FLEXIBILITIES REVIEW: INTEGRATION INTO SMART GRIDS

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ABSTRACT

In the recent past, there has been a huge pressure on the power system as there is an increased demand for energy consumption. Power systems have not only been faced with supply and demand pressure but also been faced with the problem of ensuring the supply of clean and reliable energy. need for flexibility in the system is required with the introduction of renewable energies. Integration of renewable energy into existing architecture was not easy but with the birth of smart grids, there have been endless opportunities and optimization of power systems this paper focuses on virtual power plants(VPP). It starts with a brief overview of smartgrids, components of smartgrids, analysis into how virtual VPP works, integration of VPP into Smart Grid Architecture Model (SGAM) architecture and current VPP projects.

INTRODUCTION

The energy sector is in the middle of the transition, the power generation is shifting from centralized fossil-fueled generation to decentralized renewable generation at the same time the road transport is moving from internal combustion engine towards battery electric vehicles. While these technologies are as good as they lower emissions and lower costs, they can cause some significant side effects.

From the supply side, we are moving from stable and controllable loads towards more volatile and less predictable power generation sources. On top of that, the volatility has to be mitigated by the decreasing traditional power generators on the demand side. The charging of electric vehicles puts a lot of pressure on the grid because of their high demand correlating charging, with over one million public charging plugs for electric-vehicles as indicated by BloombergNEF as of August 2020 [1]. The combination of these developments makes it harder and harder for the system operators and utilities to balance out supply and demand to ensure a stable and reliable grid.

Demand-side response innovations can help to shave peaks, fill valleys, and shift loads, [2] this will allow non-traditional stakeholders such as large commercial and industrial energy consumers to capture the value of flexibilities. Battery storage can serve on a residential scale as part of the demand side and on a utility-scale to help to stabilize supply. Excessive power can be converted into a variety of forms gas, heat, hydrogen, or can be used to pump hydro and to be re-converted at a later moment in time when it is needed most.

Advanced power plant flexibility and virtual power plants help to enhance the adaptability of the power supply. Charging electric vehicles at times of low demand or high supply, or even using their batteries to charge back into the grid can enable electric-vehicles to be an effective resource to the grid.

Supply and demand can differ over geographical areas, so coupling of markets and networks can help to balance the grid. Emerging technologies such as blockchain, artificial intelligence, and machine learning will provide tools to improve current or even enable completely new solutions. This has all been enabled due to the smart-grid. This paper starts with a short overview of what is smart-grids and flexibilities then narrows down to virtual power plants.

VPP Illustration

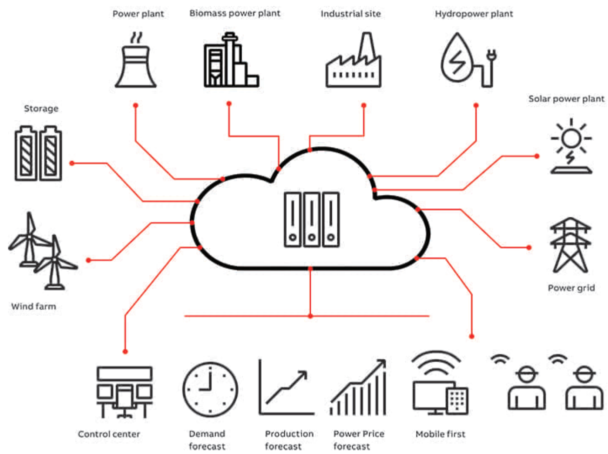

Figure 1: A large variety of resources incorporated into a virtual power plant (VPP). The interconnected units can then be dispatched using special software and traded intelligently on the energy market. Courtesy: ABB [6]

BACKGROUND

Smartgrids and Virtual Power Plants (VPPs)

The smart-grid Technologies are creating new methods and opportunities to support the energy distribution system and enhance reliability by establishing precise control and planning through state estimation.[3]

Smart grid technologies can support new energy distribution systems by the provision of additional flexibility from the aggregated distributed energy resources(DER) by design to provide Frequency Control Ancillary Services (FCAS) that ensure stability and security of supply[4]. And this satisfies the worrying question about sufficient operational flexibility at the transmission level[5].

Advances in communication, computing, and sensor technology are creating new alternative solutions to traditional approaches to meeting the ever-increasing demand. Virtual Power plants improve grid reliability as an alternative to install additional infrastructure.

In Figure 1 It illustrates a variety of resources(Wind farm,Power grid, Solar power plants , Storage, Biomass powerplant) aggregated into a VPP and the interconnected units that can be dispatched through software and intelligently traded on energy market.[6]

Components of VPP

An ideal VPP consist of three components Generation technology, Energy Storage technologies and information communication Technology(ICT) [7].

Generation Technology

These consist consist of mainly power generation units under decentralized generation category which generate electricity for use on site [8] . The DER considered for VPP are mainly Wind, solar, Combined Heat and Power (CHP), waste to energy (Biomass and Biogas), small hydro power plants

Energy storage Technologies

For the operation of power systems the energy storage systems (ESS) are essential as they ensure continuity of energy flow and improve the reliability of the power system. ESS have been an enabler for high penetration of variable renewable generation like solar and wind [9]. ESS integrated in VPP include :[10] [7]

(1) Battery ESS (BESS)
(2) Compressed air energy storage(CAES)
(3) Flywheel ESS(FESS)
(4) Pumped hydroelectric
(5) Superconducting magnetic energy storage (SMES)
(6) Ultracapacitor

Information communication Technology (ICT)

ICT systems and infrastructures are key component to VPP. Explicitily provided by the Smartgrids [11]. In VPP media technologies are considered for "communications in Energy Management Systems (EMS), Supervisory Control and Data Acquisition (SCADA) [12] and Distribution Dispatching Center (DCC)" [7], [13]

ANALYSIS

What are virtual Power Plants and How they Operate?

According to next-Kraftwerk, “A VPP is a network of decentralized, medium-scale power generating units such as wind farms, solar parks, and Combined Heat and Power (CHP) units, as well as flexible power consumers and storage systems.”[14] By consolidating communications infrastructure, intelligence, and sensors big selection of distributed energy resources(DERs) may be consolidated and treated as VPP. This involves the collection of knowledge from over many DERs via a secure communication infrastructure. These results are aggregated and controlled in a sort of a traditional power station although they continue to be independent of operation and ownership.

Due to the bidirectional flow of communication between individual power plants, this not only facilitates for transmission of control commands but also real-time data delivery to the control system and this can be used for precise electricity trading forecast and scheduling of flexible power plants.

VPP is connected to one central system, they consist mainly of DERs like hydropower, solar power, biomass Wind energy coupled with demand-side management and storage to make accurate forecasting, optimization, and dispatching of their generation and consumption. [15]

The VPP provides balance to the power fluctuations arising variables renewables generations like solar and wind by ramping up and down power generations and power consumptions of controllable units.

virtual power plants have made it possible to integrate renewable sources into the existing energy markets. by integrating many renewables the virtual power plant can trade as a single entity and it can meet the market demands of availability and reliability.

Integration of VPP into the Smart Grid Architecture Model (SGAM).

VPP Business overview

To integrate the VPP in the Smart Grid Architecture Model (SGAM) this paper considers a remote-controlled VPP [16]. Four different entities are involved: “the VPP operator (VPPOP), the distributed energy units (DEUs) constituting the VPP via their operation and control units (DEUOP, DEUC), the energy market, and the distribution system operators (DSOs) to whom the DEUs are electrically connected” [16] In figure 2 a detailed 3 dimension VPP business overview is illustrated on the SGAM:

Virtual Power Plant Operator (VPPOP)
This represents the central control center. It creates aggregated forecasts to trade energy on the energy market. In the SGAM it is located in the DER domain and enterprise and operation zone [16]

Distributed Energy Unit Operator (DEUOP)
It controls a local group of DEUs. in the SGAM it is located in the station zone.

Distributed Energy Unit Controller (DEUC)
It represents an addressable control interface that controls a specific DEU. In the SGAM it is located in the field zone.

Distributed Energy Unit (DEU)
It produces, consumes, or stores energy. in the SGAM it is located in the DER domain and process zone.

Distribution System Operator (DSO)
The DSO owns and manages the electric power grid distribution. The DSO is also responsible for safe and reliable operations of electric power in the distribution grid.

Energy Exchange
Represents the energy marketplace for buying and selling of the electric energy.

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VPP Business Overview

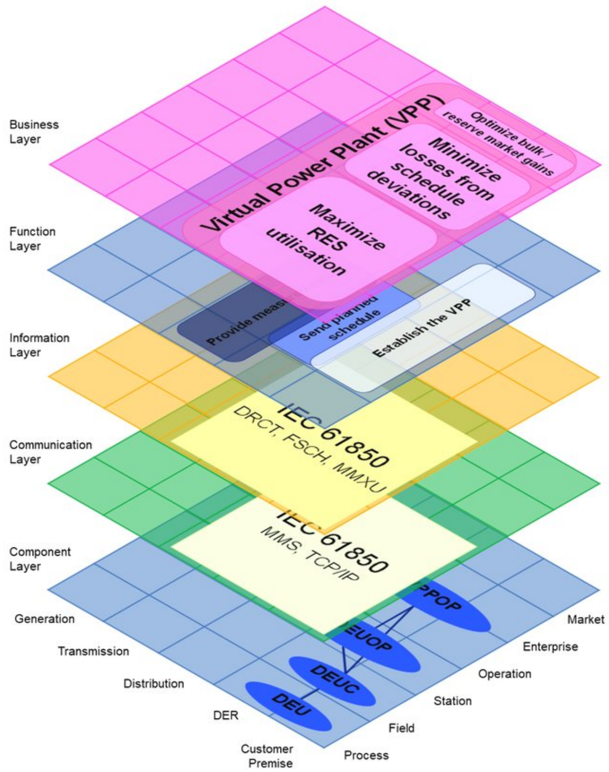

Figure 2: 3Dimension illustration of VPP business Overview on the SGAM

VPP Business Use Cases

From the business overview eleven use cases can be defined according to IEC 62559[16] [17] The figure 3 shows an overview of the VPP business Use Cases on the SGAM:

- VPP00-EstablishtheVPP
- VPP01- Create individual forecast for the VPP
- VPP02- Exchange the VPP forecast with the DSO
- VPP03- Participate on the Energy Exchange
- VPP04- Send schedule to the DEUOP
- VPP05- Send planned schedule to the DSO
- VPP06- Send actual schedule to the VPPOP
- VPP07- Transmit adjustments on the planned schedule to the VPPOP
- VPP08- Renegotiate schedule on the Energy Exchange

VPP Business Use Cases

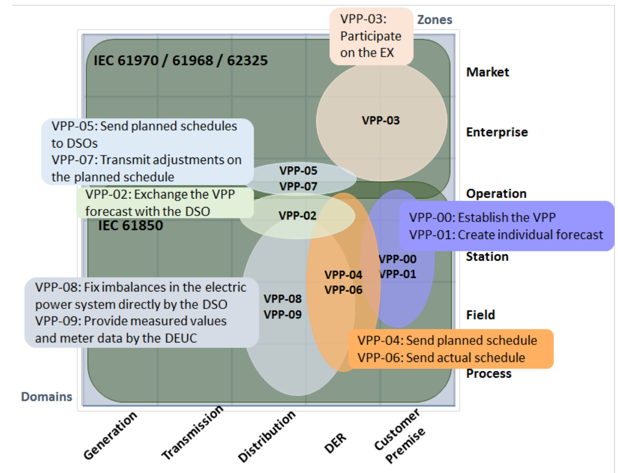

Figure 3: Overview of VPP business cases on the SGAM

- VPP09- Provide measured values and meter data by the DEUC
- VPP10- Fix imbalances in the electric power system directly by the DSO

Benefits of VPPs

The VPP have provide wide benefits to stakeholders, The stakeholders have been grouped into the following groups:-

(1) Owners of DER units
(2) suppliers and aggregators
(3) Transmission System Operators (TSOs) and Distribution System Operators (DSOs)
(4) Policy Makers

Key benefit to each stakeholder have been identified as follows [?]

Main benefits for owners of DER units:

- Utilize the benefits of flexibility
- Increasing value of assets through the markets
- Aggregation of the DER units reduces the financial risk to individual DER unit
- Raise chances for the DER unit owners to negotiate energy market conditions

Main benefits for DSOs and TSOs:

- Ability to utilize control flexibility of DER units for network management
- improved visibility of DER units for consideration in network operation
- Improved use of grid investments
- Improved co-ordination between DSO and TSO
- Mitigate the complexity of operation caused by the growth of inflexible distributed generation

Main benefits for Policy Makers:

- Cost-effective scalability and integration of large-scale renewable energies while maintaining system security
- Open the energy markets to small-scale participants
- Increasing the increasing worldwide efficiency of the electrical power system by utilizing the flexibility of DER units
- enabler for penetrations and reaching set targets for the deployment of renewable energies with reduced CO2 emissions.
- Improve consumer choice
- it is a source of employment

Main benefits for suppliers and aggregators
:

- New offers for consumers and DER units.
- Mitigating commercial risk.
- It is a source of business opportunities.

Examples of VPPs

(1) **Next Kraftwerke**
it is a virtual power plant operator based in Cologne Germany with a networked capacity of 8,538 MegaWatts(MW) and comprises 9,966 aggregated units as of September 2020. Next Kraftwerke was founded in the year 2009. [18]

(2) **Statkraft**
It's considered Europe's biggest virtual power plant with a capacity of 10,000MW and comprising of 1400 independent power producers. It began in Norway and its global headquarters are in Oslo, Norway. [19]

(3) **Centrica and Sonnen**
Centrica and Sonnen operate 2.5 Gigawatts(GW) virtual power plants in Europe, Asia, and North America as of September 2019. [20]

(4) **Simply energy Virtual power plant Adelaide**
It is a VPP based in Adelaide South Australia, it has a capacity of 8MW[21]

CONCLUSION

Virtual power plants(VPP's) are quite beneficial to the stakeholders, with the continuing advancement of Technology and a future centered on sustainable renewable energies, significant growth of VPP across the globe is expected. This growth will be driven by the need for economic growth as VPPs are avenues for new business opportunities and the need for curbing global warming as VPPs help in integrating renewables energies contributing to reduced carbon dioxide (CO2) emissions.

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