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Experimental Study of the Applicability of Simple Microcontrollers for Implementing the Microgrid Decentralized Synchronization Method in the Electrical Network

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ABSTRACT

Abstract: Currently, on the basis of local power supply systems with small distributed generation, active networks called Microgrid are formed. Such networks can be adapted to work both independently and in parallel with the external network. In such networks, it is difficult to synchronize sources. The purpose of this paper is to study the features of implementing the Microgrid decentralized synchronization method on simple controllers and assess the sufficiency of their technical capabilities. Atmega 328P – Arduino NANO and UNO were used as microcontrollers.

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1. INTRODUCTION

One of the important tasks of ensuring the normal functioning of small-scale generation facilities distributed over the network is synchronization and their further parallel operation with other small-scale generation facilities or with a high-power network in order to achieve the maximum system effect and ensure high reliability in power supply to consumers [1,2].

The main factors that determine the features of MicroGrid synchronization with each other and with the external power system are their low inertia (about 1 s) and high load stochasticity, which determine an order of magnitude more intense fluctuations in frequency and mutual angles during synchronization.

Microgrid synchronization differs from the classical synchronization of generators and parts of power systems with each other. The difference lies in capturing the stochastic moment of synchronism.

Depending on the type of management, there are two ways to synchronize Microgrid with each other or with an external network [3,4], such as:

- Passive synchronization method – when a situation is expected in which the measured synchronization parameters on both sides of the switching device are equal or close to each other. This type is easy to implement, but as a rule, the synchronization process is delayed [5,6];

- Active synchronization method-uses additional control, as well as transmitting data about mode parameters to enter the synchronized parameters into the allowed range, and this provides a faster and smoother connection of Microgrid to an external network [7,8].

To achieve successful synchronization of Mini- and Microgrid in active networks, a method for remote synchronization and restoration of the normal mode of an emergency-separated electric network with generators is proposed [9]. The purpose of the method is to automatically synchronize and restore the normal mode of parallel operation of separated parts of the electrical network on remote switching devices without using data transmission and remote control commands.

As a rule, after the collapse of the network in its divided parts, it is not always guaranteed that the power balance is maintained. As a result, there is no possibility of successful synchronization. To achieve successful synchronization, a special system for controlling the power and excitation of generators is proposed (Fig. 1).

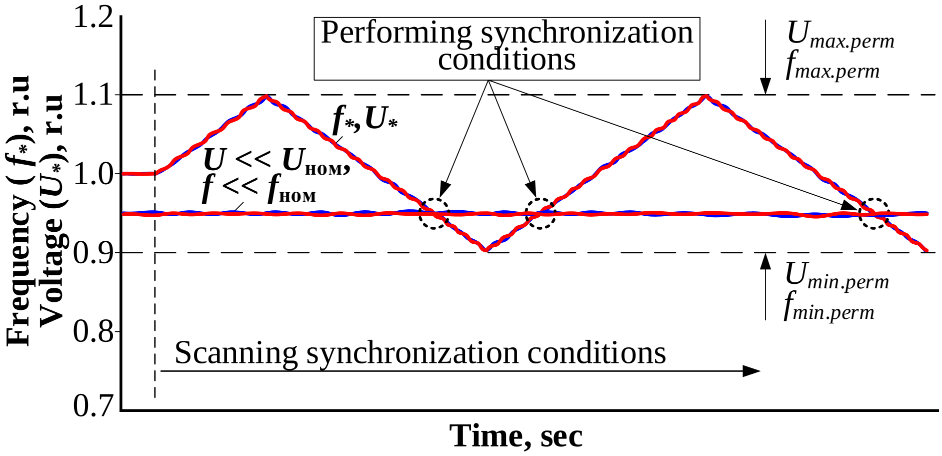


Figure 1. Typical schedule for scanning synchronization conditions

When performing scans in balanced classes, when syncing with other harmonized classes, the point of intersection of the parameters of the two parts of the network will necessarily appear, which naturally leads to the fulfillment of synchronization conditions. As a result, the starting elements of the automatic re-activation device with synchronization detection are triggered, including the switching device connecting these parts of the network.

The aim of this study is to implement a method for decentralized synchronization of Minigrids on simple microcontrollers and assess the sufficiency of their technical capabilities.

2. IMPLEMENTATIONS OF THE PROPOSED METHOD ON SIMPLE MICROCONTROLLERS

The scheme of the experimental setup is shown in Fig.2. It contains two Microgrid models, represented by a generator with its own load (G1, H1 and G2, H2) and an electrically remote switch. Model generators consisting of 3 and 5 kW power units were used as generators.

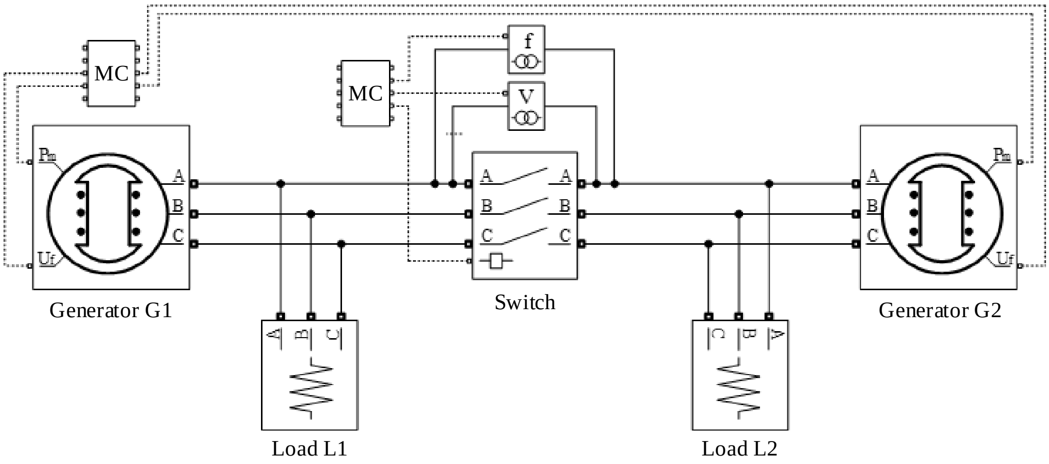
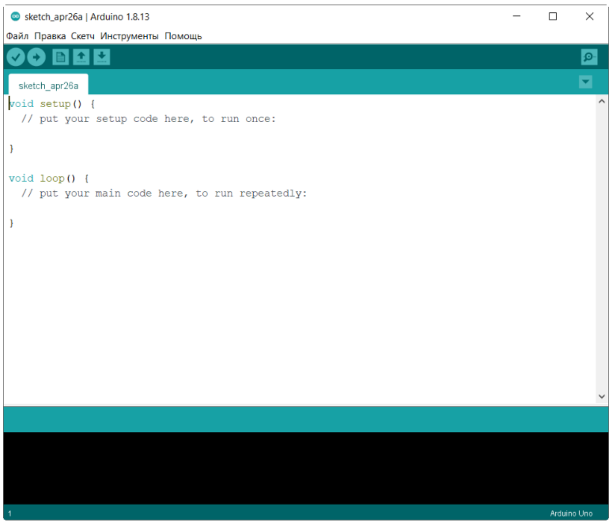


Figure 2. Experimental setup diagram.

Control is implemented on two microcontrollers (MC). Widely used microcontrollers of the ATmega (Arduino) family are used as control controllers. Arduino is an open-source platform based on the built-in ATmega microcontroller and the Arduino IDE development environment with a software interface [10-12] (Figure 3).

a)



b)

Figure 3. ATmega microcontroller (a) and its software interface (b)

In the experiment (Fig. 2), one of the microcontrollers performs the functions of identifying the network division into parts, normalizing the voltage and frequency in each of the Microgrid after separation, supplying periodic (scanning) power and excitation control signals to each of the generators, and identifying the remote switching on of the generators for parallel operation with the termination of scanning mode.

The second microcontroller monitors the fulfillment of synchronization conditions on the remote switch (normality of voltages, tolerance of frequency differences, modules and phase of voltages) and issues a command to turn it on.

Microcontrollers based on Atmega 328P – Arduino NANO (on generators) and Arduino UNO (on a switch) were used as MC. Measurement of operating parameters, in particular frequency and voltage on both sides of the switch, was carried out using transistor optocouplers of the PC817C type and voltage sensors of the ZMPT101B type [13, 14], respectively (Fig. 4).

a) b)

Figure 4. Frequency meter based on PC817C optocoupler (a) and ZMPT101B voltage sensor (b)

Microcontrollers are multifunctional, have developed peripherals, bidirectional I / O ports with built-in pull-up resistors. The configuration of the Input/Output (I/O) ports is set programmatically. The main parameters of the ATmega328P microcontroller are shown in Table 1 [16].

Table 1. ATmega328P Microcontroller Parameters

Name	Features
Core	8-bit AVR
Clock frequency	16 MHz
Flash-memory	32 KB
RAM-memory	2 KB
EEPROM-memory	1 KB
I/O Pins	20
Interrupt pins	2
Pins with ADC	6
ADC bit depth	10 bits
PWM Pins	6
PWM width	8 bits
Hardware interfaces	1× UART, 1× I^{2}C, 1× SPI
Logic level voltage	5 V
Input supply voltage	5 V
Maximum output current of 3V3 pin	150 mA
Maximum pin output current 5V	1 A

The peculiarity of monitoring the fulfillment of synchronization conditions is that the characteristics of simple controllers limit the complexity of the algorithms used and their speed, in particular, the measurement of voltage phases. Therefore, the conditions for the admissibility of switching on the switch are converted to the normality of the voltage and frequency modules, the admissibility of the frequency difference, and the admissibility of the voltage difference module at the ends of the switch (if the voltage modules are equal and the voltage difference module is zero, we have equality of angles between the voltage vectors).

Figure 5 shows the connection of microcontrollers to the measurement and control circuits of the active network circuit (Figure 2).

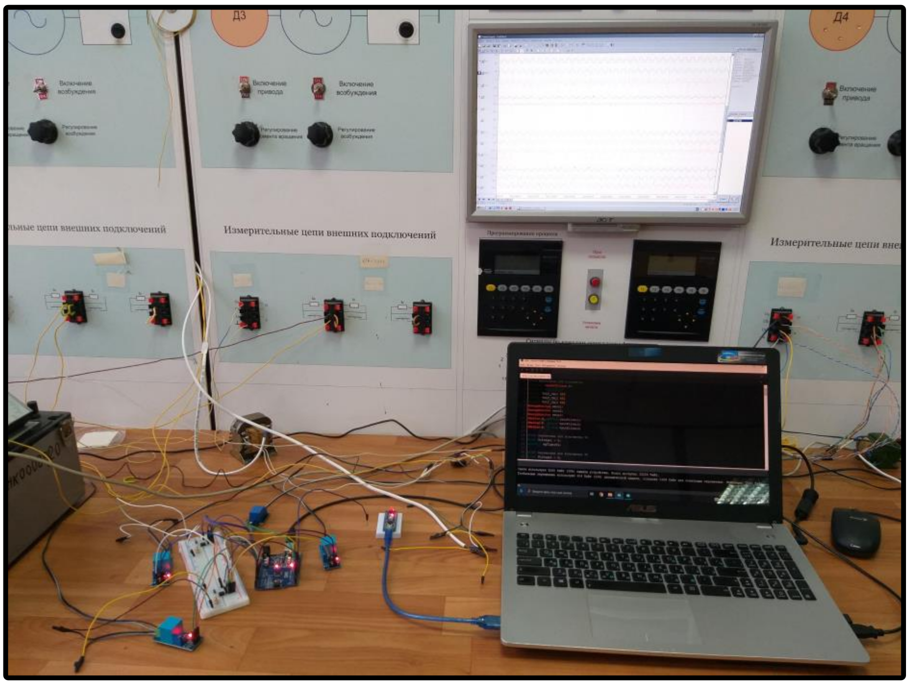


Figure. 5. Photo frames from the course of the experiment

3. EXPERIMENTAL RESULTS

Figures 6 and 7 show characteristic waveforms of processes during the decentralized inclusion of Microgrid models in parallel operation.

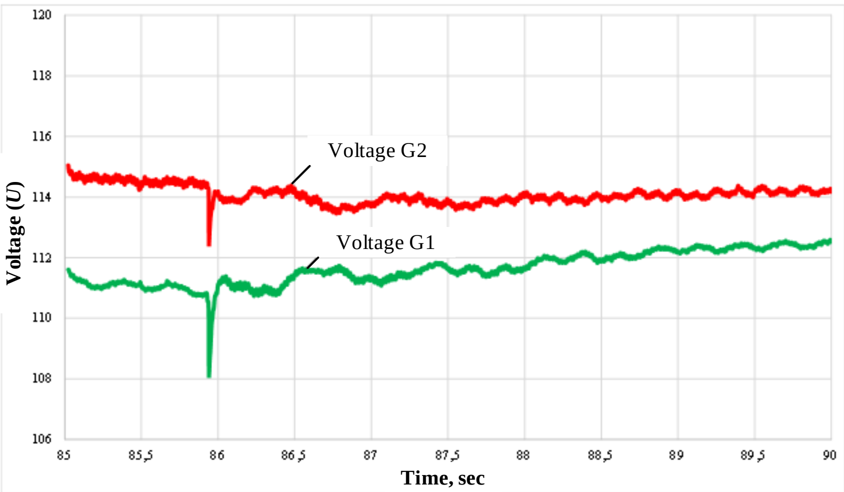


Figure 6. Oscillogram of generator voltages

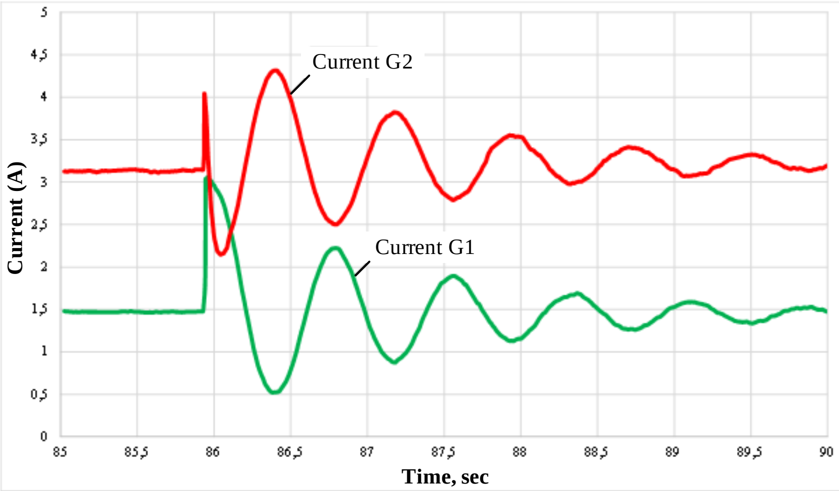


Figure 7. Oscillogram of generator currents

Thus, on the basis of microcontrollers of the Atmega 328P family, a successful application of decentralized synchronization of generators was carried out. However, due to the low performance of the Arduino UNO microcontroller, which led to an increase in the error when measuring the voltage angle, it was not possible to achieve the minimum switching current.

4. CONCLUSION

During the experiment, it turned out that simple microcontrollers provide the possibility of using remote synchronization. When analyzing the results obtained during the experiment using simple microcontrollers of the Atmega 328P family (UNO, NANO), it turned out that these microcontrollers have a low calculation speed. This led to a delay in receiving / transmitting information and commands when the switch was turned on. As a result, due to a large error in the angle, the connection to parallel operation was accompanied by a surge of equalizing current.

In order to minimize the measurement error, the continuation of this study is planned to use more advanced microprocessors that have greater power and high calculation speed.

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