Microgrid Energy Management System for Reducing Required Power Reserves

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***Abstract*—One of the promising directions for finding solutions to the problems of regimes management and commercial electricity accounting in electric power systems is the application of distributed ledger technologies - Blockchain, which is due to increased availability of renewable energy sources. Currently, in the Russian Federation, the use of Blockchain technology is difficult for electric power systems operating in parallel with regional or unified power system due to the legislative restrictions imposed on operations in the retail and wholesale market for electrical energy. However, based on the distributed ledger technologies, the principles of the functioning of the electric energy market can be applied within the framework of small isolated electricity systems - microgrids. Mathematical modeling and calculation of the microgrid electric regimes were performed in the RastrWin3 program with the aim of accounting for losses in the electric power system. During the simulation it was obtained dependence of the power at the slack node from the number of load nodes for a different ratio of own generation to consumption in the node. In the case of positive power, there was a shortage of actual power in the system at the slack node, and in the case of a negative one, there was an excess of it. The use of distributed generation is economically justified in small isolated electricity system: the payback period of distributed generation devices is much less than their lifetime. It is possible to use Blockchain technology to organize mutual settlements between owners of small generation facilities in microgrid.**

Keywords—microgrid; solar power generation; energy management; batteries; distributed power generation

I. INTRODUCTION

Modern electric power industry is one of the most science-intensive and technological industries. One of the promising areas for finding solutions to the problems of managing regimes and commercial metering of electricity in electric power systems is the use of distributed registry technologies, which is due to the increased availability of renewable energy sources that are combined into systems with distributed generation [1]. At present, in the Russian Federation, due to legislative restrictions imposed on operations in the retail and wholesale electricity markets, the use of systems with distributed generation is difficult for power systems operating in parallel with united power system.

Currently, there are a lot of regime's control methods and ways organization of commercial accounting in microgrids. These include: the method of controlling inverters connected to the network, combining adaptive control of reducing the reduction rate with fuzzy PID control [2]; methods using intelligent neural network technology to obtain the correct gain for inverters [3]; a finite control set model predictive control (FCS-MPC) structure is aimed to compensate for voltage deviations rapidly [4]; a control method based on the consensus of distributed and centralized algorithms in order to improve the control of the distributed energy of the microgrid [5]. However, these methods don't focus on the reducing microgrid infrastructure costs.

This paper proposes the use of an automatic device implementing the distributed registry technology to account for the electricity transmitted and consumed at each node of the electricity network through a system of self-fulfilling contracts, as well as performing the functions of automated control of microgrid modes.

The purpose of this work is to substantiate and implement the principles of control modes and commercial metering of electricity in microgrids using an automatic device implementing distributed registry technology to solve the problem of high costs of personal generating devices at private energy sector. Management in this case is aimed at reducing the required power reserves, considering the required level of reliability of power supply and power quality. At the same time, the market mechanism within the micro-network is organized based on approaches [6-7].

The proposed system allows each microgrid participant to significantly reduce their capital costs at the design stage, which will undoubtedly be relevant for common consumers of isolated districts in the conditions of high cost of autonomous generation using renewable energy sources [8-11].

II. RESULTS

The calculation of the operating mode of the system under consideration was made in the RastrWin3 program to account for losses in the electric power system.

The 0.4 kV power supply scheme consists of a few load nodes and one balancing node. Each node is a house with its own generation in the form of a small solar power plant in combination with batteries. The secondary winding of a 6 (10) /0.4 kV transformer or diesel generator set can act as a balancing node in a real system.

For the power supply system of a residential settlement of several (from 2 to 40) households, the potential for reducing the generation capacity of a single household was analyzed

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under the condition of combining households into a microgrid, which implements the proposed algorithm for steady states management.

Figure 1 shows a plot of the power shortage (the difference between the power consumed and the power generated) versus the number of microgrid participants for the cottage community. The installed capacity of each house is 14 kW. For the calculations, 7 variants of solar stations were used: 1.5 kW; 2.4 kW; 3.2 kW; 4 kW; 4.5 kW; 6 kW; 8 kW.

The calculation of power consumption was carried out according to the method of a similar method for calculating the power of 10 / 0.4 power transformers. In this method, the following factors are used: the demand factor that is responsible for the fact that every single house will not consume power equal to the established one and the coefficient of simultaneity, which is responsible for the fact that all houses in the microgrid will not simultaneously consume power equal to their fixed one. The values of these coefficients are determined by the number of participants in the microgrid.

From the graph (Fig. 1) with 37 participants in the system, it is enough to purchase a solar station of 1.5 kW. That is, to reduce the installed capacity of the station of one microgrid participant by 9.3 times.

Figure 2 shows a plot of the power deficit versus the number of microgrid participants for the blocks of flats. The installed capacity of each flat is 12 kW. For calculations, 7 variants of solar stations were used: 1.5; 2.4; 3.2; 4; 4,5; 6; 8 kW.

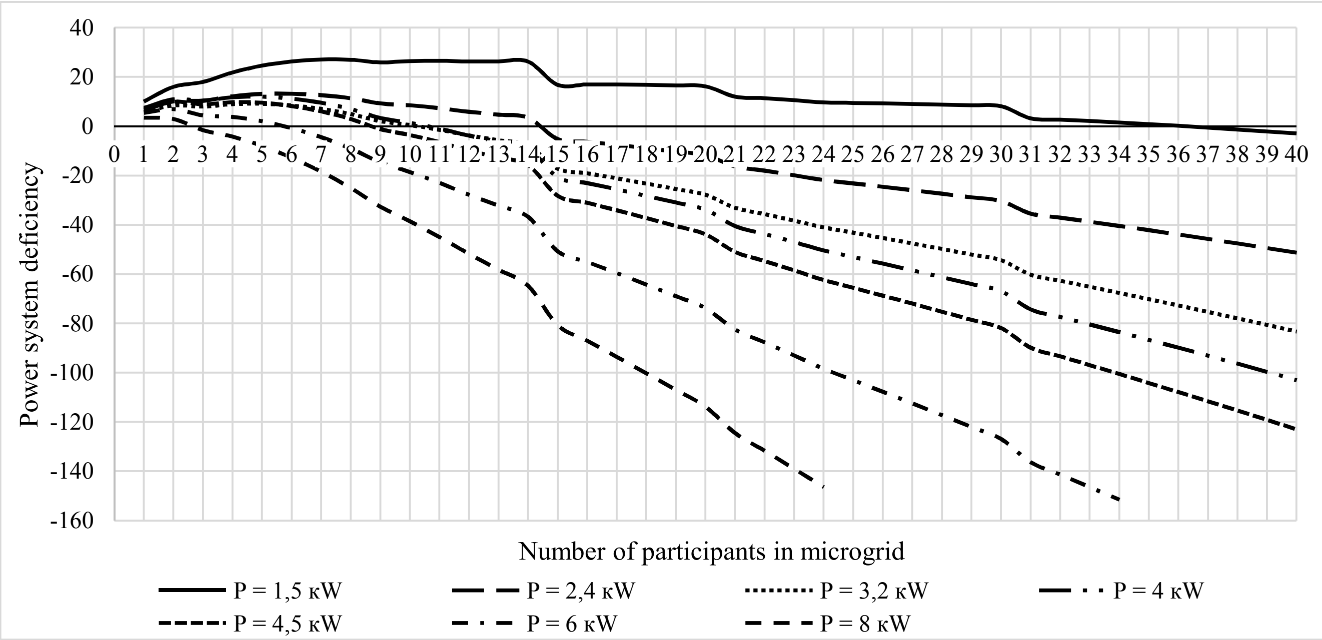

Fig. 1. Dependency graph of power system deficiency number of participants for villa community

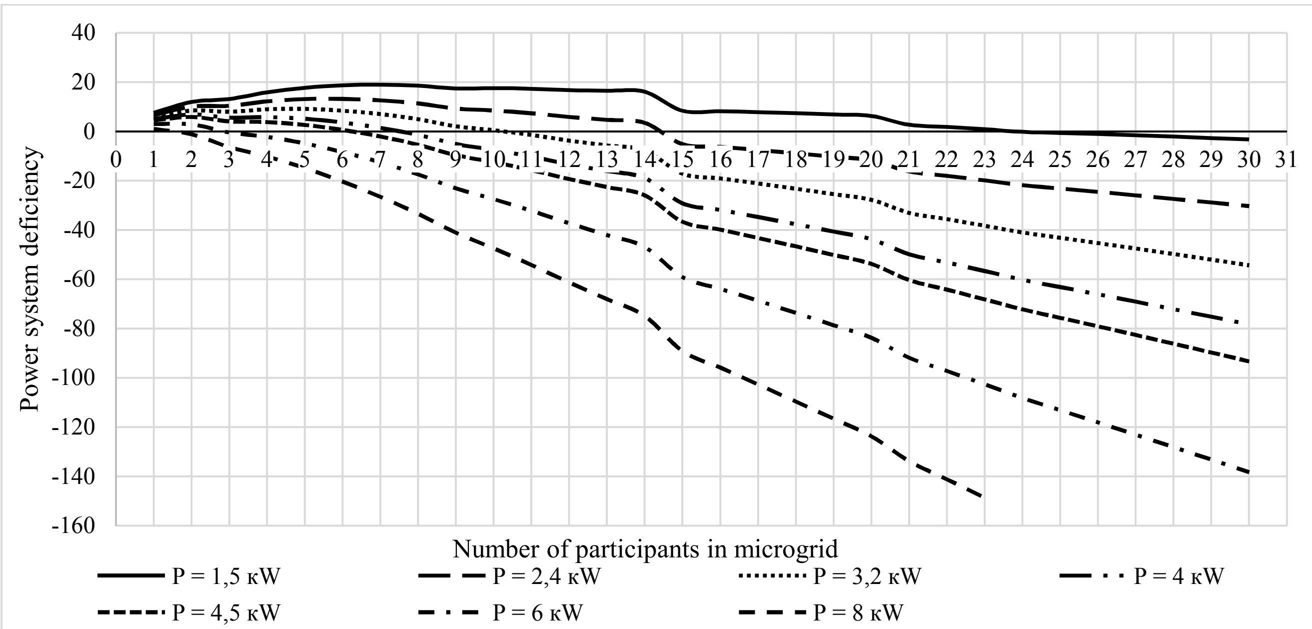

Fig. 2. Dependency graph of power system deficiency number of participants for blocks of flats

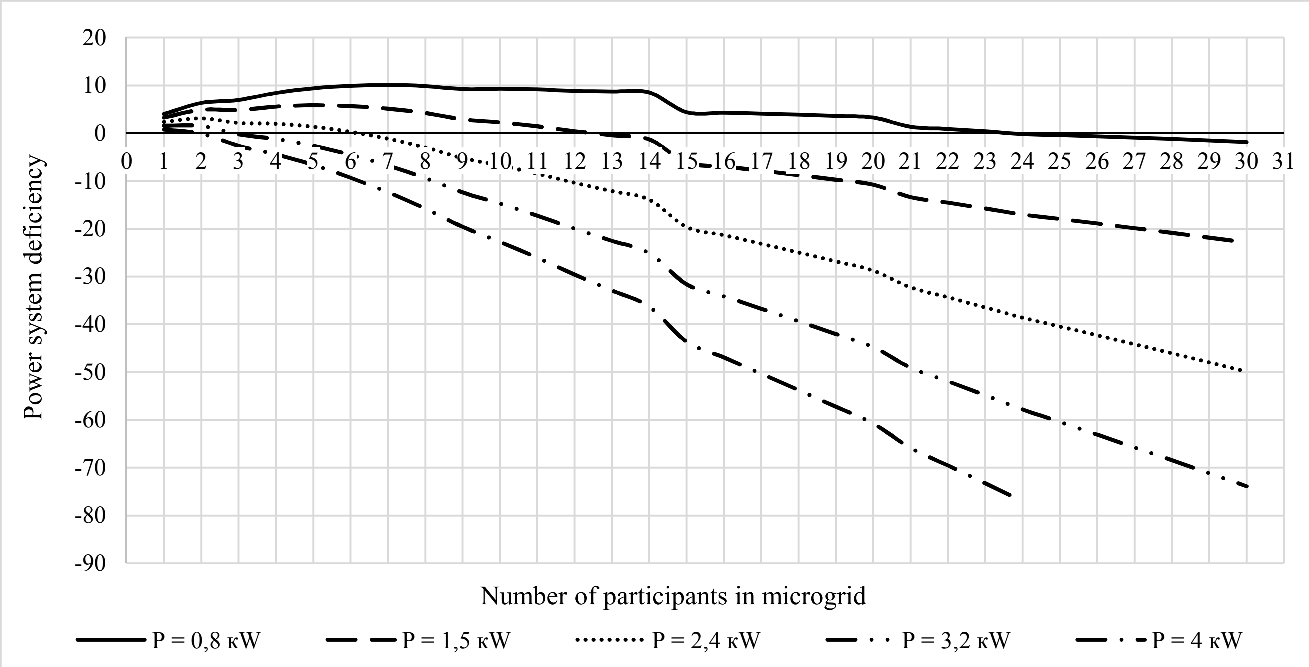

Fig. 3. Dependency graph of power system deficiency number of participants for holiday village

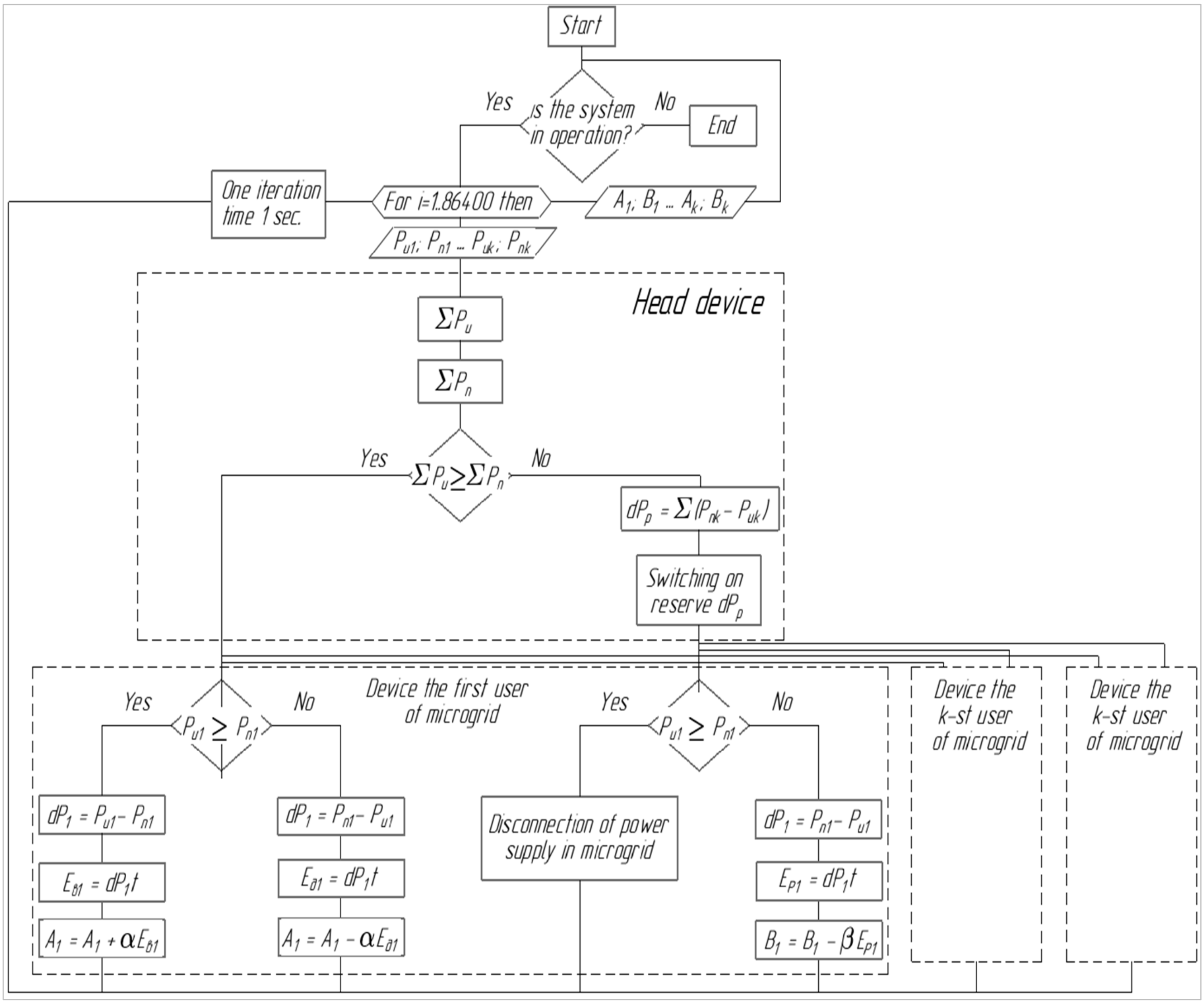

Fig. 4. Algorithm for an isolated power system

From the graph (Fig. 2) with 24 participants in the system, it is enough to purchase a solar station of 1.5 kW. That is, to reduce the installed capacity of the station of one participant microgrid 8 times.

Figure 3 shows a plot of the power deficit versus the number of microgrid participants for the holiday village. The installed capacity of each house is 5 kW. For calculations, 5 variants of solar stations were used: 0.8; 1.5; 2.4; 3.2 and 4 kW.

Figure 4, where P_{uk} - own generation power of the k-th user of microgrid; P_{nk} - the power consumption of the k-th user of microgrid; ΣP_u - the total power of its own generation; ΣP_n - total power consumption; dP_k - the difference between consumed and generated power in the node; dP_p - the power of the input reserve; E_{Bk} - electric power delivered to the network by its k-th user; E_{dk} - electricity consumed from the network by the k-th user; E_{pk} - electricity consumed by the k-th user of the network from the reserve; α - the tariff for intra-grid electricity in local currency; β - tariff for electricity from the reserve in real currency; A_k is the balance of the k-th network user in local currency; B_K is the balance of the k-th network user in real currency, shows the control algorithm for an isolated power system. It implements automated control of the microgrid mode. After sending a signal to the head unit in the system, a continuous calculation and recording of the active power balance in the power system starts with a discretization of 1 s. If the balance of power is observed, if the generated ΣP_{ik} exceeds the power consumption of ΣP_{pk} or vice versa, the corresponding signal is sent to each slave device in the network. In the user's slave device, the local balance of active power is calculated, on which the further accounting of user balances in real and local currencies depends. If there is an excess of generated active power P_{ik} in the home of the k-th user of the network, then he gives it to the microgrid network.

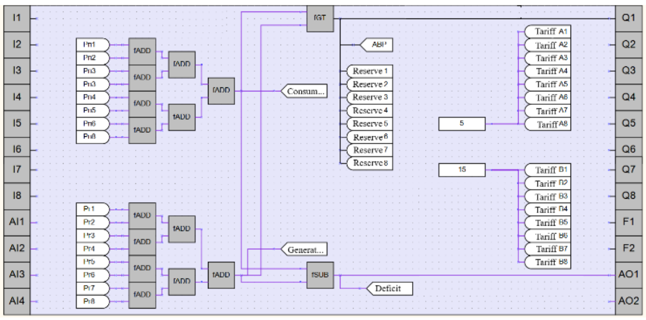

Fig. 5. Isolated grid control program for head devices

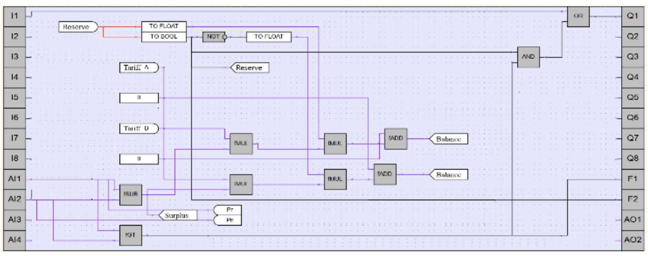

Fig. 6. Isolated grid control program for slave devices

Consider a situation where the own electric power in a microgrid is not enough - the power consumption of ΣP_{pk} exceeds the generated ΣP_{ik}. In this situation, according to the signal of the head unit, an automatic input of the reserve to the power specified by it occurs. The industrial programmable electronic controllers OWEN Logic are used as the head and slave devices in the real system (Fig. 5 and 6).

III. CONCLUSIONS

The use of distributed generation in small isolated power systems is economically justified: the payback period of distributed generation devices is significantly less than their service life. For the organization of mutual settlements between owners of small generation facilities in a micro grid it is possible to use the technology of self-fulfilling contracts. The considered settlement system scales well and can be applied not only within the microgrid, but also when several microgrids are combined into a single network.

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