Distributed energy technology development

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Abstract. This article presents preliminary results of work on the development of advanced technologies for the development of distributed energy. In particular, the results of the first stage of creating control algorithms in a distributed power supply network and creating a simple scheme of interaction between two consumers with their own generation sources are shown. Calculations and testing of the selected principles of interaction in the MATLAB/Simulink program showed the efficiency of the decisions made.

1. Introduction
The large-scale tasks of the technical modernization of the electric power industry in Russia require the development of new efficient and environmentally friendly distributed energy technologies that can operate in a wide range of capacities in various climatic conditions [1].

To solve these problems, new structural schemes of distributed energy systems based on advanced technologies for generating, converting and storing electricity are being developed (see figure 1). The development and debugging of systematic mathematical tools and computer programs are underway, which allows using the methods of computational experiments to model, evaluate the efficiency and optimize the parameters of distributed power systems [2, 3].

2. Energy sources in distributed energy
There are several technologies that can supply a residential or commercial property with the electricity they need. Among them are solar panels, wind generators, gas reciprocating plants and microturbines operating on gaseous hydrocarbons, micro hydroelectric power stations, and fuel cells operating on pure hydrogen or other hydrocarbons [4, 5]. These technologies are used to create distributed energy generation complexes. At the present stage of development, so far these technologies have received rather limited development due to their high cost, the lack of agreed standards for interaction with the central electric grid and the lack of a full-fledged legislative base [6].

The experience of distributed generation technologies operating shows that energy storage devices are needed for the energy complexes built on their basis. These energy storage facilities can supply the consumer with the necessary energy in case of energy supply failure from the main source of electricity. Storage devices in conjunction with power generation devices can, in addition to providing the consumer, also supply electricity to the utility network. In many countries, federal government agencies, as well as private utilities, encourage the transfer of surplus electricity by users with their own generation sources to the central network.

In recent years, the international community has placed great emphasis on the development of environmentally friendly energy sources. This gave a pulse to the development of distributed generation technologies, which led to an increase in production capacities and increased market competitiveness for both power generation devices and storage devices. In Russia, meanwhile, according to a number of
experts, the relatively low cost of electricity offered by the central electric grid is a barrier to mass adoption of distributed energy technologies.

![Network architecture of power grid with hydrogen-based energy storage system.](image)

**Figure 1.** Network architecture of power grid with hydrogen-based energy storage system.

However, one of the most promising segments, where distributed energy technologies can be actively developed in Russia, are isolated energy systems that do not have a connection to the central power grid [7]. Formally, the energy supply of these regions is carried out according to the centralized principle, with only one difference, that generation facilities have a small capacity, which increases the number of such generators. They, in turn, require constant and costly maintenance, which naturally turns the energy supply in this region into subsidized.

The implementation of distributed energy technologies and energy storage technologies takes place in conjunction with the development of advanced measuring infrastructure. The measuring infrastructure of the energy complex consists of modern electronic/digital equipment and software. These systems make it possible to obtain detailed indications about the operation of the energy complex and collect and transmit the received information to various parties [8].

The measuring infrastructure includes meters at the customer’s site, communication networks between the customer and the service provider, such as electric, gas, or water networks, as well as data reception and management systems that provide information to the service provider. Using the measuring infrastructure, utilities can manage installed devices in consumers' homes, selectively turn off energy-consuming devices (such as hot water heaters or air conditioners), thereby controlling peak consumption. In addition, utilities may in some cases remotely activate and aggregate distributed sources of energy and energy supply to increase the supply of electricity to limited parts of the electric network.

So, the key elements of distributed energy are:

1. Power generation devices.
2. Energy storage devices.
3. Measuring infrastructure.
4. Management body.
3. Requirements for design of distributed network nodes

It is necessary to form the needed voltage for the consumer inside the house/building from the Battery Pack (Battery), both with an increase in voltage (for example, to get 220 V for powering typical devices and devices) and with a decrease in voltage (for example, to get 12 V for powering LED lamps). It is necessary to connect the batteries of all network participants into a common network in such a way as to compensate for the lack of energy in some facilities, excess energy in others, which in essence is voltage management of all parts in the entire network.

It is necessary to install bi-directional energy meters between objects to account for energy production and consumption.

The work of the body ("Management") that monitors and controls the consumption of electricity for an individual house includes the following functions:

1. General dispatching and control of common network energy sources.
2. Management and control of energy generation by network participants.
3. Billing for electric energy for the network as a whole and for participants – house holdings individually.
4. Management of full or partial restriction of network electricity consumption.
5. Control of electric energy quality.
6. Accounting and budgeting of expenses for losses, operation maintenance, planned equipment change.

For the residential village, lighting control of the general village load is also added.

To obtain reliable information about the real energy consumption, intelligent DC and AC electric meters are used with the function of transmitting data via Ethernet and the ability to remotely control switching units.

In order to create a distributed energy network from the very beginning, it is necessary to start with an extremely generalized equivalent circuit that can be used to work out the principles of interaction of key elements of a distributed energy supply system. As an example, we offer two users with their own sources of energy generation and storage, which are networked and have the ability to both independently provide their own load with their own generation sources, and exchange energy with each other (figure 2). In order to explore the features of power generation and power consumption, it is proposed to create two users with a set of equipment of different nominal values, i.e. user No. 1 will have a 48V battery and the corresponding equipment, which should ensure the operability of this system and user No. 2 with a 220V battery and the equipment corresponding to this nominal.

![Figure 2. Two objects with their own generation sources.](image-url)
the entire system as a whole. With the help of this controller, the Central energy distribution controller receives information about the state of charge of energy storage devices, if they are present in this system element. It also receives information about the amount of fuel that is needed to run backup generators, information about the battery status (age, number of cycles, temperature). Up-to-date information is also transmitted by generation sources, such as the remaining engine life, the number of on/off cycles, the type of fuel, and data on combustion product emissions. All this information is necessary to assign a particular element of the system priority for the return of energy in the event of a request for energy from another element of the system.

The electrical functional diagram below shows two users, similar to figure 2. These users have a set of identical loads and their own sources of energy generation and storage. The load in households is a standard element, powered by a 220V network. The difference between these two users is that the batteries are of different voltage. For user #1, the battery voltage is 48 V, for user #2, it is 220V. Thus, for the first user standard charge controllers are required, they will allow using energy from primary energy sources (sun, fuel cell, motor generator) to charge 48 V battery, in the second case, a special charge controller is required that can charge the 220 V battery. This selection of parameters is done in order to determine all the pros and cons of these power supply schemes.

![Figure 3: Electrical functional diagram.](image-url)
The specific feature of this research and the proposed scheme of the power supply is that all elements of the system are connected by direct current lines. Also, the study of the interaction details of the elements of the storage and generation system configured for a nominal voltage of 220 V is necessary in order to create a DC power plant that could supply electric energy with a minimum number of conversions to a standard house load, which was previously powered by a 220 V AC network.

4. Preliminary results of the modeling
In order to make the necessary calculations, a simulation model was created in the MATLAB Simulink environment, where the above scheme was created using standard blocks.

During the simulation, the following conditions and parameters were set and debugged:
1. Actuation of controlled switching elements in accordance with commands from the microcontroller for controlling nodes of the distributed power system.
2. The presence of current flowing from the 48V node to the 220V node.
3. The presence of current flowing from the 220V node to the 48V node.
4. The presence of the load current of the 220V node's own consumers during the power supply from the node 48V.
5. The presence of the load current of the 48V node's own consumption during the power supply from the node 220V.
6. The value of the charge current for 220 V battery powered from DC 220 V, which is converted from the node 48V.
7. The value of the charge current for 48V battery powered by DC 48V, which is converted from the 220V node.

This is achieved by using special DC / DC converters.

Figure 5. Simulation model in the Simulink.

This model is arranged on the approach widely used, which consists of using standardized mathematical descriptions in calculations. Using the Matlab/Simulink tool for calculations, one gets access to the source database for performing the calculation analysis. Each block used in the model has a mathematical description and is already implemented in the information module.

5. Conclusion
Simulation has revealed some features of the DC network operation. Because the two storage systems are tied to a particular voltage, in this case to the nominal battery voltage, which in one case is 48V and the other is 220V, the load is set to the nominal value of 220V, in one case, this voltage must be converted from 48V through step-up DC/DC Converter, and in another case, this voltage must be stabilized with the help of DC/DC Converter, because the voltage of the 220 V battery charged is 238 V. Hence, it was found that the regulation of the load supply at a stable voltage can only be carried out through current regulation. And for the case when the customer voltage is 220V and the load current is 4A, the electric power will be 880 Wt, discharge current the 220 V battery will be the same 4A. In the case when the load of 220V must be supplied from a system of the nominal voltage of 48V with the
conversion to 220V, and the electric power of 880Wt will require the discharge current of the battery of nominal voltage of 48V be of 18.3 A. The obtained values must be taken into account for designing or selection of DC/DC boost converters and other equipment.

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