Microprocessor-based watching control system for improved ladder-type rectifier

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Abstract. Currently, the most energy-efficient device designed to convert AC to DC is a zone converter built on the basis of controlled power semiconductor devices: thyristors and transistors. The basis of these converters work is the zone-phase regulation method. The paper discusses the construction of a microprocessor control system for improved four-zone rectifier. The tasks aimed at energy efficiency achievement have been set and solved, the relevance of the tasks is justified. The microprocessor control system development stages including the drivers creation with galvanic isolation for thyristors and transistors control and greed synchronization are shown. Justification and choice of feedback are produced. The control algorithm for power semiconductor devices incorporated in the control program is given. For better understanding of the system operation principle, a block diagram which is based on a program written for the microcontroller is given. That program reflects the control system algorithm. Software modeling of the proposed system is carried out, the modeling results are presented.

1. Introduction
Energy indicators increasing is one of the most important area for the development of electrical engineering, since they directly depend on energy savings, the production of which becomes more expensive every year. At the Department of Electrotechnical complexes NSTU the work aimed to improve the existing converter devices with improved energy performance is held [1]. These devices use modern power semiconductor devices (PSD) – IGBT transistors, which provide possibility of sector control, and thyristors, which require an efficient and safe control system [2].

2. Control system development
For the correct work of the zone rectifier power module, an electronic microprocessor system that represents both hardware and software implementation of a multi-channel control system is proposed. Due to the fact that certain parts of the circuit power module will be under different potentials of large value there is a control system low-voltage part electrical breakdown danger and electric locomotive control loss. In addition, high electric potential is a danger to the person who works directly with the control system. To avoid possibility of operator electrical current strikes, it is necessary to provide a connecting element between the control system and the power module. Such element in the work proposes a module of drivers with galvanic decoupling, the presence of which will ensure the transfer of control signals without transferring dangerous electric potential (Figure 1) [3].
The galvanic isolation in the driver module is achieved through the use of an optron. The authors have developed and successfully tested in practice driver modules with galvanic decoupling for IGBT transistors and thyristors control [4]. Schematic solutions of such drivers proposed by the authors are shown in figure 2 and figure 3.

![Figure 1. Galvanic isolation between circuits with different potentials.](image1)

**Figure 2.** The driver electric circuit for a single transistor.

![Figure 3.](image2)

**Figure 3.** The driver electric circuit for a single thyristor.
In order to properly organize the control in the AC network, control pulses of the rectifier should be supplied with control pulses at certain points in time that are synchronized in phase with the supply voltage. To do this, it is necessary to use device that allows determining the origin of a single-phase AC network. One of the power transformer secondary windings is used as supply voltage phase position signal source. The voltage from this winding is fed to the device – the detector, which programmatically monitors the supply voltage sinusoid position in real time [5].

As feedback, it was decided to use speed feedback, as the most accurate, and at the same time, simple to implement.

To implement the feedback, a speed sensor suitable for use with the microcontroller used was chosen. Namely, the speed-voltage generator is designed by Baumer Hubner brand GT7.

At the heart of the microprocessor control system, there is RISC – architectural microcontroller ATMega2560. The source of the control input signal is a dial, the position of the handle of which is processed by the control system, after which the control zone is programmatically determined. The angle of the handle determines the signals time delay for the PSD opening and closing, corresponding to a specific control zone and a specially developed algorithm for the signals generating, shown in figure 4 [6].

Figure 4. An improved zone-phase rectifier: (a) a power unit circuit; (b) a control diagram of semiconductor control depending on a regulation zone.

One of the most difficult issues in the zone regulation principle implementation is the supply voltage level variability due to the dynamic nature of the stochastic processes which are occurred in the power supply system and the load connected to it. This makes it difficult to use an algorithm with fixed time frames. In this regard, the task of ensuring the PDS control algorithm flexibility, taking into account the variability of the parameters of the single-phase AC power supply network for control parameters efficient and reliable observance set by the driver was set and solved [7]. Such solution is based on subprograms which have ability to track phase shifts in the supply network [8].

To test the effectiveness of the proposed solutions, a software model of a zone rectifier is developed at the ETC department.

3. Results and discussion
On the basis of the technical solutions proposed and tested by the software method, physical modeling of the proposed system was carried out (Figure 5). The most interesting results of experiments are in the first and second control zones. The first zone implements sector regulation of IGBT transistors, which allows a significant increase in the power factor of a rectifier operating in the low input voltage range [9, 10]. In the second zone, the transition to the phase regulation of the thyristors at the maximum opening time of the transistors. Phase regulation in the third and fourth zones is carried out by analogy with the second, so for testing on the physical model of all the nuances of the control system operation, it is enough to recreate the first two control zones (Figures 6 and 7).
Figure 5. Ladder-type rectifier physical model.

Figure 6. A diagram of the rectifier output voltage (operation in the sector control mode): 12.5 %, 75 %, 95 % fill coefficient (FC), respectively.

The experiments results confirms the expected nature of the voltage under study, depending on the control angle $\alpha$ and the specified PSD control algorithms, and maintains stable continuous operation when switching from one zone to another under the dynamic nature of the change in the value of the AC supply voltage within 10 %.
Figure 7. A diagram of the rectifier output voltage (2nd regulation zone): 23°, 92°, 167°, thyristor opening angle, respectively.

4. Conclusion
During the system development, the following tasks should be solved: control algorithm for improved zonal rectifier circuit creation, a program for a single-chip microcontroller compilation, ensuring safe system operation by creating drivers for PSD, coordinated operation of the control system with the power module ensuring, and system testing by the modeling method.

The following objectives have been achieved:
1. Control algorithm for improved zonal rectifier circuit is created.
2. Program for a single-chip microcontroller is compiled.
3. Safe system operation is ensured by creating drivers for PSD.
4. Operation of the control system with the greed is coordinated.
5. System is successfully tested.

Thus, the physical model of an improved zone-phase ladder-type rectifier, controlled by the developed microprocessor control system, allows conducting a series of experiments to identify energy indicators in various operating modes.

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