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YU.V. MALOHULKO, O.V. SIKORSKA, YU.V. SEMENIUK, V.V. HAVTIRKO
Vinnytsia National Technical University

# RESEARCH OF PROBLEMS OF DISTRIBUTED GENERATION SOURCES IN LOCAL POWER SYSTEMS

Actually *local power grid is distribution grid, which includes a source of distributed generation. Reconfiguration is the process of changing the configuration of the distribution network by changing the position of switching devices. Distributed generation sources are optimally located at points where they provide the maximum reduction in losses in the distribution network. Distributed generation sources make changes to network configuration and modes. Sources of distributed generation are a rational way to ensure the reliability of power supply in the areas of centralized energy. Distributed generation sources allows to maintain the level of stresses in the local power systems nodes, reducing the loss of active and reactive power in the network, ensuring a higher level of reliability of consumers' power supply by maintaining the power of some consumers from distributed generation sources in the case of an emergency shutdown of the main power supply of the power supply system. The connection of the distributed generation sources to the local electrical systems has a positive effect on its properties, but has some problems with the modes controlling of power supply system. The article shows the research of problems of distributed generation sources connecting and their normal functioning in local power systems. It was shown the necessity of coordination of the management of the normal and post-accident modes of distribution electric networks with the distributed generation sources by the reconfiguration of these networks. It is proposed to take into account the reliability of electricity supply of consumers due to losses from lack of electricity. The control coordination of the normal and post-accident modes of the distribution electric network is solved by minimizing switching from normal to post-accident mode.*

*Keywords: distributed generation sources, normal mode, post-accident mode, local power system.*

Ю.В. МАЛОГУЛКО, О.В. СІКОРСЬКА, Ю.В. СЕМЕНЮК, В.В. ХАВТРИРКО
Вінницький національний технічний університет

**ДОСЛІДЖЕННЯ ПРОБЛЕМ ДЖЕРЕЛ РОЗПОДІЛЕНОГО ГЕНЕРУВАННЯ В ЛОКАЛЬНИХ ЕНЕРГОСИСТЕМАХ**

*В статті досліджено проблеми підключення джерел розподіленого генерування та їх нормального функціонування в локальних енергосистемах. Показано необхідність координації керування нормальними та післяаварійними режимами розподільних електричних мереж з джерелами розосередженого генерування шляхом реконфігурації цих мереж. Запропоновано врахувати надійність електропостачання споживачів через збитки від недовідпуску електроенергії.*

*Ключові слова: джерела розосередженого генерування, нормальний режим, післяаварійний режим, локальна енергосистема.*

## Introduction

In recent decades, the world has been experiencing intensive development of distributed generation sources (DGS). Power plants that use fuel combustion processes (mini-gas turbine and gas-fired plants, biomass plants, etc.) as well as renewable natural resources (small hydro power plants, wind turbines, photovoltaic installations, etc.) belong to such sources [1, 2]. During operation in the system of distributed generation source, they are connected at low voltage (6–35 kV) to the local power system (LPS) [3]. The connection of the DGS to LPS has a positive effect on its properties, but along with it creates new problems that are encountered in controlling the modes of power supply system with distributed generation.

## Research results

A local power grid, which is essentially a distribution grid, which includes a source of distributed generation, may be unevenly loaded, and therefore needs to be adjusted for power spreading, which can be achieved by appropriate LPS reconfiguration. Reconfiguration is the process of changing the configuration of the distribution network by changing the position of switching devices, which changes the state of the network. Network reconfiguration is necessary for minimizing losses, switching the load from one feeder to another, improving voltage and stability levels, and eliminating the emergency sections of the power line.

DGS installations are optimally located at points where they provide the maximum reduction in losses in the distribution network. If the correct location of these sources is done, power loss can be significantly reduced. "Island" mode is one of the important post-accident modes of LPS with DGS. In the presence of voltage in the network, distributed generation generates electricity with parameters that fully correspond to the network. With the loss of electricity from the main supply substation, it is possible to isolate the installation of the DGS at a power close to the load, which will ensure, first of all, the supply of electricity to consumers of the first category. In the case of an accident in the main network, the DGS switches to stand-alone mode and follows the load parameters.

Distributed generation sources make major changes to network configuration and modes, resulting in requirements for traditional protection and system management vary. Currently, standards for connecting DGS to the power supply system are based on the principle that distributed generation should not affect the normal performance of protection and management of the system. Sources of distributed generation are a practically rational way to ensure the reliability of power supply in the areas of centralized energy. The main way for improving reliability is the structural redundancy.

When solving various problems, the calculation of the established mode of the electric system plays an important role. Distributed electrical networks (DENs) have some features that make it possible to use simpler methods than for hard-core electrical networks. For distributed electric networks, methods that take into account the

topological peculiarity of such networks are more effective. The most widely used method is the reverse (direct) trace, which allows you to solve the problem of calculating the steady mode of the DEN with a sufficiently complete mathematical description [4–7].

The presence of DGS allows to maintain the level of stresses in the LPS nodes, reducing the loss of active and reactive power in the network, ensuring a higher level of reliability of consumers' power supply by maintaining the power of some consumers from DGS in the case of an emergency shutdown of the main power supply of the power supply system.

In view of this, an important problem is the coordination of the management of the normal modes of LPS with DGS by reconfiguring the network while ensuring minimum power losses and maintaining the necessary limits of voltage and currents, as well as managing post-accident modes while ensuring a minimum of power shortages as a result of the loss of the main power supply by forming "islands". Such a multicriterion problem can not always be reduced to a one-sentence statement. Such a task can be solved by consistent actions, with the use of the method of colony of ants or the allocation of "islands" by the formation of cells to reconfigure the distribution network [8].

The general approach to coordinate the management of the normal and post-accident modes of LPS, including the DGS, is as follows. In normal modes, the purpose of control is to reconfigure the DEN by breaking the circuits, while the minimum active power loss in the network is considered as a criterion:

$$\sum_{n\in N} R_{nm} I_{nm}^2 \to \min,\ m\in M, \tag{1}$$

where $M$ is the set of considered normal modes in accordance with the schedules of the load of consumers and the loading of DGS; $N$ is number of branches in the network; $R_{nk}$, $I_{lk}$ are active resistance and current in the branch $n$ for $m$ mode.

In the post-accident mode, when the main supply point is lost, the task arises to provide the responsible customers with electricity by isolating the "islands" that activate the DGS, which operate on a balanced load. The criterion for the allocation of "islands" is the minimum of power shortages in post-accident modes:

$$\left(\sum_{m\in J} P_{jm} - \sum_{m\in J} P_{ki}\right) \to \min,\ m\in M,\ i\in G, \tag{2}$$

where $G$ – the number of considered post-accident modes at the loss of the main power supply; $P_{jm}$ – load in $j$ network node in normal mode $m$; $P_{ki}$ – load in node $k$ in the post-accident mode of the $i$-th part of the network, including $J$ nodes belonging to all the "islands"; $J$ – number of nodes in the network.

In the process of management coordinating of the normal and post-accident modes of LPS, an important task is to check the implementation of restrictions on the levels of stresses in nodes and currents in the network branches, both in normal and in post-accident modes

$$U_{jm\ \min} \le U_{jm} \le U_{jm\ \max}, \tag{3}$$

$$U_{ki\min} \le U_{ki} \le U_{ki\max}, \tag{4}$$

$$I_{nm} \le I_{nm\max}, \tag{5}$$

$$I_{nm} \le I_{nm\max}, \tag{6}$$

Verification of restrictions (3)–(6) in the process of optimization of criteria (1) and (2), based on calculations of the established modes of DEN, which are carried out using the method of reverse (direct) trace, taking into account DGS in LPS.

When allocating and forming "islands" it is necessary to take into account two peculiarities:

1) the presence of restrictions (4), (6), along with restrictions (3), (5), which means the difference in the requirements for the levels of stress in the nodes and the marginal loading of the branches of the network in post-accident modes compared to normal regimes;

2) providing the supply of electricity primarily to the most responsible consumers in the LPS nodes.

The control coordination of the normal and post-accident modes of the distribution electric network is solved by minimizing switching from normal to post-accident mode. This is important in terms of minimizing the number of switching devices, their possible failures, as well as staff errors, and causes the task to be considered as a complex multicriterion task.

Common approach is to take into account the reliability of electricity supply to consumers due to losses from lack of electricity, which allows the multi-criteria problem to be reduced to one-criterion [8]. To do this, you need to have accurate estimates of specific losses from power breaks for different consumers, which is not always possible. Therefore, a method of successive approximations was used to solve this multicriterion problem. In the task of allocating distributed generation to the equivalent load when power losses from the supply substation of the main electrical network (the allocation of "islands") one must take into account a number of requirements:

1) the balance between distributed generation and load must be met, so as not only to fully utilize but not to overload the distributed generation. The condition of the power balance in the "island" is using a surplus algorithm through the formation of cells. For each cell the condition is checked:

$$\sum P_{Sn} - \sum P_{Ln} \ge 0, \tag{7}$$

where *S, L* – source and load indices in the cell, *n* – cell index;

2) the formation of cells is carried out by connecting the nearest loads in the first place, while the distance of the load nodes is estimated by the total resistance of the branches connecting the source and the consumer;

3) in the formation of cells most important consumers are provided with the electricity first of all;

4) at each step of the algorithm, the flow distribution is calculated on the "island" and the restrictions are checked (4), (6). In the case of non-compliance with these restrictions, the formation of an "island" is terminated in the previous step.

One of the problems in calculating the established mode of the electric network is the uncertainty of the output data. Such uncertainty may arise when measuring the parameters of the electrical network elements. However, the main uncertainty is due to the inaccuracy of measuring, calculating or predicting loads.

The algorithm of the reverse (direct) trace works as follows:

- the initial approximation of stresses in the nodes is set equal to the voltage of the feeding node (source);
- the reverse trace is to calculate the currents of loads in the nodes and branches, starting from the final nodes of the circuit and moving to the feeding node;
- the direct trace consists in the calculation of the voltage drops in the branches, the values of the voltages in the nodes, starting from the feeding node, and the control of the convergence of the iterative process on the basis of voltage modules comparison of the current iteration and the previous one.

The procedure for solving a multicriterion problem by the method of successive approximations is as follows:

- all partial criteria are located and numbered in the order of their relative importance;
- optimize the first, most important criterion;
- assign the value of the permissible deviation from the optimum of the first criterion (errors);
- optimize the second most important partial criterion, provided that the value of the first criterion does not differ from the optimal value more than the value of the established error.

In general, if necessary, the described procedure may include several iterations converging to a satisfactory compromise solution.

## Conclusion

When the local power system with the distributed generation sources is functioning, there is a need for coordination of normal modes control. This is possible when reconfiguring the network, which will reduce power losses. Also, the necessary limits of voltage and current changes will be observed.

The research has shown that the as managing post-accident modes while ensuring a minimum of power shortages as a result of the loss of the main power supply by forming "islands". Taking into account the complication of calculating the multi-criteria problem, it is proposed to take into account the reliability of consumers' power supply due to losses from lack of electricity, which allows the multi-criteria problem to be reduced to one-criteria.

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