https://doi.org/10.36296/1819-8058.2024.1(76)51-56

USING MICROINVERTERS FOR PHOTOVOLTAIC CLUSTER

Received Jan. 16. 2024; accepted Mar. 22. 2024
Available online Apr. 01. 2024

Bondarenko D.[1], Matyakh S.[2]

Corresponding author: Bondarenko Dmytro,
e-mail: dima7007bond@gmail.com

[1] PhD.
https://orcid.org/0000-0002-5629-930X

[2] PhD.
https://orcid.org/0000-0002-1707-3519

[1,2] Institute of Renewable Energy NAS of Ukraine, Kyiv, Ukraine

Abstract. *Decentralization and distribution of generating capacities leads to the stability and scalability of the energy system, that in the work proposes the construction of solar power plants in the form of a cluster structure with the creation of unified generating modules. The main idea is to use microinverters as equipment that converts direct current into alternating current. The advantages of using microinverters as devices that ensure decentralization within the framework of a solar power plant, locally, are noted. The implementation of microinverters together with storages of electrical energy is shown. Systems with different types of battery placement are described. The possibility of using individual photovoltaic panels as an independent generating unit in the overall structure of the cluster was noted.*

Keywords: *microinverter, pv-panel, battery, converter, inverter, cluster, unit.*

ВИКОРИСТАННЯ МІКРОІНВЕРТОРІВ ЯК ЕЛЕМЕНТІВ ФОТОЕЛЕКТРИЧНОГО КЛАСТЕРА

Отримано 16 січ. 2024 р.; рекомендовано до публікації 22 бер. 2024 р.
Доступно онлайн 01 квіт. 2024 р.

Бондаренко Д. В.[1], Матях С. В.[2]

Автор для кореспонденції: Бондаренко Дмитро,
e-mail: dima7007bond@gmail.com

[1] канд. техн. наук.
https://orcid.org/0000-0002-5629-930X

[2] канд. техн. наук.
https://orcid.org/0000-0002-1707-3519

[1,2] Інститут відновлюваної енергетики НАН України, м. Київ, Україна

Анотація. *Децентралізація та розподілення генерувальних потужностей сприяє стійкості та масштабованості енергетичної системи, тому в роботі пропонується побудова сонячних електричних станцій у вигляді кластерної структури зі створенням уніфікованих генерувальних модулів. Головною ідеєю є використання мікроінверторів як обладнання, що перетворює постійний струм на змінний. Відмічені переваги використання мікроінверторів як приладів, що забезпечують децентралізацію у межах сонячної електростанції, локально. Показана реалізація мікроінверторів разом із засобами накопичування електричної енергії. Описані системи з різним типом розміщення акумуляторів. Указується на можливість застосування окремих фотоелектричних панелей як самостійної генерувальної одиниці в загальній структурі кластера.*

Ключові слова: *мікроінвертор, фотоелектрична панель, акумулятор, конвертор, інвертор, кластер, модуль.*

Introduction. The use of energy clusters in solar energy is a promising direction for the development of renewable energy. This approach ensures decentralization of the energy system, modularity, universality and its resistance to external and internal factors [1]. In addition, the implementation of intelligent control systems [2, 3] of energy systems requires flexible and distributed electrical engineering solutions [4]. The construction of a cluster requires the use of uniform units of the same type, which encourages the development of localized energy equipment of small size and power. Such an element of the system can be a microinverter, which, for connection to the network, converts direct current into alternating current directly next to the generating module, or not far from it.

Setting objectives. Develop a typical unit of a solar power supply system using microinverters. Describe optimal designs.

Microinverter. A microinverter is a device that has the function of converting low voltage direct current into high voltage alternating current, which is a commonly used power supply standard. For example, for offices, small businesses, apartments, etc., it is 220V 50/60Hz. But the size and power of such an inverter allow them to be installed directly next to solar panels [5]. That is, each panel (or two or four) has own DC-to-AC converter. The microinverter has a power of approximately 200-400W, with good quality of power conversion and 97% efficiency. These microinverters form their own alternating current grid (Fig. 1) [6].

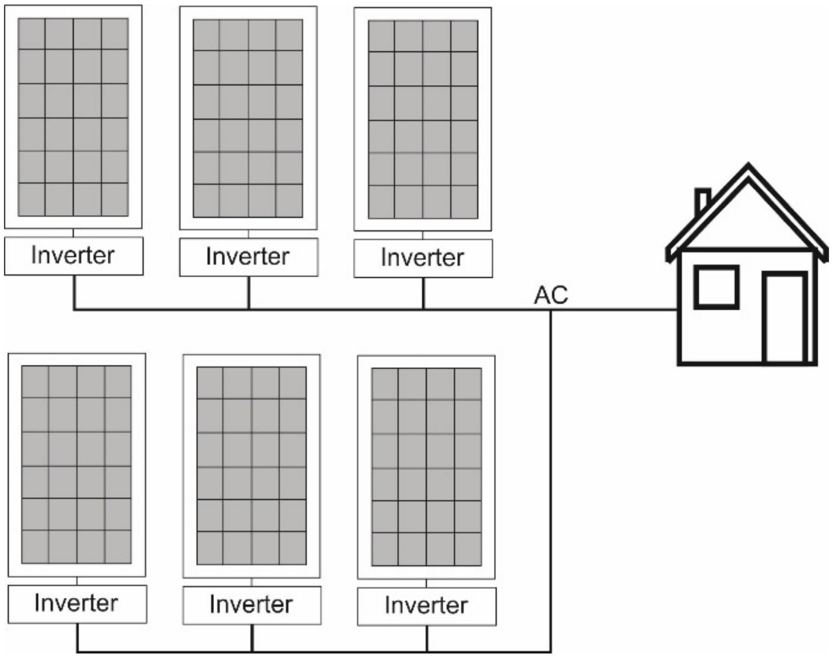

Fig. 1. Energy system with microinverter

The main functional parts of the microinverter are the DC-DC StepUp module and the DC/AC-inverter [7, 8]. In the step-up module, the voltage of 12-18V rises to 320V, and in the DC/AC-inverter the current of this voltage is converted either into pulses or into a harmonic signal of the required frequency and amplitude of 320V (220V effective or r.m.s. voltage). The majority of the DC-DC StepUp converter is a Flyback converter (Fig. 2) [9, 10, 11], the most successful implementation of such a converter is with an active clamp. In the vast majority, the DC/AC-inverter is a Full bridge inverter (Fig. 3) [12, 13].

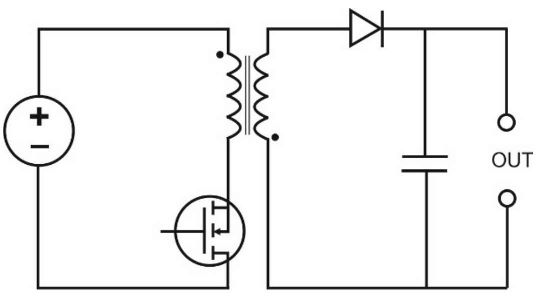

Fig. 2. Flyback converter

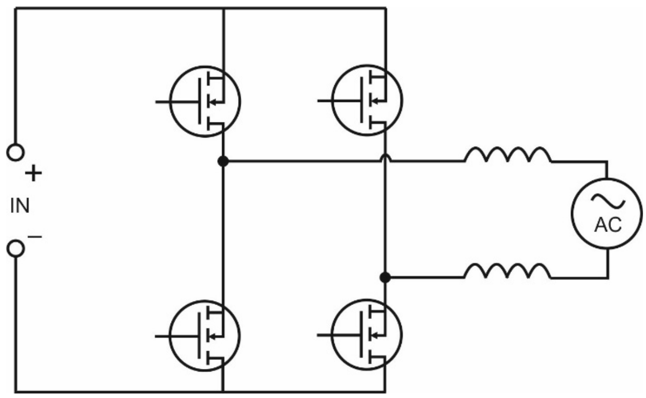

Fig. 3. Full bridge inverter

Also, the microinverter must contain an MPPT-controller to obtain the maximum generation power [14]. And also, it includes a matching module with other microinverters on the line, as grid parameters such as amplitude, frequency, and phase must be matched [15]. The matching module and MPPT-controller have to be made on the basis of modern microcontroller technology, such as programmable logic controllers with the presence of an analog-to-digital converter (ADC) and controlled digital and analog outputs. Thus, the system looks as follows (Fig. 4) [16].

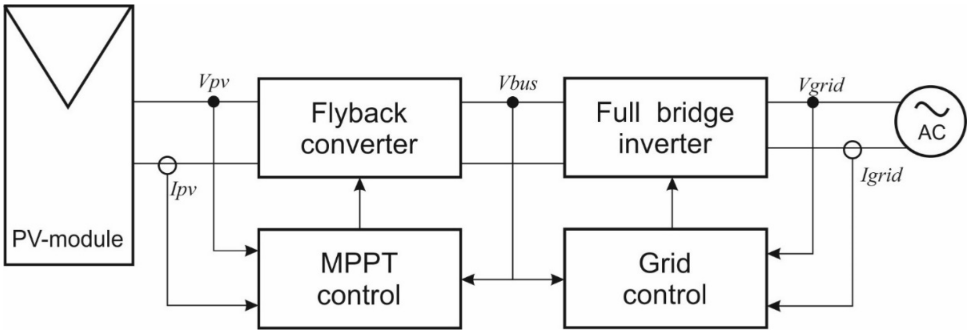

Fig. 4. Microinverter with control

Use of microinverters in a cluster unit. To form an energy cluster based on photovoltaic systems, it is necessary to have unified units that are combined into a cluster. In this case, the unit consists of photovoltaic panels, microinverters, which are combined into a local alternating current network. In the proposed scheme (Fig. 5), the alternating current from the photovoltaic panels, or rather from their inverters, is fed to the control panel, which manages the system and collects data from the inverters using interfaces or data exchange protocols, such as Power Line Communication. Switching from the local grid and to the general electric power grid is carried out by manual and automatic transfer switch. In addition, along with the control panel, electrical energy is stored using an electrochemical battery, for which it is necessary to implement a charge and discharge system, as well as a system of conversion from alternating current to direct current and vice versa.

To create a cluster, our local grid must also exchange data with the general network. The Control Panel has external communication interfaces. which can be PLC, 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 [15].

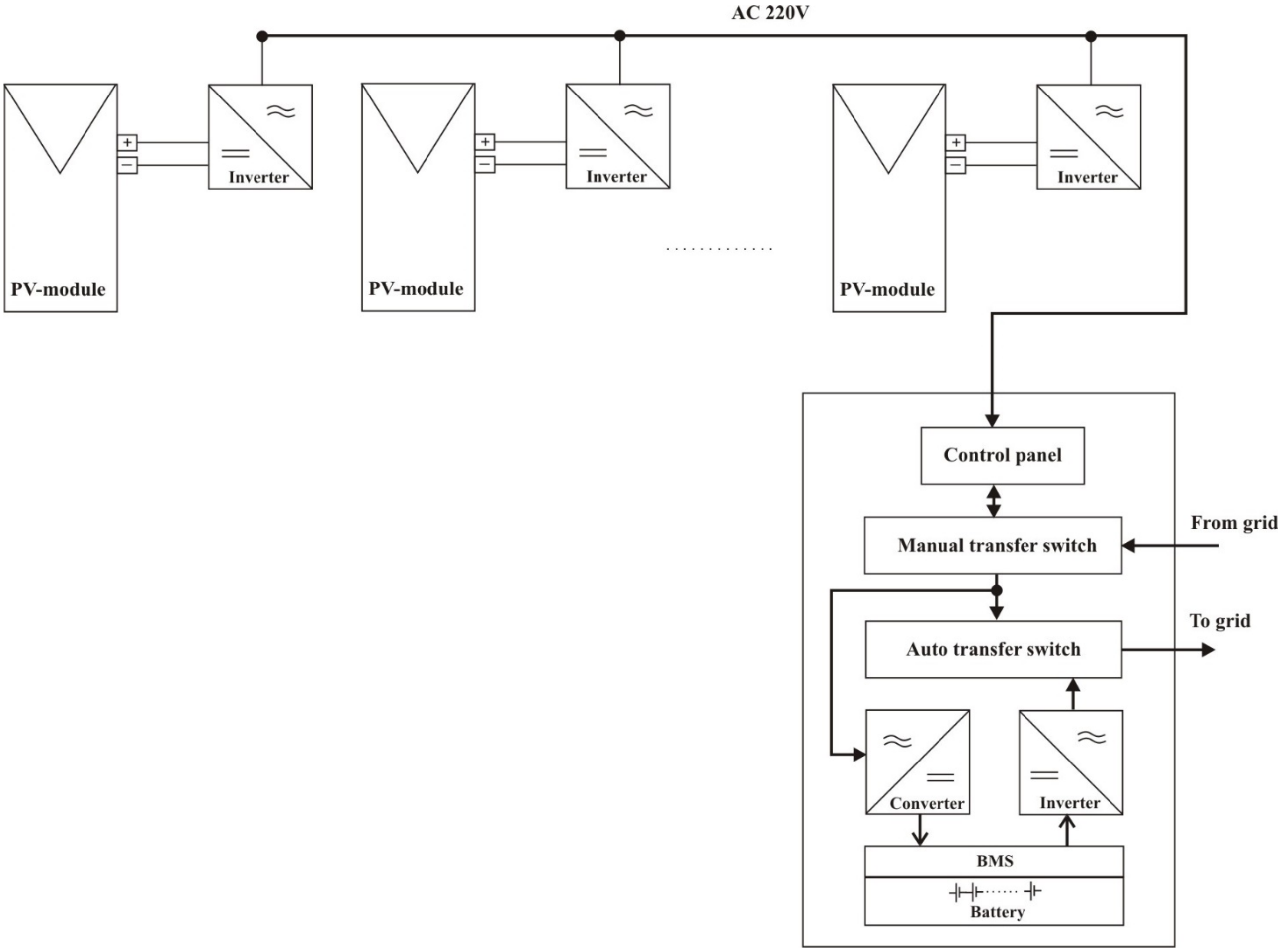

Fig. 5. Unit with microinverters

Unit with microinverters and storages inside PV-panels. To implement a distributed system not only in terms of generation, but also in terms of accumulation electrical energy, it is possible to place the storage device next to the inverter. For this, together with the microinverter, the system of charge and discharge of the electrochemical battery must be implemented [17]. The choice of the type of electrochemical battery usually point to lithium models, but it is necessary to take into account the temperature mode of operation, which will mostly be bad to lithium models [18]. Therefore, it is advisable to consider alkaline or acidic options. In one case, the accumulator with the charge system is included in the DC/DC-convertor before the DC/AC-inverters in the microinverter [19]. In this case, it is advisable to use a combination of Back and Boost converters (Fig. 6). Another option is to include the battery, as a separate device, between the photovoltaic panel and the microinverter, as shown in Fig.7.

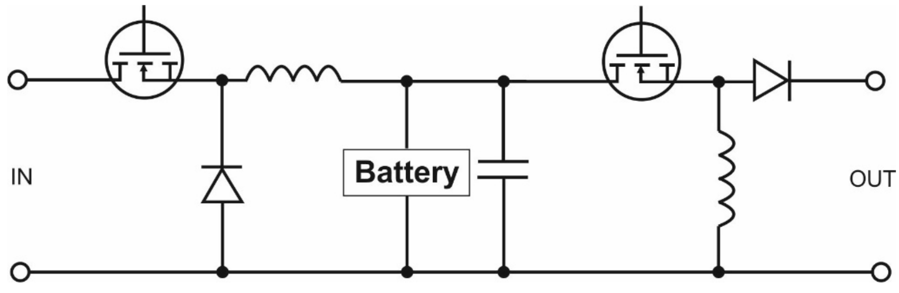

Fig. 6. DC-DC converter with storage

In the variant from Figure 7, the scheme of decreasing the voltage to the charging and increasing the voltage to the working one is performed inside of the battery charge and discharge system using a DC-DC converter. It is advisable to use a bidirectional DC-DC converter [20, 21].

In the case which the storage devices are distributed and placed next to the photovoltaic panels allows to increase the stability of the system.

It is necessary to pay attention to the fact that in the case of placing a distributed backup power system, it is necessary to provide additional protection and safety elements, since high voltage will be contained on the alternating current line without being controlled from the central control panel. The removal of power from the local AC line must be monitored on each inverter.

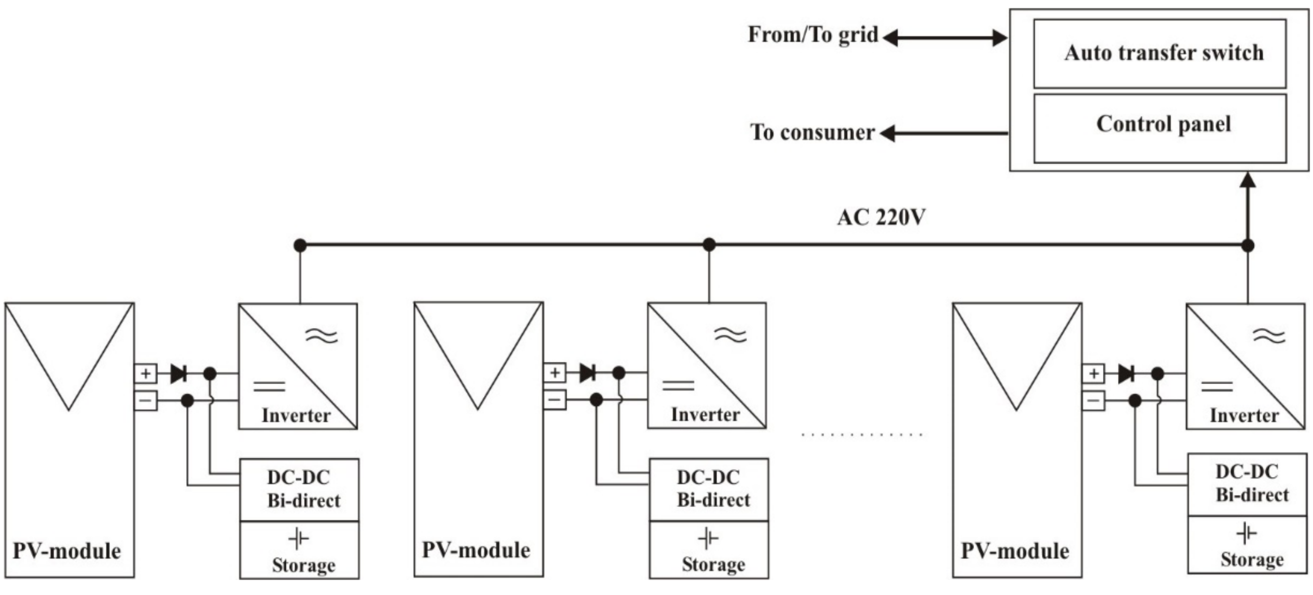

Fig. 7. Unit with microinverters and storages inside PV-panels

Unit with microinverters and storages outside PV-panels. In the case of impossibility or impracticality of placing microinverters and accumulators next to the photovoltaic panel, for example due to inappropriate temperature modes for the operation of electrochemical batteries, it is possible to implement a system with group connection of photovoltaic panels in a remote and isolated place (Fig. 8). It should be noted that even in this case, the principle of individual direct current conversion from each panel, as well as individual energy storage, is implemented.

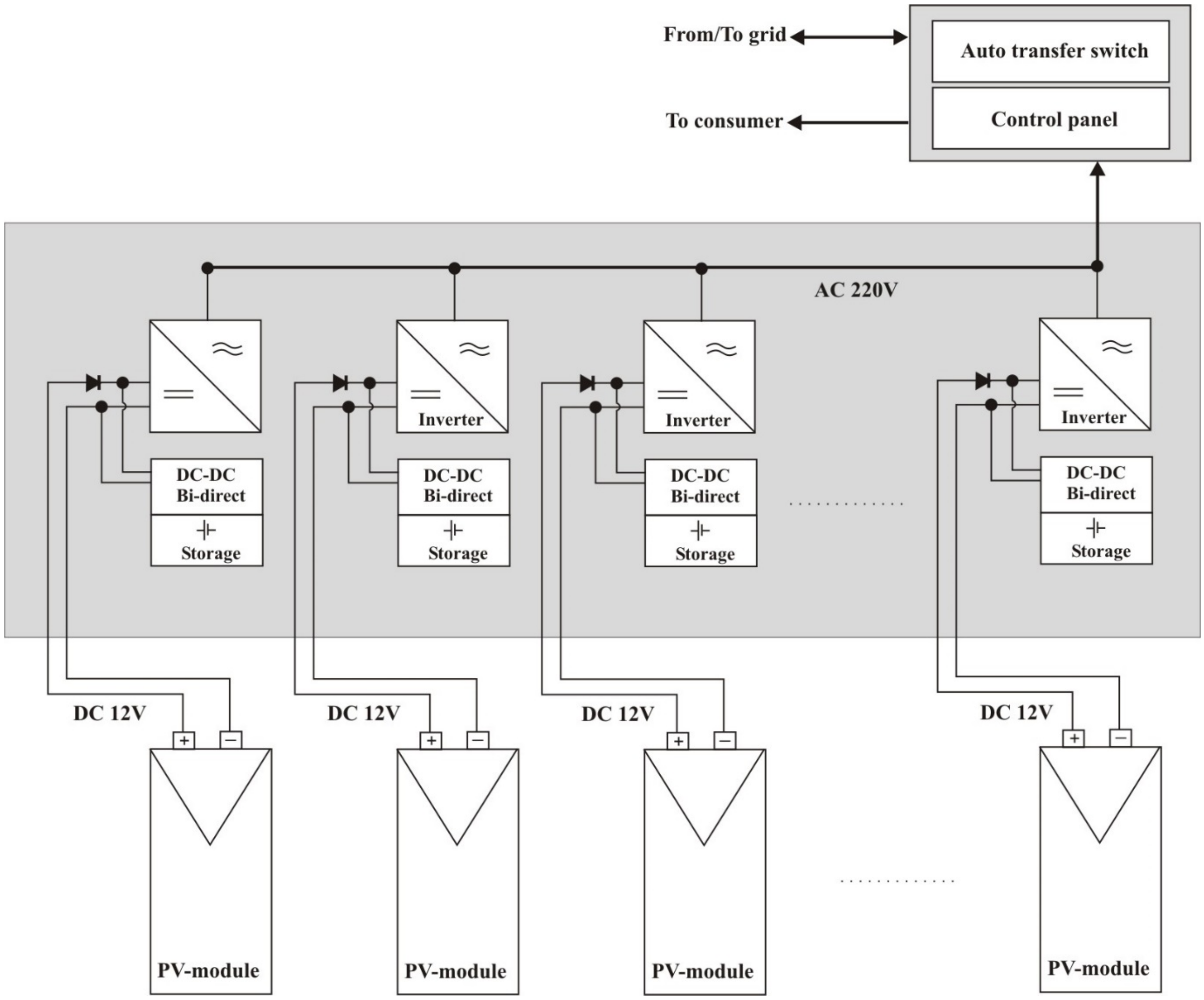

Fig. 8. Unit with microinverters and storages outside PV-panels

Conclusion. Using of microinverters is good way for united of small power systems, like units of distributed system to cluster. The cluster-unit approach improves the stability and scalability of the wide energy system as a whole, and in local areas too. Also, the distributed cluster can replace or create an alternative to industrial power plants.

Actually, solution with microinverters is more convenient, that we can connect to AC bus in any parts of circuit. 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.

Also, it should be noted that the advantage of using microinverters is the possible standalone use of a photovoltaic panel directly as an element of a cluster, that is, connecting the panel microinverter directly to the cluster grid. But as mentioned above, it is necessary to implement security measures separately for each panel.

Using of parts of intelligent systems and operating algorithms in the units 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.

This article is made in accordance with the scientific program 6541230 – "Energogarant".

REFERENCES

1. Gail Rajgor. Microinverters – a solar game changer. Renewable Energy Focus. (2013), v. 14, Issue 3, 16-17. https://doi.org/10.1016/S1755-0084(13)70047-4
2. Bondarenko D. V. Smart digital photoelectric systems. Vidnovljuvana energetyka. (2016), No.1, 38-44 (in Ukrainian).
3. Bondarenko D. V. Smart systems in solar energy. Vidnovljuvana energetyka ta energoefektyvnist u 21 stolitti. (2016), 278-283 (in Ukrainian).
4. Ying Yu, Yuanwei Xiao, Jinshuai Chou, Xingyu Wang, Liu Yang. Dual-layer optimization design method for collaborative benefits of renewable energy systems in

building clusters: Case study of campus buildings. Energy and Buildings. (2024), v.303, 113802. https://doi.org/10.1016/j.enbuild.2023.113802

5. Rabindra Satpathy, Venkateswarlu Pamuru. Chapter 8 - Rooftop and BIPV solar PV systems,

1. Editor(s): Rabindra Satpathy, Venkateswarlu Pamuru. Solar PV Power. Academic Press. (2021), 317-364. https://doi.org/10.1016/B978-0-12-817626-9.00008-3

6. Ruchira, Ekta Tamrakar, R. N. Patel, Pallavi Choudekar. Customized design of microinverter based solar photovoltaic system for small houses in developing nations. Renewable Energy Focus. (2022), v.42, 178-189. https://doi.org/10.1016/j.ref.2022.06.004

7. Sahoo, Satyaprajna & Roy, Trishant & Saraf, Pushkar. Design of a Micro-inverter. (2020).

8. Rasedul Hasan, Saad Mekhilef, Mehdi Seyedmahmoudian, Ben Horan. Grid-connected isolated PV microinverters: A review. Renewable and Sustainable Energy Reviews. (2017), v.67, 1065-1080. https://doi.org/10.1016/j.rser.2016.09.082

9. Erickson R. W. and Maksimovic D., Fundamentals of power electronics. Springer Science & Business Media, (2007).

10. Flyback converter From Wikipedia. [Electronic resource] URL: https://en.wikipedia.org/wiki/Flyback_converter (Applying date: 01.01.2024).

11. Rasedul Hasan, Saad Mekhilef. Highly efficient flyback microinverter for grid-connected rooftop PV system. Solar Energy. (2017), v.146, 511-522. https://doi.org/10.1016/j.solener.2017.03.015.

12. Ji, Baojian & Wang, Jianhua & Hong, Feng & Huang, Shengming. A Family of Non-Isolated Photovoltaic Grid Connected Inverters without Leakage Current Issues. Journal of Power Electronics. (2015), 15, 920-928. https://doi.org/10.6113/JPE.2015.15.4.920.

13. Zine Eddine Touhami Ternifi, Pierre Petit, Ghalem Bachir, Michel Aillerie. New Topology of Photovoltaic Microinverter based on Boost converter. Energy Procedia. (2017), v.119, 938-944. https://doi.org/10.1016/j.egypro.2017.07.106.

14. Eltawil Mohamed A., Zhao Zhengming. MPPT techniques for photovoltaic applications. Renewable and Sustainable Energy Reviews. (2013), v.25, 793-813. https://doi.org/10.1016/j.rser.2013.05.022.

15. Bondarenko D., Matyakh S., Surzhyk T., Shevchuk V. Energy unit kit for photovoltaic cluster. Vidnovluvana Energetyka. (2023), №3(74), 53-58. https://doi.org/10.36296/1819-8058.2023.3(74).53-58

16. Liu, Yu-Chen & Chen, Ming-Cheng & Yang, Chun-Yu & Kim, Katherine & Chiu, Huang-Jen. High-Efficiency Isolated Photovoltaic Microinverter Using Wide-Band Gap Switches for Standalone and Grid-Tied Applications. Energies. (2018), 11(3), 569. https://doi.org/10.3390/en11030569

17. Vega-Garita Victor, Ramirez-Elizondo Laura, Bauer Pavol. Physical integration of a photovoltaic-battery system: A thermal analysis. Applied Energy. (2017), v.208, 446-455. https://doi.org/10.1016/j.apenergy.2017.10.007.

18. Behmann René, Phan Jack, Root Artur, Schmidt Michael, Bessler Wolfgang G. Integration of a lithium-ion battery in a micro-photovoltaic system: Passive versus active coupling architectures. Solar Energy. (2023), v.262, 111748. https://doi.org/10.1016/j.solener.2023.05.025.

19. Siouane, Saima Sophie & Jovanovic, Slavisa & Poure, Philippe. Service Continuity of PV Synchronous Buck/Buck-Boost Converter with Energy Storage. Energies. (2018), 11(6), 1369. https://doi.org/10.3390/en11061369.

20. Viswanatha, V., Ramachandra, A. C. & Venkata Siva Reddy, R. RETRACTED ARTICLE: Bidirectional DC-DC converter circuits and smart control algorithms: a review. Journal of Electrical Systems and Inf Technol. (2022), 9, 6. https://doi.org/10.1186/s43067-022-000-48-z

21. Tytelmaier, Kostiantyn & Husev, Oleksandr & Veligorskyi, Oleksandr & Yershov, Roman. A review of non-isolated bidirectional dc-dc converters for energy storage systems. II International Young Scientists Forum on Applied Physics and Engineering (YSF). (2016), 22-28. https://doi.org/10.1109/YSF.2016.7753752.