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# ВИРТУАЛЬНЫЕ ЭЛЕКТРОСТАНЦИИ КАК НОВЫЙ ЭТАП ТОПЛИВНО-ЭНЕРГЕТИЧЕСКОГО КОМПЛЕКСА

**Москаленко Павел Анатольевич,**
Студент 532 группы Санкт-Петербургского государственного университета промышленных технологий и дизайна. Высшая школа технологии и энергетики, Санкт-Петербург, ул. Ивана Черных, 4

**Слюта Марина Олеговна,**
Преподаватель кафедры ИИТСУ Санкт-Петербургского государственного университета промышленных технологий и дизайна. Высшая школа технологии и энергетики, Санкт-Петербург, ул. Ивана Черных, 4.

**Максимов Яков Вячеславович,**
Студент 523 группы Санкт-Петербургского государственного университета промышленных технологий и дизайна. Высшая школа технологии и энергетики, Санкт-Петербург, ул. Ивана Черных, 4

**Габдуллин Эльдар Хайдарович,**
Студент 532 группы Санкт-Петербургского государственного университета промышленных технологий и дизайна. Высшая школа технологии и энергетики, Санкт-Петербург, ул. Ивана Черных, 4

**Аннотация**

В настоящее время сформирована тенденция на внедрение различных современных технологий в стратегически важные отрасли. Одним из приоритетных направлений является топливно-энергетический комплекс. С каждым годом человечество потребляет всё больше электроэнергии. Для более эффективной работы значительного количества электростанций было принято решение внедрить виртуальные электростанции. Положительный эффект, полученный от внедрения данных технологий, окажет влияние не только на топливно-энергетический комплекс, но и на другие отрасли экономики.

**Ключевые слова:** электроэнергия, виртуальная электростанция, энергетика, ресурсы, аккумулятор энергии, генерация, производство.

# VIRTUAL POWER PLANTS AS A NEW STAGE OF THE FUEL AND ENERGY COMPLEX

**Pavel A. Moskalenko,**
Student of group 532 of St. Petersburg State University of Industrial Technologies and Design. Higher School of Technology and Energy, St. Petersburg, st. Ivan Chernykh, 4

**Marina O. Slyuta,**
Lecturer at the Department of IITSU, St. Petersburg State University of Industrial Technologies and Design. Higher School of Technology and Energy, St. Petersburg, st. Ivan Chernykh, 4.

**Yakov V. Maksimov**
Student of group 523 of St. Petersburg State University of Industrial Technologies and Design. Higher School of Technology and Energy, St. Petersburg, st. Ivan Chernykh, 4

**Eldar K. Gabdullin**
Student of group 532 of St. Petersburg State University of Industrial Technologies and Design. Higher School of Technology and Energy, St. Petersburg, st. Ivan Chernykh, 4

ABSTRACT

At the present time, the trend is formed for the introduction of various modern technologies in strategically important industries. One of the priority areas is the fuel and energy complex. Every year mankind consumes more and more electricity. For more effective operation of a significant number of power plants it was decided to introduce virtual power plants. The positive effect obtained from the introduction of these technologies will have an impact not only on the fuel-energy complex, but also on other sectors of the economy.

**Keywords:** electricity, virtual power plant, energy, resources, energy storage, generation, production.

A virtual power plant (VES) is a high-tech system capable of aggregating the electricity of several generators and consumers simultaneously. In practice, a virtual power plant is a process that governs the behavior of producers and consumers. Producers can be decentralized generation facilities, solar, wind and biogas plants, small hydropower plants, etc. Consumers can be refrigeration units, air conditioners, drainage pumps, rolling mills, greenhouses, mills, electrolyzers and other similar devices that consume electricity (Fig. 1).

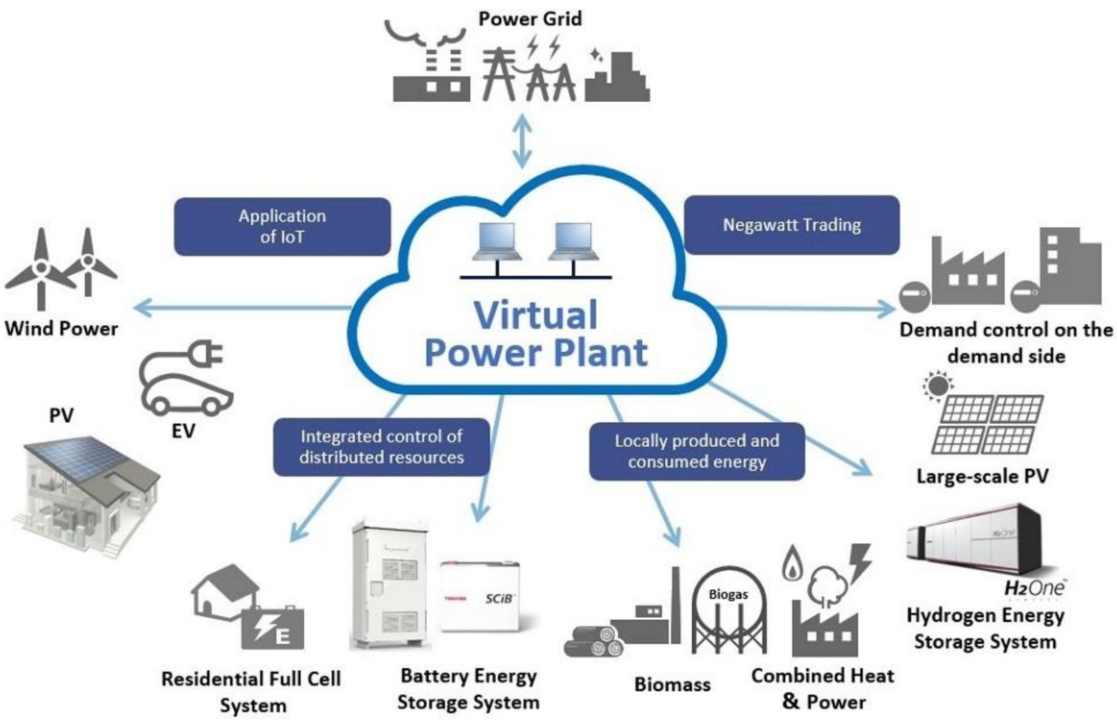


Figure 1 - Aggregation of electricity from producers to consumers [1]

The above objects of consumption and production must respond flexibly to both production and consumption of electrical energy. VPP does not interfere with the production process itself, in particular, at the grinding stage at a cement plant, 3-5 MW can be released without interrupting production, and from 5 to 30 MW at all in arc furnaces at a steel plant. Therefore, WES regulates installations, accompanies and controls the system both during production and during consumption at the peak of permissible loads.

For the stable operation of wind farms, a smart infrastructure is required, including smart systems for measuring electricity production and consumption, communication tools such as using the Internet for communication, and special software that balances available sources of electricity and softens peak loads in the system.

Now a lot of time is devoted to distributed generation. Since the use of the described sources during peak demand is possible locally, the question arises why these same sources cannot be used to produce additional energy during off-peak hours. Energy previously aggregated from various sources can be placed on the energy market and sold at market prices. It turns out that the virtual power plant provides an opportunity to centralize the distributed generation of production, which in turn gives it more weight in the market. Considering this possibility from the point of view of a single national energy system, all sources of generation are combined and streamlined, which, in turn, ensures stability.

A VPP can act as a power grid stabilizer, since at any time it has information about the possibility of discharging the power of each of the consumers connected to the grid, which helps it to receive a signal from the regulator. It helps to smooth out the overall peak load plan and stabilize the network by controlling the consumption of each consumer [1].

When developing a “smart power plant”, control methods and technologies must be undertaken to ensure error-free and productive operation of process equipment. Given the current requirements for speed of action, more information and load, as well as opportunities for quality improvement, it is necessary to apply intelligent control methods and systems.

Intelligent control of production processes at the station includes: (ссылка) automatic control of the technical condition and diagnostics of installations;

− automatic recording of the operating time of all equipment units and automatic planning of repair work.

Intelligent business process management at the station includes:

automatic creation of technical and economic reports;

− automatic creation of primary documents.

An intelligent security system implies a modern solution for protecting facilities and information systems of a power plant from unauthorized external and internal access. This system includes:

intellectual control of physical access for vehicles and personnel;

− intelligent cybersecurity of the plant.

From a formal point of view, power plant operation models can be divided into the following models: (4)

1. Aggregator model: an independent energy service organization (aggregator) appears on the market, which is the operator of a virtual power plant. It constantly connects consumers to itself, and at the same time, participants in "consumption management" programs receive remuneration, which directly depends on the conditions of the chosen market network operator.

2. Traditional model or electricity distribution company. An energy market organization (for example, an electricity importer) creates an energy network that operates several decentralized production capacities and flexible capacities for its customers.

3. The consumer-oriented model. Consumers independently integrate VPP technology to meet their needs. In this case, the power plant is operated solely for the control and monitoring of its own consumption. For example, Wal-Mart uses these systems to control the energy consumption of all types of appliances in its stores: refrigerators, self-service checkouts, lights, and so on. Once the system finds an appliance that is consuming too much power, it notifies the store manager for further action.

In fact, a single final model for the operation of a virtual power plant has not yet been created, since it directly depends on the dynamics of the energy market and on who and for what purpose wants to introduce a virtual power plant into the system. A virtual power plant can be operated by any grid company, any VPP operator, a group of distribution companies, or a single organization and a consumer or a group of consumers.

One of the main advantages of a virtual power plant is that it stores information about the generation or demand available in the zone connected to the plant in near real time. It is important to note that the system itself performs calculations and finds the most efficient resource at a given time, which allows it to be flexible in using a given generation or unused consumer power.

Another advantage of the virtual power plant is that the architecture of the VPP is very flexible and can take many forms. It can be installed both vertically and horizontally. It has the appearance of working as a standalone device or as part of a larger wind farm system. One of the main advantages is that several power plants can be connected to a common power grid.

The main goal of the VPP is to create a win-win situation in which all participants in the energy system, including customers, benefit.

Understanding this system is actually not difficult, although it is difficult to use. The system is controlled by a computer platform, which is the core of the entire network. It is here that the data of consumers and energy producers that are part of the network is stored, maintained and processed, sent.

Generator data is the given power of energy sources, their current performance, technical condition, operating time, owner data, etc. Consumer data includes information about the operation of electrical appliances, periods of peak electricity consumption, consumer habits, wishes for saving resources, etc. Supply and demand must find common ground, which is done through software. If there is an excess, it is redirected to the storage system, where it accumulates, and if there is a shortage, it is compensated by the accumulated energy. It is also possible to intervene in household energy consumption to balance the system without taking energy from storage systems [2,167].

The system becomes even more complex when the consumer is also the producer, and in the case of virtual power plants, this is a common practice. In this case, the system must take into account and calculate not only the energy needs of the household, but also the extent to which its own consumption can cover these needs. It also takes into account what is currently most profitable from a financial point of view: to cover the needs through own production or better to store energy in order to sell it to the grid and use the surplus production on the market. All these actions are calculated for each consumer - the most equal and favorable conditions are created for everyone.

The sale and exchange of energy is also carried out through the platform - prices are analyzed at different times of the day and from different sources, and the most favorable time is chosen for energy storage - when electricity is cheaper, and for sale - when electricity is more expensive.

All these processes - production, consumption, storage, sale, purchase and exchange of energy - occur simultaneously, and the role of the virtual think tank is to balance all this in real time.

The VPP collects a wealth of information about available capacity, current and forecast demand, user load avoidance, and the desired load plan (usually by the network operator). All collected information is processed almost in real time. WES has information about the most efficient producer and/or user at any time, taking into account the current market situation and weather forecast, which is important for renewable energy installations (Fig. 2).

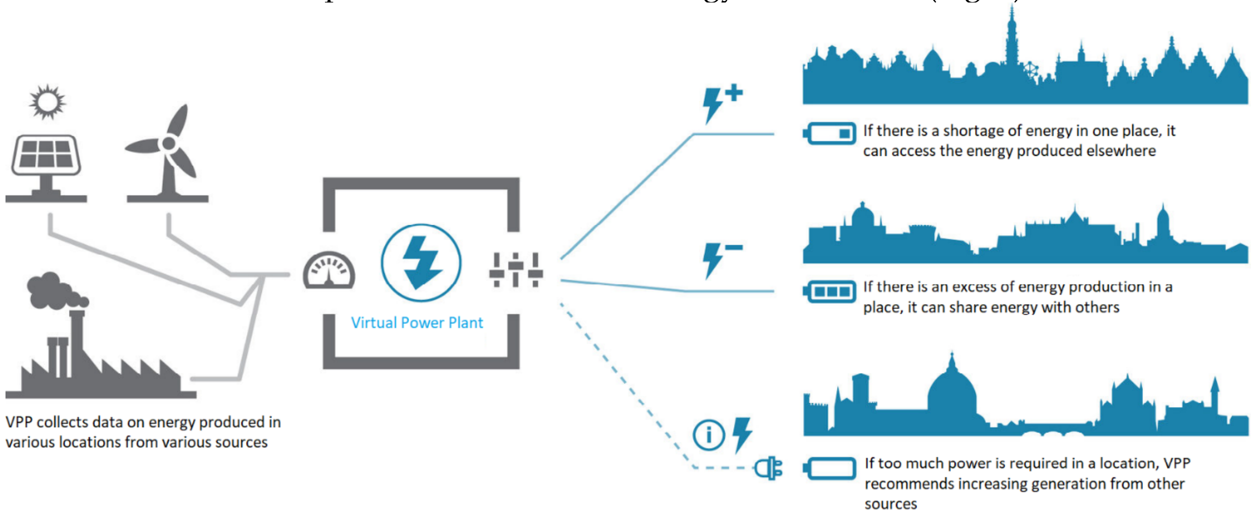


Figure 2 - The principle of operation of the wind farm [4]

On the dashboard, the map shows all available capacities (factories, consumers, etc.), the diagram shows the general plan of the actual load, the available capacities and the desired load plan. The system automatically calculates the efficiency of each facility, and also deducts the total costs and receives the final profit.

As for the direct use of the VPP concept by energy distribution companies, the experience of Elektro Ljubljana (Slovenia) in implementing and studying such a project is interesting. VPP technology was transferred by cyberGRID (Austria). The main goals set by Electro Ljubljana were to reduce the load on the energy system and regulate decentralized power generation. If a distribution company can optimize electricity flows, it can minimize imbalance costs or trade the released electricity on the market.

Elektro Ljubljana is the largest electricity distributor in Slovenia with over 350,000 consumers.

“Through the introduction of smart meters in the operation of wind farms, a solid foundation is created for providing advanced services to consumers, which has a significant impact on the overall optimization of the energy value chain,” says the head of the company.

The wind farm of Elektro Ljubljana has been fully operating on a commercial basis since 2011 and includes wind farm capacity for tertiary reserve purposes. This has since been successfully achieved: 100% availability of positive and negative peak power and more than 63 MW of connected power. Elektro Ljubljana's customers in the wind farm project are steel, foundries, paper mills, shopping malls, glass and ceramic manufacturers, and the chemical industry.

According to Reinhard Korsitzke, director and founder of cyberGRID (Austria), virtual power plants are the basis for creating the energy system of the future and can operate on a gigawatt scale at the level of utilities and grid companies.

Advanced IT systems enable utilities to efficiently manage the ever-increasing number of unpredictable renewable energy installations, energy storage and flexible consumption. “The aggregation of various decentralized generating resources (including consumption) can replace or support the operation of traditional peak power plants quite efficiently,” according to the director of cyberGRID.

The development of virtual power plants is strongly hindered by legislation. In many countries, the sale of electricity to consumers is allowed only to the state, which buys it from private producers. Therefore, it is impossible to create a private distributed network without the participation of the state.

If you look at the Russian experience, you can see slow but steady progress. In 2017, the Government of the Russian Federation adopted the Action Plan to Stimulate the Development of Generating Facilities Based on Renewable Energy Sources with an Installed Capacity of 15 kW or Less, which provides for the full use of small-scale renewable energy sources, such as private wind turbines and solar panels. A special feed-in tariff that would allow owners of domestic power plants to sell surplus electricity to the state has not yet been introduced, but the bill is under consideration in the Duma and there is a good chance that it will be passed [4].

Another disadvantage of virtual power plants is the high cost of implementation, which is difficult to predict. Alternative power plants are needed, producing expensive electricity, which, in turn, should be subsidized. IoT sensors must be installed and synchronized, which, in turn, implies high requirements for the quality of the Internet connection (in advanced countries, however, this problem will be solved with the introduction of 5G networks). Requires sophisticated software and ongoing support. This brings back to the question of the need for support from the government or other large investor at the initial stage of creating a wind farm [3].

In conclusion, it is necessary to recall some of the benefits that various market participants can receive from the introduction of VPP:

1. Distribution and transmission networks:

− Increasing the transparency of decentralized generation facilities and control over their activities in the market.

− Reduction of consumption peaks in the network by regulating the load of consumers.

− Reducing the risk of network outages.

− Reducing investment in the energy system.

− Better management of inflexible and discontinuous distributed generation and renewable energy sources.

2. Utilities:

− Better control over business risks.

− A new level of customer relations, the ability to offer new consumption management programs.

− Access to cheaper resources.

− Increasing the reliability of supplies.

− Improved invoicing.

3. Owners of distributed generation and consumption:

− Receiving payments for flexible capacity, for participation in consumption management programs.

− Opportunity to fully participate in the market as a producer and sell electricity on the market.

− Increase in the value of the object.

− More efficient use of electricity.

− Savings by reducing electricity consumption (if flexible capacities are available).

4. regulator or system operator:

− Balancing and optimization of the market.

− Opening the market for small participants.

− Obtaining additional flexible capacities.

− Integration of decentralized generation and RES installations into the system while maintaining system stability.

− Achieving the country's CO2 reduction targets.

− Creation of new jobs and reduction of general unemployment.

VPP can also be a solution for providing electricity to remote and isolated areas. For example, areas with a concentration of small independent power producers and distributed generators, industrial and commercial consumers and renewable energy sources can become fully or partially self-sufficient and optimize the intermittent generation of these facilities [4].

The development of virtual power plants will continue actively, and outdated legislation will be gradually repealed around the world. In the near future, a completely new electricity market will emerge, closely related to virtual power plants, intelligent distribution of energy reserves, and optimization of energy consumption by all market participants.

Well-established wind farms will help increase the share of alternative energy sources in the world, which will help improve the environmental situation in the world and save natural resources. In addition, the energy infrastructure will completely change: instead of huge power plants and a network of lines leading to consumers, we will get a decentralized network. This means that the future energy system of mankind will be less vulnerable to natural disasters. For example, in Japan, where the share of renewable energy sources is small (about 17%), VPP is of great interest in this context. Decentralized energy flows will help the Japanese avoid massive power outages in the event of an earthquake or typhoon [5].

In addition, a decentralized network of electricity producers and consumers can create more charging stations for electric vehicles and thus stimulate the sector.

Also, one should not forget that the less humanity depends on the energy generators of the superpower, the less the likelihood of major man-made disasters. In this way, little by little, our planet is turning into a better, more comfortable and safer place to live. And everyone benefits from this.

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