inefficient integration of solar and wind power. Deployed as a centralized data and control center the Virtual Power Plant would create for the first-time visibility on production schedules on the distribution level, allowing to capture especially the large production from rooftop pv plants. Retrieved, analyzed and upscaled real-time and forecasting data can be shared with grid operators on TSO and DSO levels for a more precise and flexible vRE feed-in management. It is suggested that the Power Companies are the main operator of Virtual Power Plant, including direct control over assets on the distribution level. As a consequence, the curtailment process chain would be significantly reduced since the Power Companies could directly execute curtailment requirements from NLDC or regional Dispatch Centers. The report described how this and the benefit of improved transparency on vRE production processes could be investigated in a Virtual Power Plant testing phase for rooftop pv systems.

From a policy perspective it is recommended to implement market mechanisms which stimulate integration efforts as well from the plant operators. Many European countries, in particular Germany, succeeded with their decision to transfer responsibility for the integration of vRE to the producers of solar and wind energy in a market-based approach. A market-oriented reform in Vietnam would as well be a prerequisite to enable the internationally common use of the Virtual Power Plant as a trading platform for renewables. Based on these findings it is recommended to support the application of smart energy software to support in the short-term a more efficient vRE system integration.

As new digital tools empower the energy transition in Vietnam the risk of cyberattacks increases. Whereas general regulations regarding IT security standards have been enacted in Vietnam, these software tools deserve more attention. As this report outlines, operators of energy portfolios exceeding 420 MW are categorized in Germany as being part of the critical infrastructure. As a consequence, VPP operators need to meet not only technical requirements but have to implement as well an Information and Security Management System in their organization. This is today an essential requirement for the numerous VPP operators in the German market to ensure a high level of IT security in the energy supply. It is recommended to evaluate this approach as well in Vietnam for large OCC or DERM operators and users of other control software in the energy sector.

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