MODELING OF COMPATIBLE WORK OF DISTRIBUTED POWER SOURCES OF ELECTRIC POWER AND CENTRALISED POWER SUPPLY

Urgency of the research. Current trends of distributed generation development in Ukraine indicate a rapid generation increase from renewable energy plants. Most developed countries gradually refuse from the fossil fuels use and invest more and more to the "green" energy. Therefore, there is a need for a detailed study of the operation conditions of distributed energy sources due to their instability, as well as the processes that arise in distribution electric networks with diverse types of distributed energy sources.

Target setting. In the producing process of power energy by distributed energy sources due to the increase in their number, there are situations where several renewable sources of energy operate to only one system of buses. Thus, such distributed networks acquire the features of a local power system, which complicates the control process of such systems, and also there is a problem with the electricity supply of consumers.

Actual scientific researches and issues analysis. The analysis of publications suggests that in literature more attention is paid to studying the operating modes of solar power plants, or small hydroelectric power plants. However, almost no attention was paid to the study of their co-operation work.

Uninvestigated parts of general matters defining. Only a few works are devoted to the study of the co-operation of the diverse sources of distributed energy sources in the local electrical systems. That is why, their impact on power distribution networks and on the grid in general has not been studied extensively.

The research objective. In this article was considered the influence of asynchronous generators on small hydroelectric power plants on the operation modes of distribution electrical networks, and were investigated the processes that are occurring in local power systems with different types of distributed energy sources.

The statement of basic materials. Based on the research results, was developed a computer model of a such system in the PS CAD software environment. Two solar stations and one small hydroelectric power station with an asynchronous generator were connected to the power supply. It was shown the simulation of two modes of operation: a joint operation of a small hydroelectric power station, two solar power stations and a power supply center; a joint operation of a small hydroelectric power plant, two solar power stations and a power supply disconnected.

Conclusions. As a result of computer simulation, it is shown that by switching on a small hydroelectric power plant with an asynchronous generator in the case of an emergency shutdown of centralized power supply, it is possible to restore the work of solar power plants, and thus partially or completely restore the power supply of consumers.

Keywords: local electrical systems; distributed energy sources; PS CAD; power supply.

Fig.: 3. Table: 1. References: 6.

Urgency of the research. In the 21st century, energy consumption and environmental pollution caused by traditional power plants have become an important problem, resulting in climate change in the world. And the adverse natural and man-made effects of conventional energy contribute to the transition to renewable energy sources. The policy for increasing the share of electricity from non-traditional energy sources in European countries by 2020 is as follows: Latvia plans to increase the indicator to 42 %, Finland – to 38 %, Great Britain – to 15 %, Poland – 15 %, Slovakia – 14 %, Hungary – 13 %, etc.

For example, the Swedish government announced in 2015 that it plans to abandon the use of fossil fuels to become the world's first non-fossil fuel state. In the budget submitted for consideration to the government, almost $1 billion was reserved for the installation of «green infrastructure» – solar panels and wind power plants. Costs for research were provided too – including ones for improving the ways of storing electricity. Iceland, already provides itself with renewable energy by almost 100 %. This result has been achieved thanks to large-scale investments in hydropower and the production of geothermal energy. Germany plans to provide about 80 % of the energy needed from renewable sources by 2050. According to the UN, by the middle of the century it will be possible to provide more than half of human energy needs at the expense of renewable sources. The use of renewable energy sources is one of the most important directions of Ukraine's energy policy. Due to this direction, the country's traditional fuel and energy resources are saved.

Target setting. In the last decade there has been a sharp increase in the generation capacity of distributed energy sources. Their parallel operation with the power system causes
a some problems, when several renewable energy sources work on only one system of buses, forming a local power system. This leads to significant problems with consumer supply.

Actual scientific researches and issues analysis. Analyzing the experience of foreign countries, the peculiarities of the climate and the geographical location of the Vinnytsia region, we came to the conclusion that it is advisable to use alternative sources of electricity such as water and sun. Vinnytsya region takes the leading position in the development of RES in distribution networks. The increase in their number leads to situations when several RES operate on one system of buses. Thus, such distributive networks acquire the features of a local power system (LPS).

Uninvestigated parts of general matters defining. In view of the fact that in most of the scientific papers in this area almost no attention is paid to the study of the co-operation of distributed energy sources generation in local electrical systems, then there is a need to investigate in detail the influence of such sources to the distributive power network [1–3].

The research objective. In order to study the processes occurring in distributed electric networks with different types of distributed energy sources, a computer model of such an LPS in the software environment PS CAD (Power System Simulation) was developed.

An analysis of foreign sources suggests that this software environment is widely used to simulate the operation of power grids in which distributed energy sources are exploited. PS CAD is a fast, accurate and simple tool for simulating power systems and power electronic converters when designing, analyzing, optimizing and verifying them. The PS CAD program offers a wide range of tools and a large library of components for detailed analysis of electrical equipment [4–6].

The statement of basic materials. Let's consider a model of a local electrical system, when two solar power plants (SPP) and one small hydroelectric power plant (SHPP) with an asynchronous generator (AG) are connected to one feeder (Fig. 1).

![Fig. 1. Model of local 10/0.4 kV electric system](image)

Under this scheme a model of 10/0.4 kV LPS was designed in software complex PSCAD. Computer model of the local electrical system contains 150 kW SHPP, two 2 MW SPP (SPP model diagram is shown in Fig. 2), five transmission lines for power consumers, the battery of static capacitors (BSC) to compensate reactive power (Fig. 3).
The two modes of operation were simulated:
1) joint work of the SHPP, two SPPs and centralized power supply;
2) the joint work of the SHPP, two SPPs with the disconnected centralized power supply.
The simulation results are given in Table.
For the purpose of studying the influence of distributed power sources on load and voltage of 0.4 kV buses, simulation of the mode of joint operation of the SHPP, SPP\textsubscript{1}, SPP\textsubscript{2} and centralized power supply was carried out.
When the centralized power supply is disconnected, we run SHPP with asynchronous generator, from which the voltage is applied to solar power inverters and runs SPP\textsubscript{1} SPP\textsubscript{2} restoring the power supply for consumers.

| № experiment | System | SPP\textsubscript{1} | SPP\textsubscript{2} | SHPP | Load | Notes |
|--------------|--------|-----------------|-----------------|------|------|-------|
|              | P      | P               | P               |      | P    |       |
| 1            | 0.335  | 1.975           | 2.033           | 0.200| 1.556|       |
|              |        |                 |                 |      | 2.008| with centralized power supply |
|              |        |                 |                 |      | 3.1403| |
|              |        |                 |                 |      | 0.170| |
|              |        |                 |                 |      | ∑ = 4.113| |
| 2            | -      | 2.008           | 1.986           | 0.159| 1.478| without centralized power supply |
|              |        |                 |                 |      | 2.096| |
|              |        |                 |                 |      | 3.1452| |
|              |        |                 |                 |      | 0.212| |
|              |        |                 |                 |      | ∑ = 4.106| |
Fig. 3. Schematic computer model of 10/0.4 kV LPS in PS CAD
Conclusions. Consequently, by switching on a small hydroelectric power plant with an asynchronous generator in the case of an emergency shutdown of centralized power supply, it is possible to restore the work of solar power plants, and thus partially or completely restore the power supply of consumers.

References

1. Lezhniuk, P., Kulyk, V., Kovalchuk, O. (2011). *Optimal control of distributed sources of energy in the local electrical system*. Proceedings of the Institute of Electrodynamics of NAS of Ukraine. Collected works. Special Issue, 1, 48–55 [in English].

2. Kozyrskyi, V. V., Tuhai, Yu. I., Bodunov, V. M., Hai, O. V. (2011). Intehratsiia ponovlivanych dzherel enerhii v rozpoldini elektrychni merezhi silskykh rehioniv [Integration of renewable energy sources into distributive electric networks in rural regions]. *Tekhnichna elektrodynamika – Technical electrodynamics*, 5, 63–67 [in Ukrainian].

3. Lezhniuk, P., Kulyk, V., Burykin, O., Rubanenko, O., Malogulko, Yu. (2018). *Optimization of the functioning of the renewable energy sources in the local electrical systems*. Vinnitsa: VNTU [in English].

4. Fundamentals of PSCAD and General Applications. Retrieved from http://www.nayakcorp.com/Getting_Started42.ppt.

5. Makarenko, V. (2013). Prohramma sreda modelirovany enerhositew PSCAD [The software environment for modeling power systems]. *Modelirovanie radioelektronnyih ustroystv – Simulation of radio electronic devices*, 11, 44–48 [in Russian].

6. Lezhniuk, P., Rubanenko, O., Hunko, I. (2015). Vplyv invertoriv SES na pokaznyky yakosti elektrynoi enerhii v LES [Influence of SPP inverters on indicators of quality of electric energy in LES]. *Bulletin of the Khmelnytsky National University. Series: Engineering. Visnyk Khmelnytskoho natsionalnogo universytetu. Seriia: Tekhnichni nauky*, 2, 134–145 [in Ukrainian].

References (in language original)

1. Lezhnyuk P. *Optimal control of distributed sources of energy in the local electrical system* / P. Lezhnyuk, V. Kulik, О. Kovalchuk // Proceedings of the Institute of Electrodynamics of NAS of Ukraine. Collected works. Special Issue. Part 1. – 2011. – Р. 48–55.

2. Інтеграція поновлюваних джерел енергії в розподільні електричні мережі сільських регіонів / В. В. Козирський, Ю. І. Тугай, В. М. Bodunov, О. В. Гай // Технічна електродинаміка. – 2011. – № 5. – С. 63–67.

3. Оptimizacija of the functioning of the renewable energy sources in the local electrical systems / P. Lezhniuk, V. Kulik, O. Burykin, O. Rubanenko, Yu. Malogulko. – Vinnitsa: VNTU, 2018. – 124 p.

4. Fundamentals of PSCAD and General Applications [Електронний ресурс]. – Режим доступу : http://www.nayakcorp.com/Getting_Started42.ppt.

5. Макаренко В. Программная среда моделирования энергосистем PSCAD / В. Макаренко // Моделирование радиоэлектронных устройств.– 2013. – № 11. – С. 44–48.

6. Лежнюк П. Д. Вплив інверторів СЕС на показники якості електричної енергії в ЛЕС / П. Д. Лежнюк, О. Є. Рубаненко,І. О.Гунько // Вісник Хмельницького національного університе-ту. Серія: Технічні науки. – 2015. – № 2. – С. 134–145.
Аналіз останніх досліджень і публікацій. Аналіз публікацій свідчить про те, що в літературних джерелах більше уваги приділяється або дослідженню режимів роботи сонячних станцій, або малих гідроелектростанцій. Проте майже не приділено уваги дослідженню їх сумісної роботи.

Виділення недоделених частин загальної проблеми. Дуже мало робіт присвячено дослідженню сумісної роботи різних типів джерел розосередженого генерування в локальних електричних системах. У зв'язку з цим майже не досліджено їх вплив на розподільні електричні мережі та на енергосистему загалом.

Постановка завдання. У статті розглянуто вплив асинхронних генераторів на маліх гідроелектростанціях на режими роботи розподільних електричних мереж, а також досліджено процеси, які виникають у локальних енергосистемах із різноманітними розосередженими джерелами енергії.

Виклад основного матеріалу. На основі результатів дослідження розроблено комп’ютерну модель такої системи в програмному середовищі PS CAD. До центру живлення було приєднано дві сонячні станції та одну малу гідроелектростанцію. Проведено моделювання двох режимів: сумісної роботи малої гідроелектростанції, двох сонячних електростанцій та центру живлення; сумісної роботи малої гідроелектростанції, двох сонячних електростанцій та із відключеним центром живлення.

Висновки відповідно до статті. У результаті комп’ютерного моделювання показано, що випадку аварійного відключення централізованого електроснабження за допомогою відключення малої гідроелектростанції з асинхронним генератором можна відновити роботу сонячних електростанцій, а таким чином частково або повністю відновити електроснабження споживачів.

Ключові слова: локальна енергосистема; джерела розосередженого генерування; PS CAD; електроснабження.

Рис.: 3. Табл.: 1. Бібл.: 6.
Lezhnyuk, P., Hunko, I., Malogulko, Ju., Kotylko, I., Krot, L. (2018). Modeling of compatible work of distributed power sources of electric power and centralised power supply. Technical sciences and technologies, 2 (12), 189-195.