

## ENERGY UNIT KIT FOR PHOTOVOLTAIC CLUSTER

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**Abstract.** *Since solar generating capacity can be segmented, it is promising to move to the construction of generating power stations 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-stations 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. In article, detailed set of the unit is shown.*

**Keywords:** cluster, unit, pv-panel, battery, kit, inverter, controller

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## КОМПЛЕКТ ЕНЕРГЕТИЧНОГО МОДУЛЯ ЯК ЕЛЕМЕНТА ФОТОЕЛЕКТРИЧНОГО КЛАСТЕРА

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**Анотація.** *Оскільки сонячні генерувальні потужності можуть бути сегментовані, то є перспективним перехід до побудови генерувальних електричних станцій у вигляді кластерної структури та створення уніфікованих генерувальних модулів. Також треба зазначити, що багато домогосподарств та невеликих підприємств переходять на використання локальних, невеликих за потужністю сонячних електростанцій для власних потреб. Такі генерувальні міністанції є досить типовими та містять типові за призначенням та номінальними параметрами елементи. Таким чином, пропонується створити й у подальшому застосовувати типові універсальні мініелектростанції, які є модулями для побудови електрогенерувальних мінікластерів. У статті показана повна деталізація запропонованого модуля.*

**Ключові слова:** кластер, модуль, фотовольтаїчна панель, акумулятор, комплект, інвертор, контролер

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**Introduction.** 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 local micro plants are quite typical and contain elements typical for their purpose and nominal parameters [1]. The theory of clusters is presented in [2,3,4,5], but it concerns large clusters, on the scale of regions and countries. And research for connecting microgrids into a cluster is important [6,7,8,9]. To build unified scaled clusters, it is more rational to use a microgrids.

**Setting objectives.** It is proposed to create, and in the future to apply, typical universal micro power pv-plants, which are units for the construction of power-generating mini clusters.

**Unit.** Full set detailing of such pv-unit should show any cases of using of parts and these parts could be changeable and removable. Some parts of Unit could change to other type similar devices. Note that the typical contracted power capacity in Ukraine is 5 kW [10], and the electrical infrastructure of the vast majority of end consumers is designed for a power consumption of 5 kW, therefore it is expedient to create a generating unit with a power of 5 kW as well.

Such Unit should consist of a generating part, a storage part (for secondary power supply and balancing), converting and control parts (Fig.1). That is, for generation, you need to use photovoltaic panels with a total nameplate capacity of 5 kW. 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 or DC current 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, to 120V or 400V, for that the photovoltaic panels are connected in series. For connection panels and for controlling output parameters we should use different switching devices [11] in Combiner box. Combiner box consist from contactors, fuses, blocking diodes, switchers and control equipment (Fig.1).

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 Lilon or LiFePo4 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. Also, BMS should have heating controls and communication ports, for example CAN or WiFi.

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.

Main device of this Unit is Automatic panel (Fig.2). This box consists from Manual transfer switch (MTS) and Auto transfer switch (ATS) for connection the unit to grid or reserve supplier. Also, 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, to on-grid using and using of motors, 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 or grid. Devices that use an algorithm for tracking the maximum generating power from photovoltaic panels, such as MPPT controllers, are optimal. And for conversion alternating current to direct current for charging battery, we need use AC-DC converter. To connect to a grid, you need to use an inverter (DC-AC) with automatic synchronization of parameters of generation, such as voltage, frequency and phase. And inverter should have ability to regulation of this parameters. Also, if it needs for grid, we should use a transformer that forms a neutral (NFT).

Alternative of the Automatic panel could be On-grid or Hybrid inverter, like non-separable device.

Main block of unit is Operation, monitoring and communication module. This module controls collection of data and operating of devices. It has microcontroller module (MCU), inputs and outputs, display and keyboard (Fig3). The 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 (Fig3.). 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.

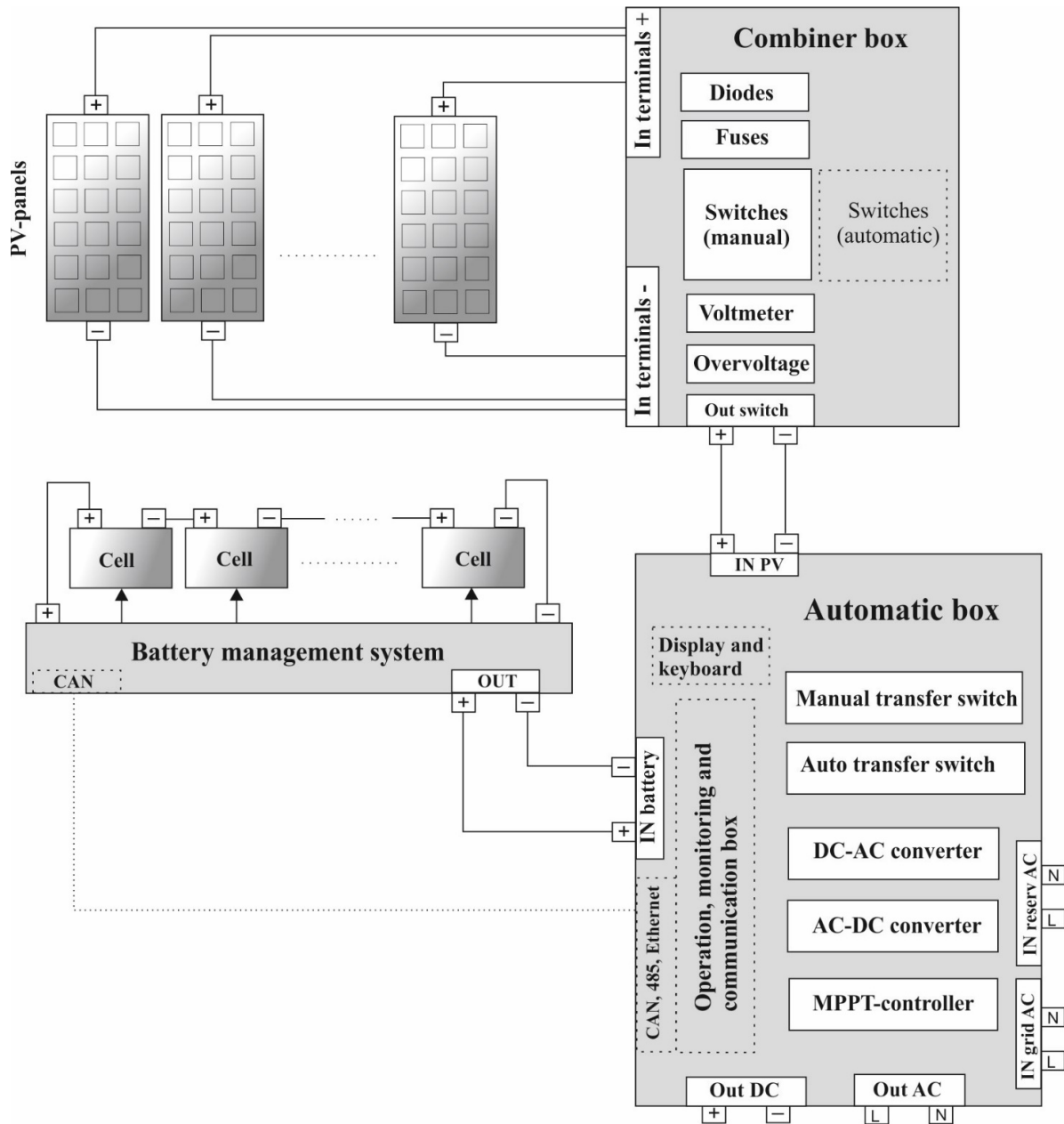


Fig. 1. Unit

**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 0.4 kV. 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 [3]. 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 [12].

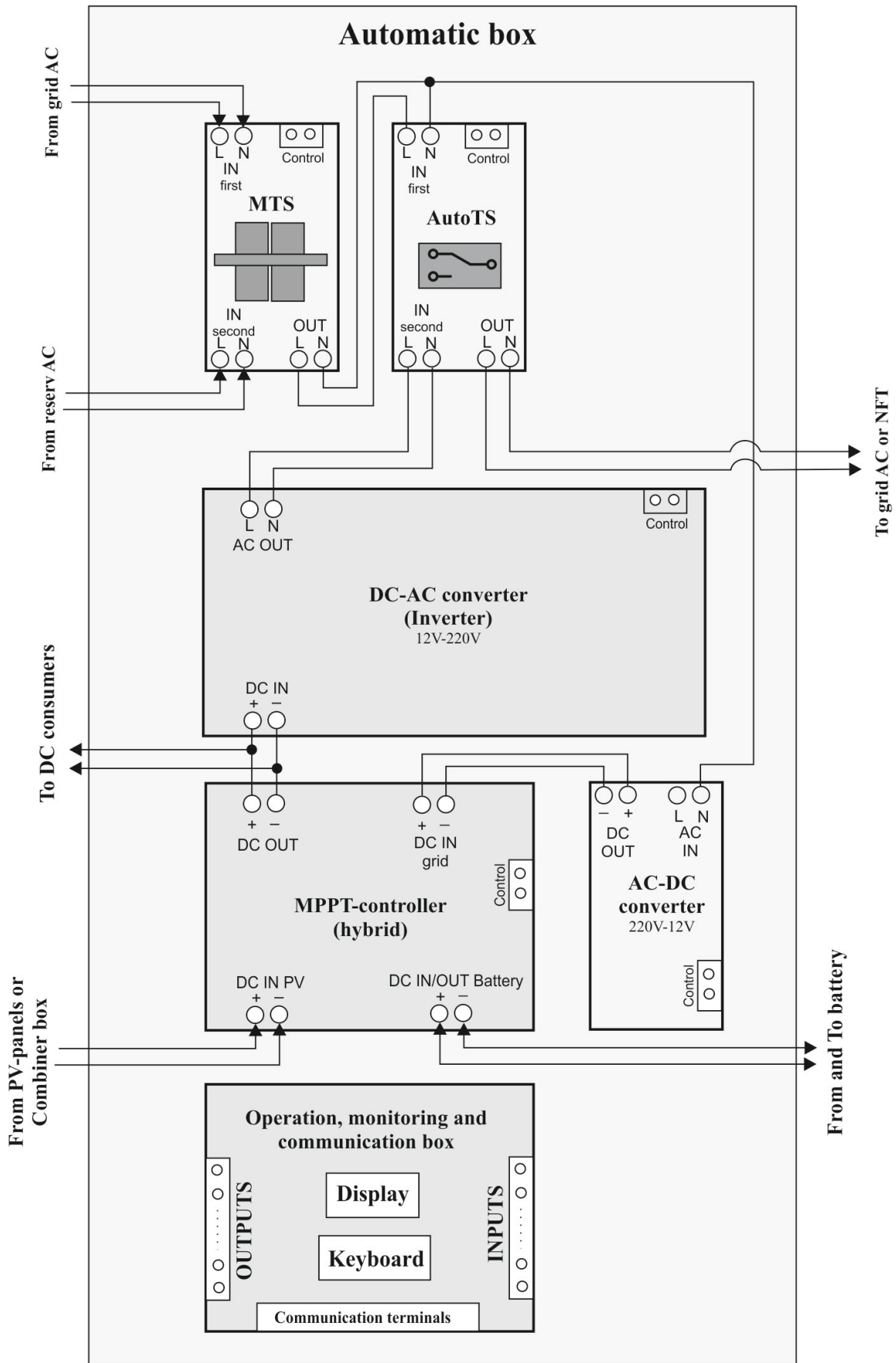


Fig. 2. Detailing of automatic panel of the unit

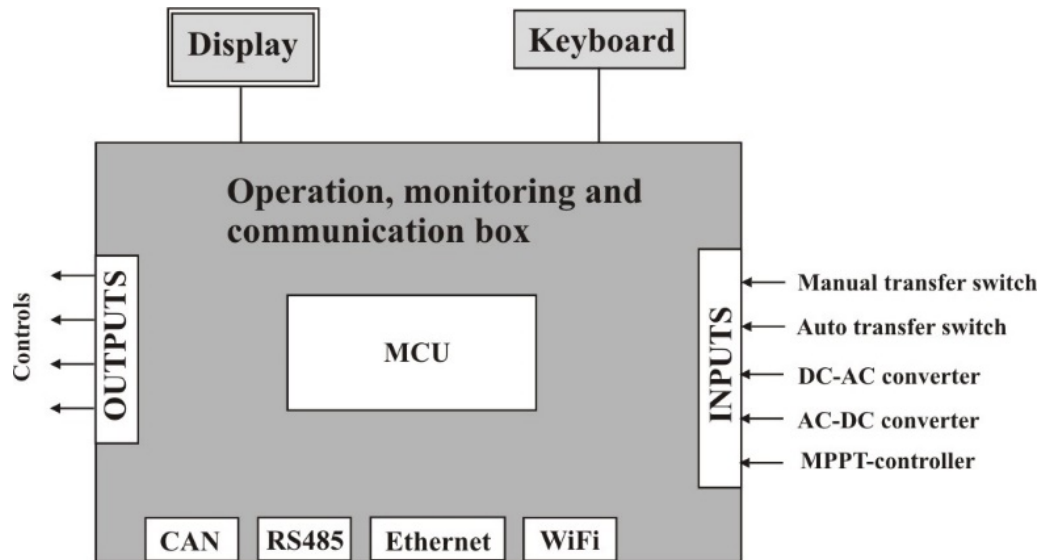


Fig. 3. Operating, monitoring and communication module of the unit

**Using of micro-inverters.** Other way is using of microinverters, that is modern solution of PV-energy systems to commercial and residential customers. It is very practical solution to distributed systems. Microinverters transform DC 12-20 volts to AC 220 volts 50/60Hz near PV-module directly (Fig.4). They are small power devices, approximately 200-400W, with good quality of power conversion and 97% efficiency [13]. Main idea of application of microinverters is using of AC from grid for transfer electricity inside of unit.

And this solution is more convenient, that we can connect to AC bus in any parts of circuit and connection to grid in the automatic or combiner box is simply. Also, we can connect different type of pv-panels or other equipment in this case. And if happened failure some inverters or shading some panel, this application is more stable. We should note about good practice galvanic isolation in grid-connected photovoltaic microinverters [14].

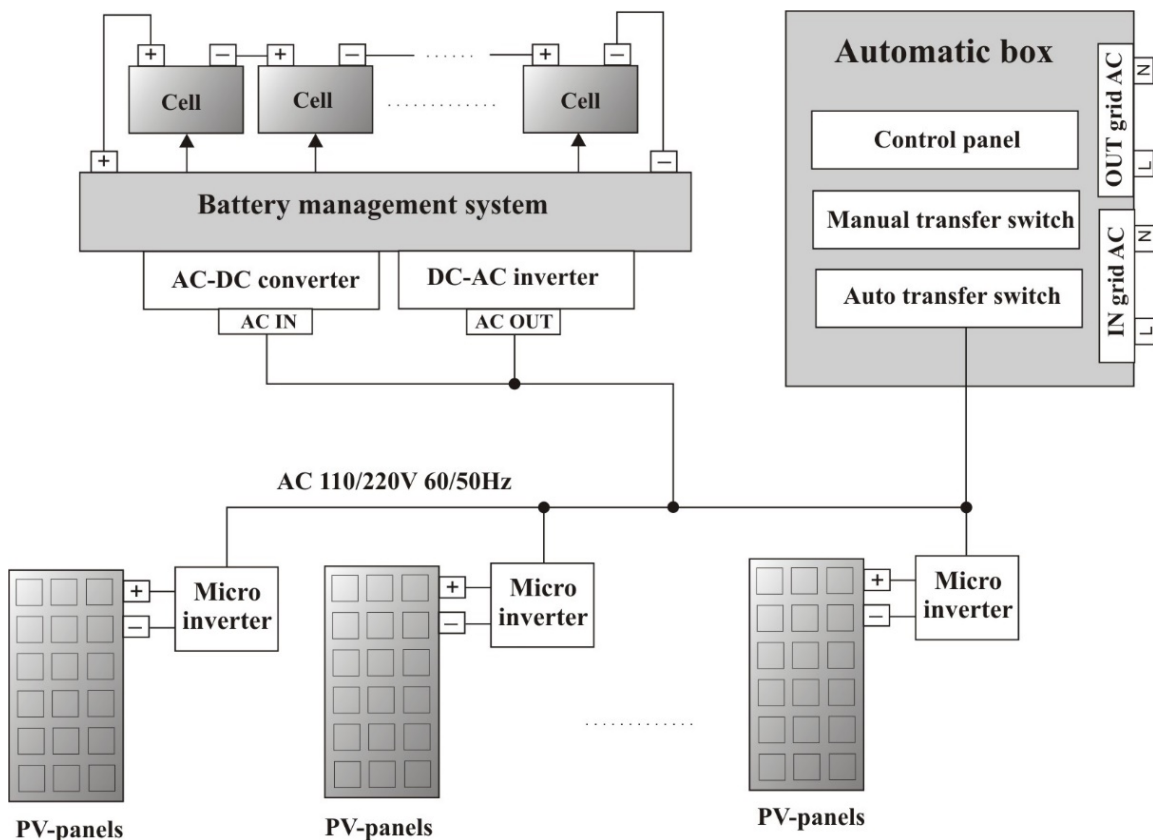


Fig. 4. Unit based on microinverters

**Conclusion.** The mini 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. And units of mini cluster need full set detailing for construct and analyze of the local energy system.

The cluster-unit approach significantly improves the stability of the energy system as a whole and in local areas, especially during blackouts [15]. Also, the cluster can replace or create an alternative to modern thermoelectric power plants.

Using 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.

Also, using of microinverters is good way for united of small power applications, like units of distributed system, to mini cluster.

Many companies offer their cluster organization system, for example Schneider [16]. But in such a case, own concepts and equipment of own production are offered, which does not lead to the unification of typical equipment of different manufacturers into a cluster. In addition, manufacturers offer significantly higher power of modules of a cluster, actually on an industrial scale, in opposite to the system proposed in the article. In next time, will need research for safety connection to the power grid to ensure the reliability of power supply [17].

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