Virtual Power Plants &
Distributed Energy Source
Aggregation Platform

Powering your solutions

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Overview

The energy sector is facing major challenges to meet the demands of global warming mitigation and today's efficiency targets. The share of renewable energy sources is growing at a significant rate and there are already indications of challenges in controlling the grid balance in highly distributed energy generation topology. Solar power plants and wind farms are good ways to generate CO2 free electricity, but the production of both is difficult to predict and almost impossible to control. Nuclear energy will still play a significant role in producing electricity when the wind and solar do not deliver. Nuclear energy production is efficient, but it is also rather difficult to control and unable to keep up with rapid changes in energy demand. New environmentally sustainable power management solutions are needed to maintain the grid balance. This white paper will introduce a way to turn passive backup batteries into a Virtual Power Plant (VPP) and several alternative use cases for Virtual Power Plants.

Abbreviations

DER	Distributed Energy Resources
DMS	Distribution Management Systems
EMS	Energy Management Systems
FFR	Fast Frequency Reserve
IoE	Internet of Energy
IoT	Internet of Things
PSCADA	Power Supervisory Control and Data Acquisition
V2G	Vehicle to Grid
VPP	Virtual Power Plant

Introduction to the Virtual Power Plant

Declarations of climate emergencies in many countries around the world have raised awareness of the need to move to clean energy sources, which in turn has led the energy industry and governments to act or set clear goals. Many governments around the world now provide incentives to industries, communities and individuals interested in generating and using electricity from renewable energy sources, such as solar and wind energy, and installing IoT-era backup battery systems. There have been many improvements in the electricity grid that have enabled the integration of power from Distributed Energy Resources (DER). In the new emerging power economy, virtual power plants are leading the way by allowing the power from different DERs to be aggregated and providing an efficient platform for energy trade. As a result of this development, a new class of "prosumer" is emerging, consisting of consumers who not only consume electricity from the grid but also generate their own green power and who may have excess power to sell. In this paper, we discuss the challenges faced by VPPs and how Industrial IoT connectivity, gateways and cloud systems can help to overcome these challenges.

A virtual power plant operates by remotely connecting multiple independent energy sources from different locations to a grid that provides reliable power 24 hours a day. VPPs are a departure from the earlier power plant architecture in that they do not exclusively rely on one centralized power source. Unlike the traditional power plants, they combine several distributed energy resources together with centralized energy generation. Aggregating power from different energy resources can help to meet the demand during peak consumption; the utility company can avoid building additional load-following power plants and new transfer network cabling to achieve demand-supply balance. Software-based technologies are being deployed to plan, schedule, monitor, and bid for distributed energy resources to make the power grid more reliable and economical. Systemically, VPPs require a new digital infrastructure and process improvements that facilitate the integration of distributed energy resources into the main grid. Another objective for VPP is to make it easier for producers to use clean energy portfolio consisting of grid-scale and behind-the-meter renewable energy resources.

Key Challenges in Virtual Power Plants

The idea of virtual power plants capable of solving all the power issues of the future sounds very encouraging. However, deployment of the equipment and technologies required by a virtual power plant is an uphill struggle. Even if the technology is in place, a change in the mindset of stakeholders is required to make virtual power plants work. Some of the challenges faced by operators are addressed below:

Integrating Distributed Energy Resources into the Grid

Integrating the electricity from distributed energy resources into the main grid has a fair amount of challenges. Introducing a large number of DERs into the grid can cause a variety of adverse conditions, including voltage swing and reverse power flow, which can make the grid unstable. Most grids must be retrofitted in order to integrate and optimize the power from DERs and to increase hosting capacity. Consumers and grid operators also need a convenient way to buy power from DER aggregators at the optimal price.

Controlling and monitoring devices associated with DER at the edge of the grid is a major challenge. Traditional substations have relied on centralized utility technologies and systems like Power Supervisory Control And Data Acquisition (PSCADA), Energy Management Systems (EMS) and Distribution Management Systems (DMS). However, as DERs have proliferated at the edge of the grid, the requirements for visibility and management of these resources have surpassed the capabilities of traditional centralized systems. VPPs need the capability to collect and process data from the edge so that the operators can predict the demand and availability of resources at all times. Devices at the grid edge need to be monitored for better system integration and to prevent grid instability. The ideal percentage of DERs in the total composition of energy sources, including conventional sources, is approximately 20%.

Virtual power plants require seamless communication solutions to maintain the stability of the grid; upstream communication to acquire data from power generating devices and downstream communication to monitor and control the devices. IoT gateways, with their computing power and integrated communication interfaces, can help provide the platform with seamless data acquisition and processing. Data from batteries, meters, transformers and other edge devices can be sent to the DER management system to keep the network stable and meet customer energy requirements.

Estimating the Power from Distributed Energy Sources

A key factor in the success of the virtual power plant model is the ability to estimate the power from distributed energy resources. Most operators today do not have a way to gain insight into the power supply of DERs. In order to correctly estimate the power generated, the data from aggregators and utilities have to be combined to get a complete picture of supply and demand.

The ability to provide power output forecasts depends on the ability to acquire multiple weather parameter values (e.g. ambient temperature, relative humidity and wind speed), data on the state of equipment in the field and availability of backup battery sources, among others.

Existing systems of grid operators may not be able to process large amounts of real-time data, so the response time may be slow. Other issues that operators need to address include data security, data integrity and data loss. A solution consisting of an IoT gateway and remote I/O can be used to securely acquire data from a variety of edge devices, such as solar panels and backup batteries located in remote and/or harsh environments.

Implementing and Managing Demand-Response Programs

Energy aggregation is a good way to connect distributed energy producers to the grid so that the excess energy produced can be sold back to the grid. Similarly, large backup battery installations can be used as an online DER without compromising the primary backup purpose. These models help to maintain the demand-supply balance. To prevent waste, the excess energy produced can be stored in batteries and released to the grid during peak consumption.

Another way to conserve energy is to shift or eliminate peaks in energy consumption through demand-responsive programs, especially in heavy load applications. For example, significant changes in peak consumption can be achieved if there is a way to bundle industrial consumers together so that they can shift or optimize their power consumption cycles during the day to avoid peaks in energy consumption. Demand response can be defined as an incentive for consumers (or demand aggregators) to reduce their electricity consumption during high energy rates and increase the consumption at low energy rates.

Monitoring power consumption is the key to maintaining a balance between supply and demand. Virtual power plants need advanced measurement and control solutions in order to provide an efficient platform for energy trading. IoT gateways, with their built-in communication and computing capabilities as well as multiple interfaces, can enable advanced metering solutions in virtual power plants, maintaining a supply-demand equilibrium.

Different assets of VPP

VPP assets can be divided into three categories.

Type 1: The loads that can be turned off remotely for a limited amount of time to temporarily reduce energy consumption. Electric water boilers are a typical example of such loads. However, this method can only be applied in very few cases.

Type 2: Different types of battery packs capable of feeding electricity back to the grid. Often brought up example of such application is V2G (Vehicle to Grid). There are multiple challenges with this technology starting with the owners of the vehicles being concerned about the state of charge of their battery when they need the vehicle, even though in reality this concern is unfounded. Also, vehicles capable of V2G are not on market yet and adding the capability is costly. The situation will probably change in coming years, but it is difficult to predict when this technology will become more widely used. More realistic example are the batteries installed to store the excess energy from solar panels in private houses. Quite often these systems already have the capability of feeding electricity back to the grid. However, the owners still need a strong incentive to let the grid operator to use their very expensive batteries for the operator's own purposes and it is also very complicated for a grid owner to manage thousands of private contracts for grid balancing. Making the household battery storage sufficiently fast reacting would still require installing new technology.

Type 3 L7 Drive: The L7 Drive active backup battery system is a hybrid of the previous solutions. It utilizes the backup batteries of telecom networks, turning them into a VPP asset. Globally, there is always a regulatory requirement to have a power backup for telecom networks. The backup time requirement varies depending on the region and the network generation. In many densely populated areas of the world, the electric grid is very unreliable, and therefore proper energy backup is also a commercial requirement for telecommunications networks. It is not commercially viable at the moment to use the active backup batteries to feed electricity back to the grid, but the batteries allow the VPP operator to control the energy flow to the battery network and connected devices. The VPP operator can make the telecom base stations operate for a certain time, exclusively or partially, on battery power to reduce the load in the grid. The charging power of the battery can also be controlled or delayed, depending on the load status in the grid.

L7 Drive VPP engine

L7 Drive VPP engine has been developed to efficiently aggregate a vast network of DERs. The DERs can be grouped based on different parameters. These groups are called Virtual Power Plants. Assigning the different DERs into VPP groups is the key to accurate and efficient aggregation. Groups can be defined by, for example, physical location, region, electric grid cell, hardware ownership etc. Each group can be managed as a single resource, and there are no restrictions on group size. All DERs in each group constantly report the resource availability and the available power. Each VPP group has an input for an external signal that can control VPP resources to drop off the grid. The L7 Drive IoT gateways can transfer this drop-off command to DERs in 300 ms.

Since VPP is a secondary function of backup battery DERs, it is critical that each resource constantly reports the resource availability and the available power. This allows them to freely serve their main purpose. The VPP engine only uses DERs as a resource when they are available, which makes VPPs a more accurate and reliable system. The operator of the VPP resources will always know in advance exactly what is available and for how long.

When DERs are assembled into sufficiently large groups, the total available power remains very stable even though some loads are not always available.

VPP resources are rated based on the response time. The fastest group, Fast Frequency Reserve (FFR), must react in fewer than 1300 ms to the signal given by the VPP controller. In order to secure a reliable functionality, it is crucial that there is a feedback signal coming from the load end. There should be enough time to deploy substitute resources if some resources do not respond in time. Therefore, it is critical that the communication delay is less than ⅓ of the required 1300 ms response time.

Data related to the energy consumption and availability of each DER is stored in the cloud. This data can then be processed with different algorithms to create individual energy profiles for each DER. These individual profiles can be used to improve the accuracy of forecasting the behavior of different DERs. The objective is to guarantee seamless and reliable VPP operation without compromising the main function of the DERs.

The control response reliability is one of the most critical factors of building a VPP. The high reliability is built based on the following features.

- **Number of distributed energy resources**

The amount of available DER:s in each group should be sufficiently high before the VPP is allowed to operate. This ensures that a single unit failure or communication problem does not compromise the group's response. If the available power or the number of devices in a VPP is insufficient, the risk can be offset by over-deploying DERs.

- **Real time monitoring of individual DERs**

Each DER is delivering active feedback to the VPP engine. This feedback includes, as a minimum, resource availability, actual power available and communication refresh. The VPP engine is calculating the available power in real-time by combining the feedback signals of each DER.

- **Over-deployment**

Each VPP reserves a certain number of DERs as surplus resource. When a VPP is activated, the first burst of commands includes some extra DERs to ensure that the response is efficient enough. The VPP is usually activated when the grid frequency is approaching the critical low frequency threshold limit. Over-deployment will not cause any damage since the frequency window between the lower and higher frequency threshold is broad enough to accommodate certain amount of surplus.

- **Substitute deployment**

It is always possible that some DERs may become unavailable during the active VPP operation. To avoid related problems, the VPP engine constantly monitors the feedback signals from DERs, and if some DERs have become disabled, it will deploy substitutes for them.

- **Automated individual rating of DERs**

The VPP engine is storing data from each individual DER. The number of activations of each DER is stored. The VPP engine also records all the instances when the individual DER's response time is too long, or when there is no response. This data will form a response rate for each DER, which can be used to determine the rate of over-deployment in each group. This also allows DERs to be completely excluded from the VPP engine if they underperform repeatedly.

- **Continuous system testing**

VPP groups consist of tens, hundreds, or thousands of different DERs. This means that a single DER does not significantly affect the balance of the network. Therefore, it is possible to continuously test individual DERs to ensure secure and reliable operation if necessary. Based on the rating, the VPP engine determines how often DER testing is required. The results of these tests also affect the response rating of each DER.

L7 Drive IoT Gateway hardware

L7 Drive has developed two different IoT gateway devices, one for Ethernet and the other for mobile network connectivity. Both devices are primarily intended for connecting L7 Drive battery modules to L7 Drive cloud monitoring system. This hardware supports aggregation of TYPE1 and TYPE3 VPP resources. TYPE 3 aggregation is carried out via CAN bus by L7 battery link protocol, but other communication protocols are also supported. For aggregating TYPE 1 resources, L7 Drive IoT gateways are equipped with binary relay outputs that can be configured to aggregate loads.

L7 Drive backup batteries combined with L7 Drive IoT gateway and L7 Drive cloud service offer a complete backup energy solution equipped with the latest IoT features. The system allows the backup batteries to serve a secondary purpose as DERs in Internet of Energy (IoE) and generate significant revenue to the system operator.

L7 SmartGaze

L7 CanGate

Summary

Virtualization of power plants is a growing megatrend in the era of Internet of Energy. Previously, the required sub-second response times were out of reach, but today's modern cloud architectures and protocols enable real-time control of tens of thousands of distributed intelligent loads on the demand side of the power grid. This permanently changes the grid balancing paradigm from pure demand driven supply management to a new model, where demand management is the new element of grid balancing. Economically, the demand side DER aggregation cost is clearly below respective power generation marginal cost. From an environmental point of view, VPP operations clearly outperform traditional electricity generation. L7 Drive is a forerunner in DER aggregation and operation solutions and open to collaborating with likeminded pioneering parties in the nascent Virtual Power Plant industry.

Powering your solutions

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