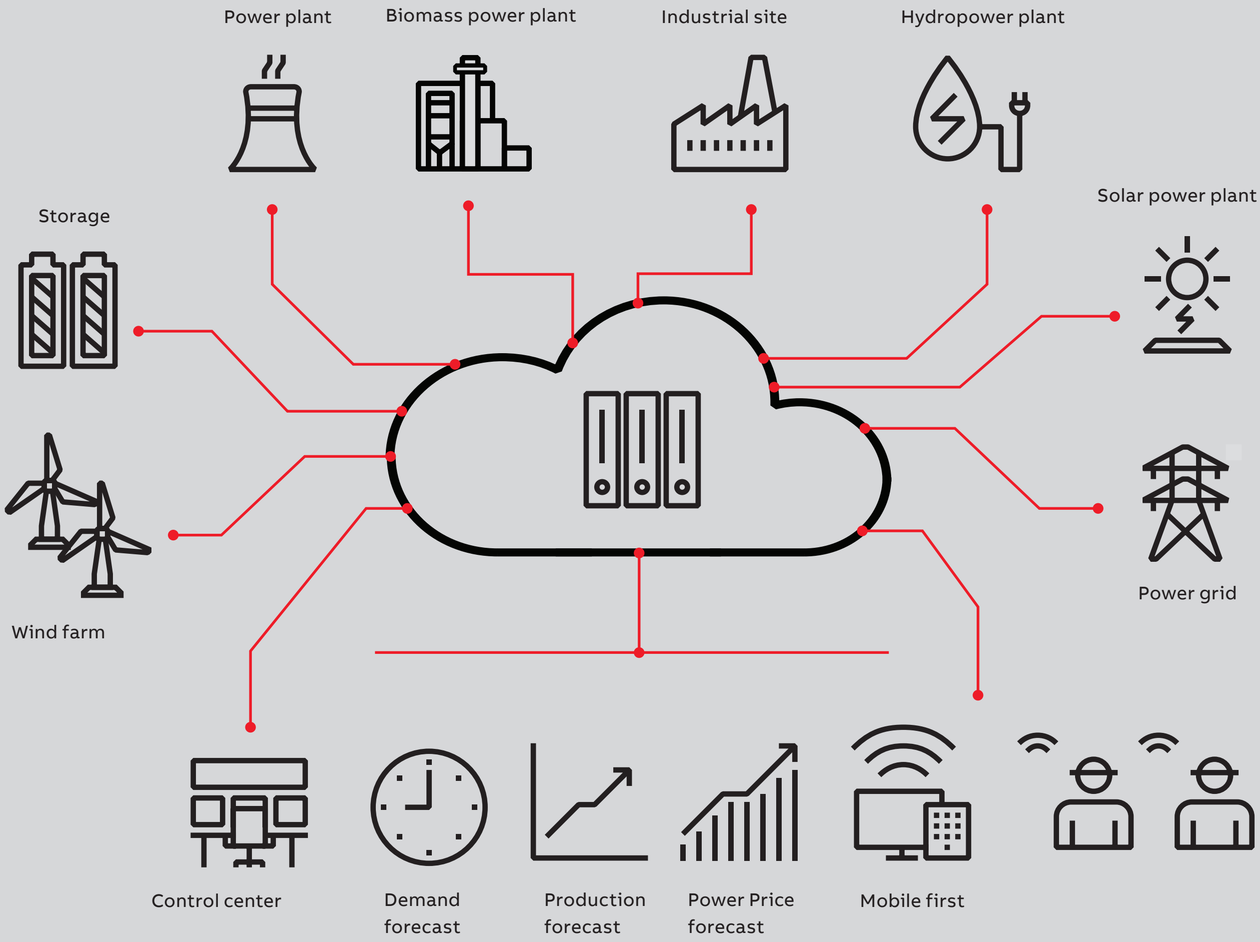
WHITE PAPER

# Virtual power plants

## Distributed generation is not a threat, it's an opportunity



# Executive summary

Almost 60 percent of utility executives in 20 countries rank distributed generation as the biggest disrupter to their operations, according to a 2017 survey by Accenture, the global services company.

Distributed generation, the executives predict, will reduce their revenues, increase grid faults and erode their business models.

But is distributed generation a threat or an opportunity? Virtual power plants, also known as virtual power pools, are a proven way to harness the advantages of multi-unit distributed generation. They do so across an impressive range of applications which enable:

- utilities and distributed energy companies to seamlessly integrate, optimize and trade production from thousands of small-scale generators across large geographic areas;
- municipal utilities to balance production with consumption in diverse, multi-source energy systems by utilizing day-ahead and intra-day planning;
- microgrids to integrate more renewables and minimize their use of costly, $CO_2$-emitting fossil fuel, without risk to grid stability and reliability;
- industries to cut their energy costs by 5-10 percent without impacting production volumes and delivery commitments; and
- conventional multi-unit power plants to optimize production and respond quickly and flexibly to market requirements by operating internally as a virtual power pool.

# Virtual power plants
## More people, more energy, more renewables

Virtual power plants/pools (VPP), are fast becoming a driving force in the power industry, due to rising demand for energy and the global turn to renewables.

By 2025 there will be 1 billion more people on the planet, all requiring electricity. And by 2040, 60 percent of the power generated worldwide will come from renewable sources, almost half of which will be from wind and solar photovoltaic. Much of this solar and wind power will be generated by small-scale producers - homes, businesses and municipalities.

As a result, the need is escalating for virtual power plants that combine multiple, geographically dispersed generation units into a single optimized entity that can plan and adjust production dynamically and trade intelligently on the energy market.

### Together, they do more and do it better

A virtual power plant/pool is a collection of power generation sources, energy storage devices and demand-response participants located in a distributed energy system.

Almost any power generating technology can be in a VPP, including biogas, biomass, combined heat and power (CHP), micro CHP, wind, solar, hydro, power-to-heat, diesel engines and so on.

Energy storage facilities can also be incorporated into a VPP, including batteries, thermal storage, compressed air and pumped storage.

### Municipalities, microgrids and industry

Typically, VPPs allow utilities and aggregators to pool production from tens, hundreds or even thousands of small and medium-sized renewable energy plants into a network that has the scale and flexibility to participate in the electricity market.

But they also serve other applications as well. They allow municipalities to optimize and manage their electricity, steam and heat production from multiple sources and participate in the electricity market.

Microgrids, which traditionally rely on costly and emission-producing diesel and gas generators, can maximize the use of renewable energy by switching to fossil fuel only when needed and in real time, should poor weather or high demand require.

Energy-intensive industries that generate their own electricity are also realizing the benefits of virtual power pools. By combining production planning, energy management and energy trading they can significantly reduce their energy costs, without changing production volumes or delivery deadlines.

And conventional multi-unit power plants can improve their flexibility, reduce fuel consumption and lower their carbon dioxide emissions by operating the plant units as a virtual power pool.

## Business models and energy trading

The goal of a VPP operator is to run its pool of units optimally and generate maximum revenues for its participants by bidding smartly on the energy trading market.

Typically, there are three types of market participation for VPP operators (see Figure 1). They can:

a) trade their power production on the energy market, using weather and load management forecasts and real-time and historic data to adjust bidding and commitments;

b) control unit production and commitments during the day in response to price signals from the market; and

c) provide balancing power to the transmission grid operator during periods of peak demand.

The design of the VPP is based on the type of market participation selected, the target customers (small-scale producers, businesses or industrial sites) and the types of generation and storage that make up the virtual power plant or pool.

There is no off-the-shelf software solution that can cover such a broad variety of requirements. The control and optimization system must, therefore, be tailored to the requirements of each VPP operator.

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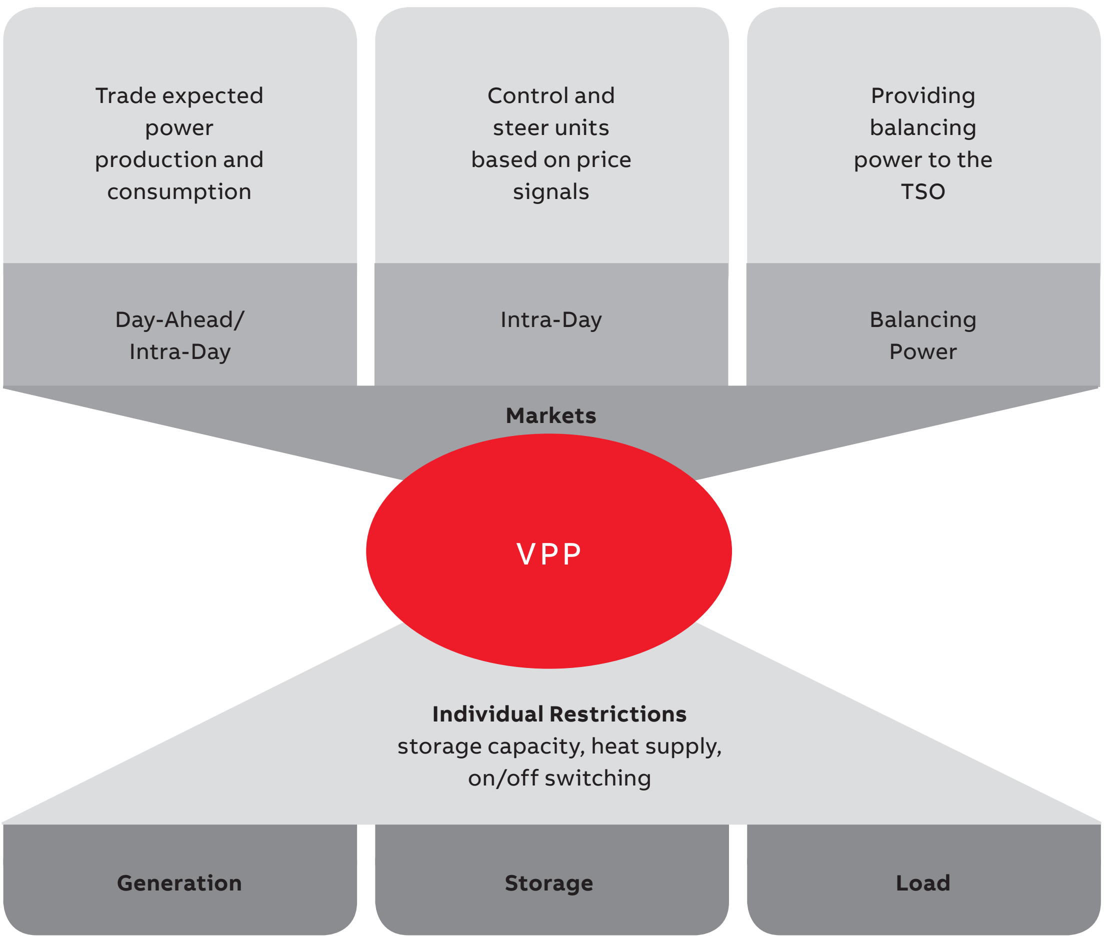
01 Business models and market participation for virtual power plants



## The digital building blocks of a VPP

The key component of a VPP, whatever the application or business model, is the plant's control and optimization system.

The system must have high availability to comply with the strict requirements for providing grid services.

It must be highly scalable, so that the VPP operator can rapidly grow the network without complication or disruption.

As connections to the units are IP-based, the VPP must meet the highest cyber security standards for transmitting set points and balancing power release calls from the control system to the units in the field.

It must be able to perform day-ahead, intra-day and real-time optimization using historical production, climate and meteorological data for temperature, wind direction and wind speed to forecast production capacity and load demand within a time horizon stretching from 1 hour to several days.

Using these forecasts, the VPP must be able to calculate optimal unit commitment and communicate the schedules to each unit in the pool, continuously updating the forecasts and commitment schedules and communicating changes to the units concerned.

And, it must be able to provide intuitive decision support for trading, as well as alarm and event management, historical data archiving, and other standard control and optimization features.

Ideally, the control and optimization system should be modular, comprising a series of building blocks for forecasting, control, optimization, trading, portfolio management and invoicing (see Figure 2). Modularity gives the system agility and adaptability to changing market conditions and future business models.

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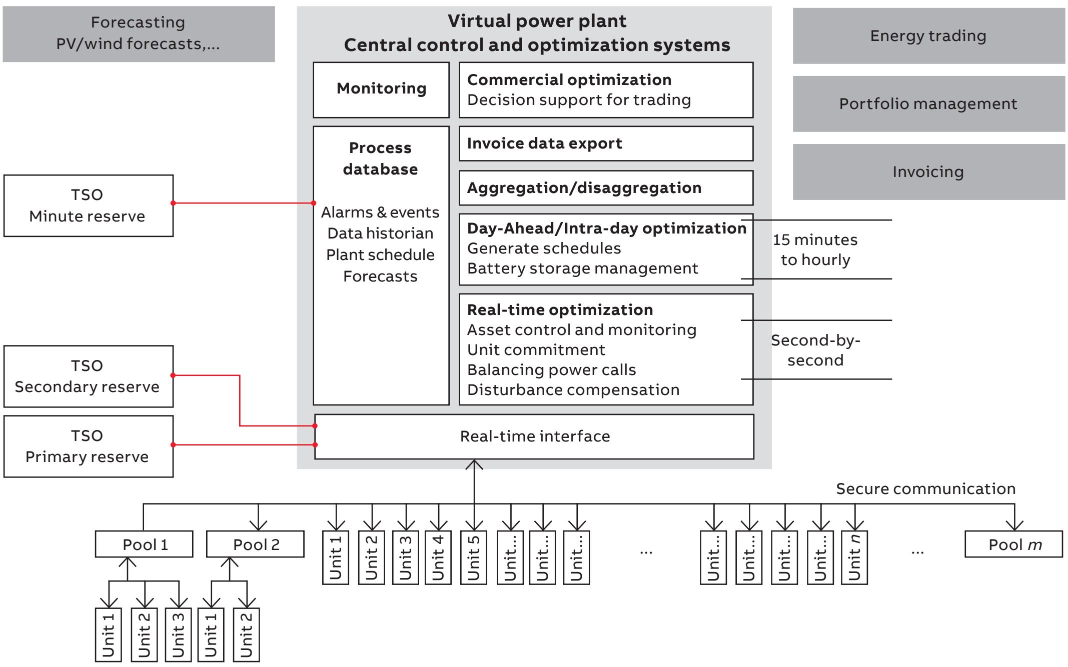
02 VPP control and optimization system modules



## Use cases

**1. Integrating 4,500 units in eight countries**
It has taken Next Kraftwerke just eight years to grow from a modest start-up to one of the biggest virtual power pool operators in Europe, probably the world.

Based in Germany, where renewable energy now counts for more than a third of the country's power generation, Next Kraftwerke´s virtual power pool links more than 4,500 producing and consuming units across eight countries. The pool manages around 3,200 MW of capacity, about 97 percent of which is from renewable sources. The smallest unit generates a few kilowatts of solar power, the largest - a biomass plant - produces 20 MW.

Thanks to the flexibility of the control and optimization system, Next Kraftwerke was able to grow from a pool of 20 units to 2,800 in its first three years. As all hardware and software additions were hot-swappable, new customers and generating units could be added continually without interrupting operations.

The solution is a win-win-win for the three main parties concerned: the VPP operator, the transmission system operators responsible for the grids, and the thousands of small and medium-size producers connected to the virtual power pool and energy market.

**2. Managing multiple municipal energy sources**
Stadtwerke Trier is a municipal energy company for the city and surrounding area of Trier, Germany. It supplies electricity, gas, drinking water and district heating to the municipality, treats wastewater and operates the public transport system.

The utility generates electricity from a diverse range of sources: wind power, solar photovoltaic, biomass, combined heat and power (both large-scale conventional and micro CHP). Its energy network includes battery storage and electric vehicle chargers, and is set to include a 300 MW pumped storage plant by 2020.

With such a high proportion of intermittent renewables in its energy system, Stadtwerke Trier required a smart energy management system to balance production with consumption and reduce the amount and cost of balancing the power it buys.

The solution optimizes production, balances it with consumption and is equipped with weather and load forecasting tools and intra-day trading functionality. It has the scalability and flexibility to seamlessly integrate new generation units, storage devices and vehicle charging stations without disruption to operations.

Thanks to its energy management system and the use of digitalization to integrate and manage municipal assets, Trier has become a recognized leader in smart city development.

**3. Making a Caribbean energy system fossil-fuel free**
The Caribbean island of Aruba has a population of 103,000 and a thriving tourism industry of 1.5 million visitors per year.

WEB Aruba, the public utility responsible for supplying the island with reliable power and clean drinking water, has a generating capacity of 134 MW, which comes from thermal (fuel oil), wind and solar photovoltaic plants.

As part of its long-term ambition to become fuel-oil free, WEB Aruba intends to generate half its annual energy from renewables and the other half from alternative fuels by 2020.

Given the volatility and intermittency of wind and solar power, it is vital for the island's grid stability and supply reliability that production is balanced with consumption.

WEB Aruba selected a partner with extensive microgrid experience and a complete microgrid portfolio to provide a control and optimization solution that would allow it to meet its fuel-free target.

The solution enables the grid to maximize its use of renewables and minimize its dependence on fuel oil. Other features include day-ahead optimization based on weather and load forecasts, real-time optimization to balance fluctuations in supply and demand, and dynamic load shedding to ensure grid stability.

Watch the video

**4. Reducing industry energy costs by 5-10%**
Energy-intensive industries like cement, steel and pulp and paper are cutting their energy costs by 5-10 percent, thanks to virtual power pool solutions.

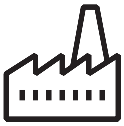
Many large industrial plants have their own power generation units - often a combination of conventional and renewable sources - as well as heat production and energy storage devices.

Through a combination of production planning, energy management and energy trading they can minimize energy costs and maximize energy revenues without impacting production targets or delivery schedules.

This entails coordinating onsite power and heat generation with the supply needs of the production process and, if the site is connected to the grid, dynamically optimizing energy consumption in response to price signals and availability indicators.

Using weather and load forecasting and day-ahead and intra-day planning, production can be increased when energy prices are lowest and decreased when they are highest. Alternatively, surplus energy can be generated and traded when prices are most favorable.

Two installations, one at a steel plant in Italy and another at a pulp and paper mill in Sweden, have already demonstrated reductions in energy costs of up to 10 percent, thanks to smart energy management and production planning.



**5. Optimizing a multi-unit power plant**
Multi-unit power plants can also operate their units as a virtual power pool to optimize overall plant performance.

One plant that successfully illustrates this application is the 6 x 500 MW Jänschwalde coal-fired power plant in Germany.

The control and optimization system enables the units to operate as a pool so that the plant can react efficiently and flexibly to market requirements. The ability to depart from base load operation and adjust unit production to market needs minimizes fuel consumption and carbon dioxide emissions, thus maximizing plant profitability.

All five of these use cases are ABB solutions.

## Conclusion

As power networks become increasingly dependent on renewables and distributed energy systems, the need to control and optimize those systems reliably and profitably is becoming a priority.

Virtual power plants and virtual power pools are an efficient and effective solution for many applications - small-scale producers, microgrids and munipal energy systems, large-scale energy-intensive industries, and multi-unit conventional power plants.

They are a proven means to turn the potentially disrupting effects of multi-source distributed power generation into an efficient and profitable business model.

## About the authors

Sleman Saliba
Business Development
ABB Power Generation & Water

Marc Antoine
Global Product Manager, Power Generation Service
ABB Power Generation & Water

Joerg Orth
Head of Competence Center, Optimization
ABB Power Generation & Water

**abb.com/symphonyplus**
**abb.com/powergeneration**
**abb.com/water**



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