Automation of control of electric generators from renewable energy sources in hybrid power supply systems

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Abstract. The article notes that due to the increasing number of electricity generating equipment based on renewable energy sources and consumers of electricity received from them, it becomes necessary to combine generating sources, consumers and control units into autonomous electric power systems. Due to the uneven generation and consumption of renewable energy sources under the influence of external conditions (wind, solar radiation, etc.), renewable energy sources should be reserved by means of traditional energy in the so-called hybrid mode, when traditional alternators must work together with renewable energy sources. In this case, the task of creating a tracking inverter that converts direct current (DC) to alternating current (AC) according to the characteristics of the AC generator arises. At Bauman Moscow State Technical University the experimental samples of a DC-to-AC inverter with its own logic and microcontroller have been developed and created. They control the conversion mode either by the signals of the reference AC network, or by the signal of the microcontroller. The proposed devices are designed to fully automate power generation processes and power consumption processes in hybrid power supply systems and are designed to manage input and output generating capacities and power consumers to ensure maximum efficiency of power generation from renewable energy sources.

The main reason for developing alternative energy based on renewable energy sources in Russia is its huge size and the inaccessibility of many regions of the country for centralized electricity supply. The area of districts not covered by centralized power supply in Russia is more than 60% of its territory. In such areas, in most cases there is a need to attract renewable energy sources for their electrification. That is, renewable energy sources should be considered as autonomous energy sources, which form the basis of a new, intensive developing direction - distributed generation. At the same time, it should be noted that there are no fundamental obstacles to the operation of renewable energy sources as part of centralized energy systems [1,2].

Methods of electrification of territories of the Russian Federation that are not covered by the centralized power supply network can be as follows:

- construction of power lines from the centralized power supply network, which are characterized by such negative features as the high cost of construction and maintenance of power lines and related equipment, as well as the risk of failure of power lines and their length dependence on the transmitted power;
- organization of local autonomous power generation centers using electric and heat generators
using classic fuel (thermal power plants, diesel and gas generators), which are characterized by
dependence on imported fuel, which often significantly increases the cost of heat and electric
energy;
• electricity supply using renewable energy sources. having such positive features as universality
of application (always available any energy carrier), absence of need for construction of long
power lines, environmental friendliness of power supply and high prospects of technical and
economic improvements [3].

The increase in the number of power generating equipment based on renewable energy sources and
consumers of the received electricity has led to the need to combine generating sources, consumers
and control units into electric power systems. The main barriers to the development of such systems
are, first, insufficient development of production facilities for power plants with renewable energy
sources, as well as uneven external factors and conditions for obtaining energy (wind, solar radiation,
etc.). In this regard, renewable energy sources are backed up by traditional energy resources.

Creating autonomous electric power systems based on renewable energy sources requires solving a
number of problems due to their features:

• a large number of independent power generating units;
• different principles of power generation and different parameters of the received current;
• distance of renewable energy sources ’ generation facilities from consumers and large areas
occupied by generation facilities;
• the need to ensure a stable power generation capacity of the generated and transmitted capacities
renewable energy sources;
• storage and conservation of generated energy;
• utilization of excess energy.

The technological process of organizing power consumption in Autonomous systems based on
renewable energy sources should be flexible by enabling and disabling various methods of power
generation or using them in hybrid mode, that is, in the mode of joint operation of traditional sources
and energy sources from renewable energy sources.

Hybrid mode of operation from the point of view of the organization of power supply is the most
difficult for the electric system: it is used when there is insufficient power generation from renewable
energy sources and in cases of peak loads in the power supply system. A short-term increase in
consumption occurs, for example, during the start of powerful electric motors, or may be caused by a
particular technological process.

The process of generating electricity from renewable energy sources is only the first step in a long
chain of energy supply to the end user. After receiving electricity from renewable energy sources, it
must be converted for subsequent storage and storage.

Creating autonomous hybrid power supply system’s involves working together with alternators
(such as diesel generators) and renewable energy sources that generate both alternating current (such
as wind turbines) and direct current (such as solar panels).

To use electricity generated by renewable energy sources, it is necessary to convert it to meet the
requirements of power consumers. DC-to-AC inversion usually occurs according to the specified
parameters. The inverting parameters are determined either by the requirements of the consumer or by
the electrical network to which the renewable energy sources generator is connected via an inverter.
Performing the required parameters by the inverter when investing is mandatory, since if the
parameters of the AC current received at the output do not match, the equipment operating at the
received voltage may fail. In the case of connection to mains electric power source generating the
current with parameters different from the current electrical network, the backup generator can start to
work in user mode, it will not lead to the increase and decrease in the total power outlet.

Thus, it became necessary to create a tracking inverter that converts DC to AC according to the
characteristics set by a parallel AC generator. For this purpose, at Bauman Moscow State Technical University a device has been developed that inverts DC to AC according to the parameters of the main (reference) network [4].

In practice, it is not uncommon for the inverter to operate in the absence of voltage in the reference network. To solve this problem, a microcontroller was integrated into the device, which sends control signals for inverting if there is no voltage in the reference network. In this case, the frequency and phase shift angle are generated by the signals generated by the microcontroller.

In the practical organization of power supply from several sources of power generation, it is possible not only to work in parallel on the load, but also to work separately in cases of low load and (or) sufficient power of one of the sources. In this case, it is necessary to automatically switch the inverter from one operating mode (from the control signal of the reference network) to another (the microcontroller signal) or backwards.

When operating the inverter, the signal from the reference network is considered to be the priority, since in this case it is necessary to ensure the coordination and operation of parallel generators in the general network for the total load. The signal from the microcontroller should work if the signal from the reference network disappears, in this case, the phase shift angle does not play a role, since the generator is the only one. Switching between signals must be provided by the device's own logic, which must be derived from the microcontroller to improve the device's reliability.

In this regard, at Bauman Moscow State Technical University an inverter circuit with automatic mode switching between inverting control signals has been developed and tested. The diagram of such an inverter is shown in figure 1.

![Inverter with automatic switching between inverting control signals](image.png)

**Figure 1.** Inverter with automatic switching between inverting control signals.
The device works as follows. To obtain the reference inverting parameters, the device is connected to the reference AC network via a step-down transformer T1, the voltage from the secondary winding of the transformer is lowered to the required value and, passing through a pair of diodes D2 and D3, is supplied to the LM239 synchronizer. Resistor R2 is used to prevent a short circuit in the electrical circuit of the secondary winding of the transformer. The second signal, taken from the secondary winding of the transformer T1, passing through the diode D4 and the resistor R3, is inverted twice by the Schmitt triggers U8B and U5B and enters the “And” logic element. If there is a signal from the reference network, the signal is equal to the logical "0" and thus interrupts the inverting signal coming from the MC1 microcontroller. The capacitance C1 and the discharge resistance R4 serve to extend the signal from the reference network for 1 (one) period in case of loss, which is necessary to prevent a sharp transition of the inverter operation to the signal from the microcontroller. When the signal from the reference network is lost, the logical "0" turns into "1" on the U5B inverter, which goes to the logic element "I" U6B. As a result, the U6B begins to pass a signal from the microcontroller, which becomes a control signal for the inverter, determining the frequency and angle of phase shift of the inverted AC voltage. The "And" logic element receives inverting control signals taken from the reference network, or from the microcontroller if there are no signals from the reference network. The output signal from the logic element "Or" passes through 2 (two) Schmitt triggers U2B and U1A is split into two signals that are in opposite phase, which are received by MOSFET transistors Q2 and Q1, which are alternately opened from signals coming from the Schmitt triggers U2B and U1A. The Potential from the V12 battery through the transistors Q2 and Q1 alternately enters the primary winding of the transformer in opposite directions, which forms an alternating voltage in the secondary winding of the transformer T2 set frequency and phase shift angle. The value of the voltage is determined by the parameters of the transformer T2 and is 220V as the most frequently used.

Hybrid power supply systems using renewable energy sources will be increasingly automated in the future based on the use of microprocessor technology in order to fully automate the processes of power generation and power consumption in them, as well as to manage the input and output generating capacities and power consumers to ensure maximum efficiency of power generation from renewable energy sources.

The development of energy from renewable energy sources, the increase in the number of generating equipment based on renewable energy sources and consumers of the received electricity leads to the need to create autonomous power systems and, first of all, in the areas far from the centralized power supply zones.

The creation of electricity systems based on renewable energy sources requires further research and development in order to improve their efficiency, which can be achieved by more efficient power generation and automation of control of generating sources, as well as by reducing energy losses in all parts of the system.

Presented in the report engineering developments of Bauman Moscow State Technical University enables to coordinate the operation of a traditional electric generator and power generation sources based on renewable energy sources, as well as integrate renewable energy sources into the centralized power systems, thereby increasing their total capacity and reliability of power supply.

References
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