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MANAGEMENT OF POWER GENERATION BY A DISTRIBUTED GENERATION MICRO GRID

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Abastract

The paper considers issues related to the management of the efficient operation of distributed generation and microgrid. It is also proposed to control a distributed generation microgrid, where the generating device is a fleet of hybrid wind-solar energy devices, based on taking into account consumer demand and supply for the generated electric power. At the same time, it is said that such accounting is carried out using a virtual power plant. A rational scheme for integrating a microgrid into a distribution network is proposed. It has been established that when connecting a distributed generation micronet to a distribution network, one of the main tasks that must be solved for each hour of the billing period is the distribution of loads between generating capacities based on consumer demand and supply. An algorithm for solving this problem is proposed.

Keywords: *Distributed generation, microgrid, demand, supply, control, DC bus, distribution network, consumer, algorithm*

Introduction

Today, there is a trend in the development of the electric power industry in the world associated with an increase not only in the scale of electricity production at traditional large power plants, but also in the share of distributed generation and micro grids based on renewable energy sources. The development of distributed generation and microgrid are modern concepts in the field of electrical engineering that play an important role in ensuring energy independence and sustainability of power supply systems. The main motivation for the development of distributed generation is to stabilize the operation of the power system. The second motivation is to provide power for a balancing market. These advantages for the energy system should also be a motivation for consumers (Malkov A.). The motivation may be the desire to participate in these programs and provide load management (in particular, this is the shutdown of cooling/heating equipment). Or – the desire to generate even more power (in particular, diesel generation). This system should work as a cycle, and some participants should motivate others in this system. These motivations for the development of distributed generation are the basis for the management of distributed generation and the microgrid (Rustamov N.T., Babakhan Sh.A., Orysbaev S.A., 2020).

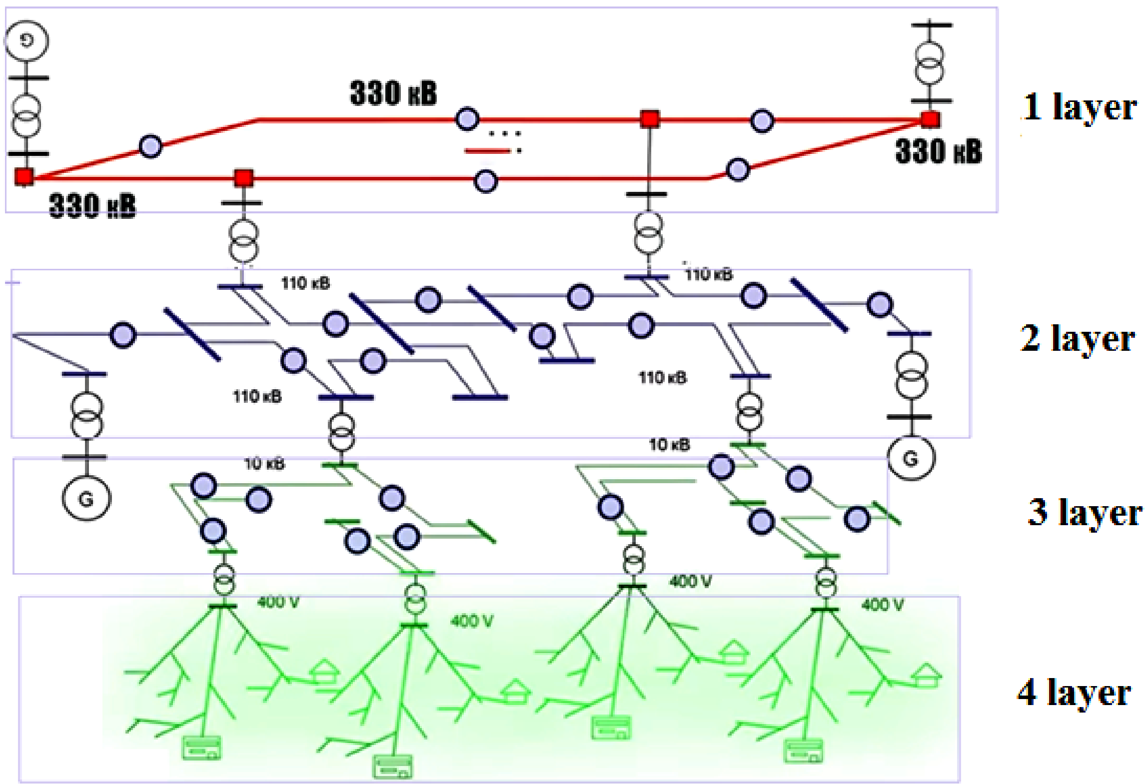
As we know, distributed generation differs from traditional centralized power generation systems in that energy production is carried out in the vicinity of consumption, and not at remote power plants. And microgrids, in turn, represent a distributed generation park that can operate independently or conjugately in a microgrip system that can interact with a centralized network (Chindyaskin V.I., Grinko D.V., 2014).

The main task of modern electrical systems is the constant balancing of supply and demand, flexible network management and ensuring an optimal level of energy efficiency. These problems also appear in distributed generation systems that provide electricity in the vicinity of the consumer. But here it should also be noted that connecting distributed generation, in order to transfer personal generated electric energy to a common distribution network, creates an additional difficulty associated with a violation of the power balance in the common network. In this case, the dispatching and automatic control of the electric power system becomes more complicated. Such a situation may slow down the development of distributed generation and microgrid. All this requires the development of a new algorithmic model for controlling the distribution of loads between generating units of a distributed generation microgrid. The solution to this problem is considered to be in demand.

The aim of the work is to develop a control algorithm based on the control of supply and demand for electric power generated by a microgrid distributed network.

The solution method. A feature of the operation of any distributed generation system is the single-stage production and consumption of electric energy. This requires equality of energy generated by a distributed generation park combined into a micro grid (Rustamov N.T., Egamberdiev B.E., Meirbekova O.D., Babakhan Sh., 2023).

Figure 1. *The structure of the traditional energy system*



Violation of this equality leads to a change in the parameters of the microgrid in voltage and frequency, and with large deviations – to a loss of dynamic stability and disruption of the normal functioning of the microgrid and disruption of consumer power supply (Obukhov S.G., Plotnikov I.A., 2012).

If we take into account the construction of modern electric power systems and networks, it will be understandable the problems that arise when connecting a distributed generation microgrid, where the generating unit is a wind-solar energy system.

As you know, the traditional power system and networks are designed in the form of a layer. The top layer is called generation and transport. In this layer, large amounts of electricity are generated at power plants and transmitted to node substations. All power plants generating electric energy of this layer are interconnected, by banding high-voltage transmission lines. In this layer, the synchronization of electricity generated at various power plants is carried out (Fig.1).

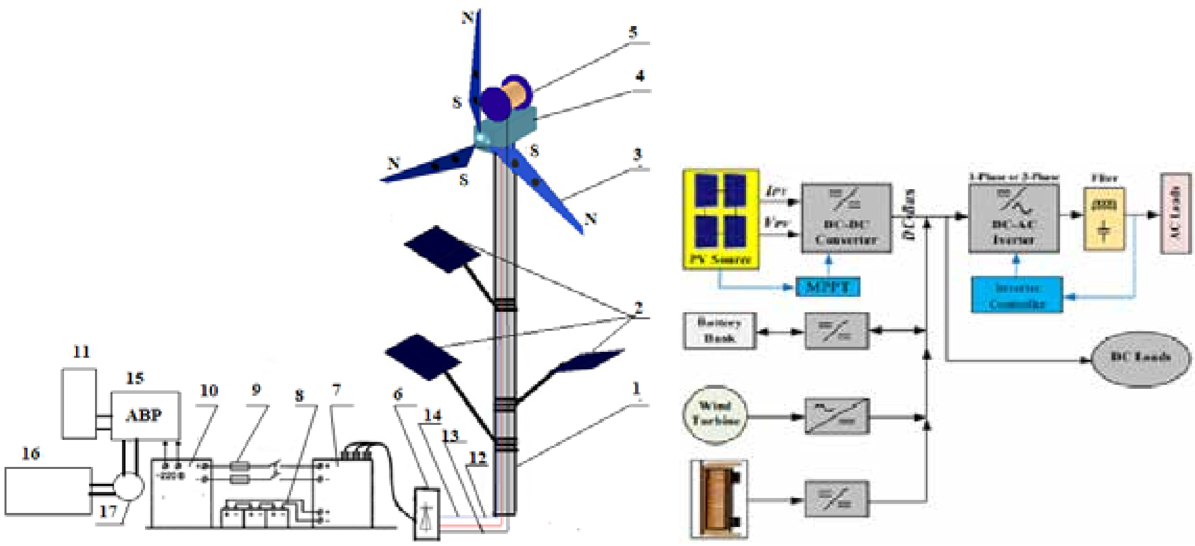
Further, through the node substations, the generated electricity is transported to the next layer of the power system. It is at these node substations that there are bridges that connect the upper layer of the power system with the next, lower layer. These bridges consist of transformers. It should be noted that these processes are also managed by the dispatchers of the system operator.

The next 2 layer is a layer of high electrical energy. In this layer, the generation of active and reactive energy is regulated, changing the operating modes of the station's generators. This layer is the main layer of the entire energy system. Then the layers go down. The next 3 layer is the average regional distribution layer or 110–220 kW network. Through bridges, electrical energy is transferred to separate looped power grids. There are even sources of electricity in this layer. These sources of energy can be small local thermal power plants, hydroelectric power plants, even distributed generation micro grids based on renewable energy sources.

They generate electricity for the third layer. In this case, an important condition is to push electrical energy from the top down, not from the bottom up. Because high-power electrical energy is generated on the upper layer. In this layer we see the looped islands of the network. These networks are called regional distribution networks. Here, each island has its own dispatch service, which manages all the energy processes taking place on the island. This is where the ring layers end.

Figure 2. *Of the distributed generation of the generating wind-solar installation a and its electrical diagram*

a) b)



Now let's look at the structure of a distributed generation micronetwork. We have chosen a hybrid wind power plant developed by us for distributed generation based on wind and solar energy, shown in (Fig. 2).

The generating unit consists of a mast 1, solar panels 2, magnetic blades 3, a generator 4, an induction coil 5, a rectifier 6, a controller 7, batteries 8, a switch 9, an inverter 10, a bypass 15, an electric energy meter and a distribution network 1 hybrid wind power plant operates as follows (Fig.2). Under the influence of wind, the magnetic blades 3 generate an electric current 13 using a generator 4, and create a magnetic field around themselves, which, crossing the windings of the induction coil, generates an induction current 12. The current generated by the solar panels 14, the electric current from the generator 13 and the induction current 9 are supplied to the rectifier 6.

The rectified current is transmitted through the controller 7 to the batteries 8 and through the switch 9 these currents are sent to the inverter 10. Electricity is supplied from the inverter 10 to consumers 11. Wind power installations with batteries and switching with the grid 15 Automatic reserve input (bypass) allows you to switch the power supply of the object in the absence of wind and full discharge of batteries to the distribution grid 16 through the counter 17. The same circuit can be used vice versa as a backup power supply. In this case, the automatic input of the reserve switches you to the batteries of wind power plants when power is lost from the distribution grid.

Based on this distributed generation, we will design the microgrid shown in (Fig. 3).

Figure 3. *A micro grid based on a distributed generation park powered by renewable energy sources*

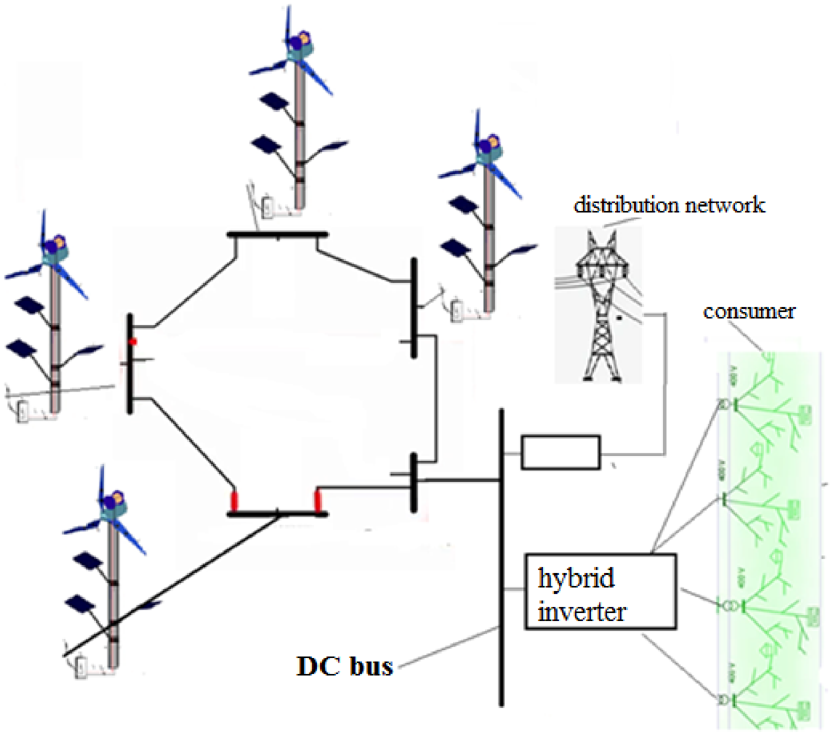
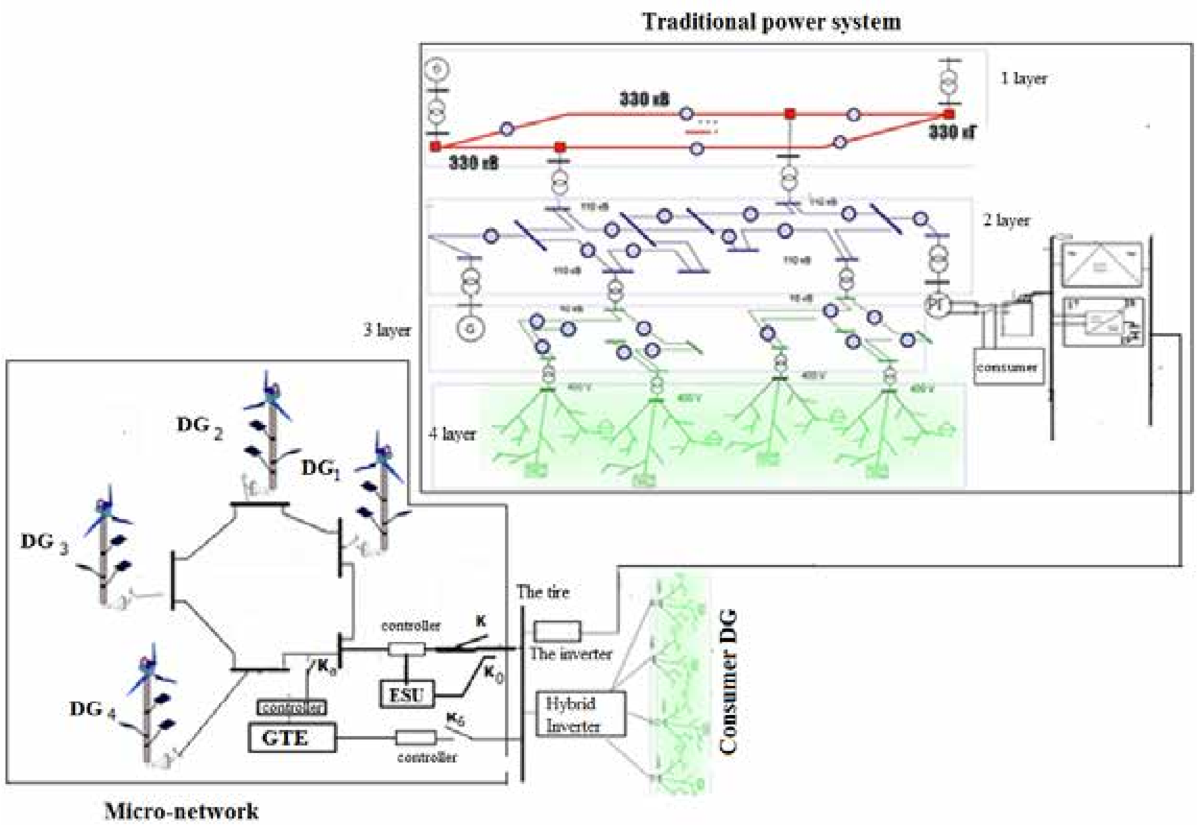


Figure 4 shows the connection of a distributed generation microgrid to a common distribution network (layer 3) via a private bus. At the same time, the equality of generated and consumed electricity in a distributed generation system is maintained continuously in time (Rustamov N.T., Babakhan Sh.A., Kaharman Ə.K. 2023; J. Rocabert, A. Luna, F. Blaabjerg h gp. 2012; J.M. Guerrero, J.C. Vasquez, J. Matas h gp. 2011).

There are two possible ways to maintain the continuous equality of generated and consumed electricity in distributed generation micro grids powered by renewable energy sources. The first method consists in constant monitoring of electric energy consumption and proper regulation of the power of the generated installations in order to constantly maintain equality between the two aforementioned capacities (J.M. Carrasco, L.G. Franquelo, J.T. Bialasiewicz h gp. 2006). The second method is to include a battery in the microgrid, which saves electricity with reduced consumption and, after conversion, supplies it to the microgrid when a certain consumption level is exceeded (Nassim Rustamov, Shokhrukh Babakhan, Naci Genc, Adylkhan Kibishov, Oksana Meirbekov. 2023; URL: http://www.alterenergy.info/interesting-facts/123-the-distributedgeneration). This process is controlled by a virtual power plant.

Figure 4. *Connecting the microgrid of the distributed generation park to the general distribution network via a high-frequency bus*



Currently, the Smart Grid concept is developing in the world, which involves the transition from generating electricity centrally at large power plants and transferring it to consumers over distances of tens and hundreds of kilometers to generating it near consumers (farms, residential buildings, etc.) from renewable sources (wind, solar battery). A feature of alternative sources is the uneven and uncontrollable intensity of the energy flow over time, as a rule, which does not coincide with the intensity required by the consumer. A battery is used to coordinate the generated and consumed energy flows.

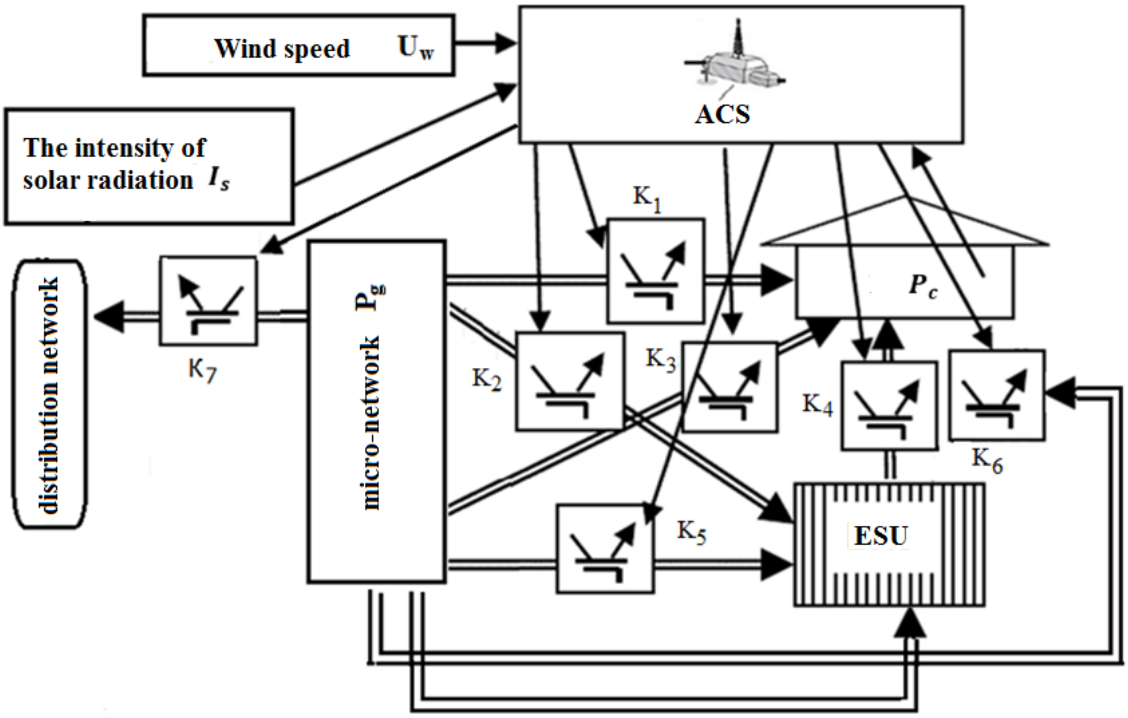
There is an obvious need to control the energy flows between the wind generator, solar battery, accumulator and consumer, ensuring reliable and uninterrupted power consumption, regardless of the state of external flows – wind and sun. Modern electronics are able to provide switching and conversion of electric power parameters, but an algorithm is needed to control it.

The object under study (Fig. 1) is a power consumer localized in space, connected electrically through switches or converters ($K_1 \div \div K_6$) K_7 – the key connects a micro-grid to a distribution network, a solar battery, a wind generator, an energy storage unit and a backup source, which can be a non-renewable energy source – a diesel generator or a centralized power line power transmission lines. $\mathbf{U_w}$ – is the wind speed, $\mathbf{I_s}$ – is the intensity of the sun, $\mathbf{P_c}$ – is the power consumption of the electric meters, $\mathbf{P_g}$ – is the power generated by the microgrid

When operating a distributed generation system, the control device compares the energy flows from sources external to the consumer with the power required by the consumer. Depending on the values of these flows, the consumer is connected to one or another energy source.

Below (Fig. 6) is a block diagram implementing the operation algorithm of the control device. The diagram shows: R_{wg} – power of the wind generator; R_{bp} – power of the solar battery; R_{es} – power of the energy storage unit; P_C – load power R_d – power of the microset, U_w – wind speed, I_s – solar radiation intensity.

Figure 5. *Microgrid management system from the distributed generation park ⇒ –energy, → – information and management*



η. If there is no wind and sun, but the energy storage unit is charged sufficiently to provide the necessary power to the consumer (situation 1 in the block diagram), the control device gives the command to turn on K_4, which supplies energy to the consumer from the energy storage unit. K_4 is an autonomous inverter that converts the voltage of the energy storage unit into an alternating voltage of standard frequency. $R_{wg} = 0$, $R_{bp} = 0$, $R_d = 0$ $R_{es} > P_C$ in this case we denote by the letter n

η_1. If there is no wind and the intensity of solar radiation is such that the solar battery cannot provide the power needed by the consumer (situation 2 in the block diagram), the short circuit and K_4 are switched on so that the consumer is powered by a solar battery and an energy storage unit. The K_3 device ensures the operation of the solar battery at the maximum possible efficiency. $R_{wg} = 0$, $R_{bp} < P_C$, $R_{es} > P_C - R_{bp}$ in this case we denote by the letter n_1

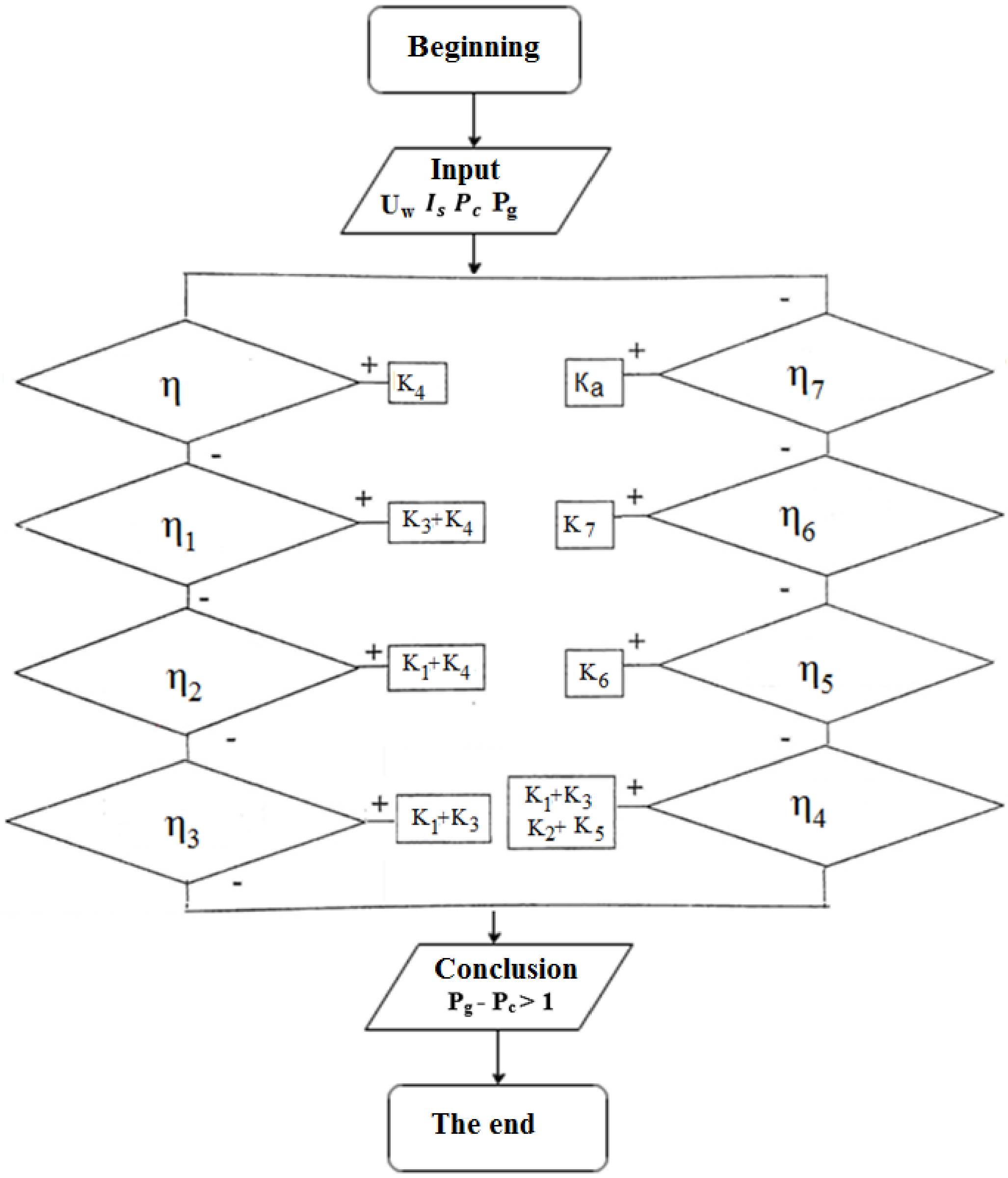
η_2. If there is no sun and the wind speed is such that the wind generator cannot provide the power needed by the consumer (situation 3 in the block diagram), K_1 and K_4 are switched on so that the consumer is powered by the wind generator and the energy storage unit. The K_1 device converts the voltage of the wind generator to the value required by the consumer. $R_{wg} < P_C$, $R_{bp} = 0$, $R_{es} > P_C - R_{wg}$ in this case we denote by the letter n_2

η_3. If the wind speed and intensity of solar radiation are such that the wind generator and solar battery individually cannot provide power to the consumer (situation 4 in the block diagram), the K_1 and K_3 devices work so that the latter is powered simultaneously from both sources. The rolled-up devices coordinate the parallel operation of the source so that energy does not flow from one to the other. $R_{wg} < P_C$, $R_{bp} < P_C$, $R_{wg} + R_{bp} > P_C$ In this case, we denote the letter n_3

η_4. If the wind speed and intensity of solar radiation are such that the wind generator and solar battery generate more power than the power of the consumer (situation 5 in the block diagram), the devices K_1, K_2, K_3 and K_5 are switched on so as to provide energy to the consumer, and the excess energy goes to charge the energy storage unit. These devices provide an energetically rational mode of generators and an energy storage unit. $R_{wg} + R_{bp} > P_C$ In this case, we denote the letter n_4

η_5. If the wind speed and solar radiation do not provide power to the consumer, and the energy storage unit is discharged (situation 6 in the block diagram), a command is given to turn on the gas turbine engine into the K_6 microgrid bus. $R_{wg} = 0$, $R_{bp} = 0$, $R_{es} = 0$ or $< P_C$ in this case we denote by the letter n_5

Figure 6. Block diagram of the distributed generation control program



η_6. If the wind speed and solar radiation provide the power output of the electrical energy needed by the consumer, and the energy storage unit is filled (situation 7 in the block diagram), the devices K_7 are turned on. $R_{wg} > P_C$, $R_{bp} > P_C$, $R_{es} > P_C$ in this case we denote by the letter n_6

η_7. If the wind speed is high, in that case the wind generator will not work, but instead the gas turbine engine will be connected to the microgrid (situation 8 in the block diagram), the device K_a is turned on. $R_{wg} = 0$, $R_{bp} > P_C$, $R_{es} > P_C$ in this case we denote the letter n_7

When implementing the described algorithm, it is necessary to combine the dynamic parameters of electric power generators with the operating period of the control device: if, for example, a decrease in the power of the solar battery occurs before the control device detects and compensates for it, the consumer will be de-energized or forced to reduce the power consumption.

Let's assume that each distributed generation under normal conditions will develop about 3 kW/hour of energy, there are 4 distributed generation devices on the microset, we get a total of 12 kW/hour of electric energy per hour. Let's say consumers require 10 kW/hour of electrical energy, the lagging 2 kW/hour of energy we will send to the energy storage unit, and if the energy storage unit is full, then we will send the rest of the energy to the distribution network.

Conclusions

Summarizing the work, the following conclusions can be drawn:

1. The use of distributed generation to generate electrical energy for the consumer is beneficial through a micro-network, where a distributed generation park is connected to a common DC bus.

2. In case of insufficient generation of electric energy at the request of the consumer, the optimal provision for this request is to connect a backup energy source, a gas turbine engine and an energy storage unit.

3. For effective management of the microgrid, it is of great importance to use a virtual power plant (Smart Grid)

4. The proposed block diagram of the microgrid management program ensures the stability of the balance of consumer demand for power and electricity.

5. The control device for the implementation of the algorithm must have dynamic parameters corresponding to the parameters of the generators.

6. An indispensable condition of a distributed generation microgrid is that the amount of energy generated per year should not be less than the amount of energy received by the consumer over the same period.

References

Мальков А. Тайны энергосистемы.– thewikihow.com/aleksandr-malkov

Рустамов Н. Т., Бабахан Ш. А., Орысбаев С. А. Одностадийное электроснабжение на базе ВИЭ.– Екатеринбург. Международный научно-исследовательский журнал,– Ч. 1. 2020.– № 12 (102).– С. 71–75.

Чиндяскин В. И., Гринько Д. В. Выбор оптимального решения для применения комбинированных установок на основе возобновляемых источников энергии // Известия Оренбургского государственного аграрного университета. 2014.– № 1(45).– С. 40–43.

Рустамов Н. Т., Эгамбердиев Б. Э., Меирбекова О. Д., Бабахан Ш., Гибридная система распределенной генерации энергии. European Journal of Technical and Natural Sciences – 1. 2023.– P. 37–44.

Обухов С. Г., Плотников И. А. Сравнительный анализ схем построения автономных электростанций, использующих установки возобновляемой энергетики // Журнал «Промышленная энергетика». 2012,№ 7. С. 46–51.

Абдрасилов Б. С., Мейрбеков А. Т., Рустамов Н. Т., Мейрамкулова К. С., Бабахан Ш. А. Гибридный ветрогенератор. Патент РК на полезный модель № 6142 от 11.06.2021

Рустамов Н. Т., Бабахан Ш. А., Қахарман Ә. Қ. К вопросу подключения системы распределенной генерации в общую распределительную сеть.– Фергана, Материалы международной научно-технической конференции – Ч. 1. 2023.– С. 193–196.

Control of power converters in AC microgrids / J. Rocabert, A. Luna, F. Blaabjerg h gp. // IEEE Trans. Power Electron. 2012.– № 27.– С. 4734–4749.

Hierarchical control of droop-controlled AC and DC microgrids – A general approach toward standardization / J. M. Guerrero, J. C. Vasquez, J. Matas h gp. // IEEE Trans. Ind. Electron. 2011.– № 58.– С. 158–172.

Power-electronic systems for the grid integration of renewable energy sources / J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz h gp. // IEEE Trans. Ind. Electron. 2006.– № 53.– С. 1002–1016.

Nassim Rustamov, Shokhrukh Babakhan, Naci Genc, Adylkhan Kibishov, Oksana Meirbekov. An Improved Hybrid Wind Power Plant for Small Power Generation. International Journal of Renewable Energy Research N,– Vol. 13.– No. 2. June, 2023.– P. 629–635.

Распределенная генерация электроэнергии – важное условие развития альтернативной энергетики. URL: http://www.alterenergy.info/interesting-facts/123-the-distributed-generation

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