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Opinion

# Generation and Retail of Electricity by Local Photovoltaic Energy Clusters During Failure of Electricity Transmission and Distribution Systems

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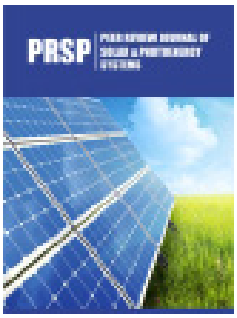


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**Abstract**

The review shows the implementation of a cluster system of local electricity generation by solar power plants. It was noted that during a failure of power transmission and distribution systems, the use of a cluster system has an advantage. The main idea is to use typical unified units to create energy clusters. It is shown that the creation of clusters that combine the generation and retail of electricity is a promising direction for the creation of an energy network resistant to global damage. The application of smart control capabilities for combining generating units into clusters is shown.

## Introduction

Nowadays, renewable sources of energy, in particular solar sources of electrical energy, such as photovoltaic plants, are becoming widespread. It should be noted that solar photovoltaic power plants can be of arbitrary size and topology, as their main generating component is a photovoltaic element and a photovoltaic panel. This fact prompts us to create generating units of the same type that can be combined into clusters. In the event of catastrophic phenomena or damage caused by man-made, natural, and especially military actions, the stability of the energy system is very important. Structure of the energy system: generation; transportation and distribution; implementation, is highly vulnerable and is a prime target for attacks. That leads to global negative energy consequences.

## Unit

Since solar generating capacity can be segmented, it is promising to move to the construction of generating power plants in the form of a cluster structure and the creation of unified generating units. It should also be noted that many households and small businesses are switching to using local, small-capacity solar power plants for their own needs. Such generating mini plants are quite typical and contain elements typical for their purpose and nominal parameters. Thus, it is proposed to create, and in the future to apply, typical universal mini power plants, which are units for the construction of power-generating clusters. Note that the typical contracted power capacity in Ukraine is 5kW, and the electrical infrastructure of the vast majority of end consumers is designed for a power consumption of 5kW, therefore it is expedient to create a generating unit with a power of 5kW as well. Such unit should consist of a generating part, a storage part (for secondary power supply and balancing), converting and control parts. That is, for generation, you need to use photovoltaic panels with a total nameplate capacity of 5kW. Although the generation capacity may be lower on cloudy days, it is not advisable to increase the installed capacity as it may lead to negative consequences. The total output voltage from photovoltaic panels could be different, depending on the energy converting and control equipment, but is usually 12V, 24V, or 48V. Some models of converters

require increased voltage from photovoltaic panels, from 120V to 450V, for that the photovoltaic panels are connected in series.

For the accumulation of electrical energy and balancing of the power system, the use of electrochemical accumulators of electrical energy is proposed. The use of LiIon and Li FePo4 batteries is quite promising. The advantage of such batteries is a large number of charge and discharge cycles, that is necessary when using them in cyclic mode. Their disadvantage is the need to balance battery cells, for that it is necessary to use BMS-devices. Based on the research of the market for the retail of electric energy, it should be said, that the daily consumption of a household or a small office, as a unit of account, is within 5-10kWh. In the conditions of catastrophic blackouts of the global energy system, it is advisable to install batteries for individual storage, just within such limits, that is, to guarantee daily consumption. Note that for the implementation of such typical modules in different countries, it is necessary to know the Norms and Codes of these countries. As mentioned above, the main consumption of electrical energy is carried out in the form of alternating current, so the element of the system should be a convertor of electricity from direct current to alternating current, preferably of the correct sinusoidal form. For such tasks, inverters based on power switches, such as MOSFET-transistors, are used. The efficiency of such devices is quite high and can reach 95%. In addition, you need to use a charge controller to charge and discharge batteries from solar panels. Devices that use an algorithm for tracking the maximum generating power from photovoltaic panels, such as MPPT controllers, are optimal.

The main idea of creating a unified module is to combine such units into a cluster. That is, for the coordinated operation of the same type of systems, it is also necessary to have the possibility of communication. To implement communication, it is necessary to apply communication modules for common information exchange protocols, such as ModBus, CAN or others. It is necessary to exchange all or many electrical parameters and modes of operation of the units. For example, information about the operation of the unit may contain such data as the output power of the generation, the value of accumulated charge in the battery, the value of the consumed load that is connected to the unit.

## Cluster

The main idea of creating a cluster is the use of unified and independent electric energy generation units that can perform their work both in combination with other units and autonomously. This approach allows you to move away from the critical infrastructure of the energy system. Thus, if one of the units fails or is damaged, the cluster as a whole remains in working order and continues to generate and distribute energy, but with less power. Also, the uniformity of the units facilitates repair and maintenance of the cluster as a whole.

It is advisable to combine units into a cluster within the limits of the voltage of the final distribution network for the retail of electric energy, so in the case of Ukraine it is 0.4kV. Of course, raising the voltage to 10kV would reduce losses in the transmission of electrical energy, especially over long distances, but it would introduce a critical infrastructure element into the system, such as a step-up/step-down transformer substation, which does not correspond to the main idea of clustering and creates a certain dependence. That is, by creating a cluster, we combine small, but distributed, generation with final consumption. Thus, by combining two hundred units into one cluster, we get 1MW of generating and distribution power within the localization of such a cluster. This power corresponds to the generation of one small thermoelectric or hydroelectric plant and also corresponds to the power of a minimal distribution substation. It should also be noted that due to batteries, such a cluster is self-balancing, that is, it does not require external power for balancing. We also mark that the information and communication system of the cluster must be distributed and may not contain the main controller. And the algorithms of the units can be such that the units work both autonomously and as part of a cluster, but without centralized control.

## Conclusion

The cluster, the creation of which is proposed, is a self-sufficient energy union, which in turn consists of self-sufficient typical and unified units that contain generation, storage and distribution. Such clusters are intended both for households and for commerce and industry, and possibly for power supply of transport infrastructure. The cluster-unit approach significantly improves the stability of the energy system as a whole and in local areas. And the use of smart systems and algorithms in the modules and the cluster will allow to control the processes of generation, accumulation and distribution in optimal modes and quickly balance the system in case of failure of individual elements of the cluster. We also note that the use of a self-learning unit control algorithms is a step towards the introduction of artificial intelligence in cluster power systems.