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Development of the model of automatic control of energy intensity of technological processes and its application

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Development of the model of automatic control of energy intensity of technological processes and its application

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Abstract. The article covers the model for automatic compensation of reactive component of consumed current of asynchronous motors operating at powers lower than the nominal values. Automated control system for individual compensation of reactive component of power consumption have been designed, which is connected directly to asynchronous electric motors of machine tools.

1. Introduction

At present, there are several approaches to automated compensation of reactive component. They differ both in the level of compensation and, for example, in the type of compensation devices.

Compensating devices are subdivided into permanent (unregulated) and automatic [1].

Permanent compensators are one or more condensers to provide constant level of compensation. This type of compensators can be used on the terminals of inductive devices (motors or transformers), on switchboards supplying a number of small motors, and inductive equipment, for which separate compensation is not economically viable, or on consumers with a sufficiently constant load, and allows reducing reactive currents and voltage drops when transmitting and transforming electrical energy.

Unregulated condensers can be controlled manually – by means of switch or load breaker, semi-automatically – by means of contractor, or directly – by direct connection to the load and commutated with it.

Automatic compensation devices provide control of energy consumption at consumers with a relatively high level of change in the active and reactive components of the consumed power. They provide automatic control of compensation of power coefficient and maintain the set level of power coefficient within narrow limits. Such devices can be used on the bus bars of the main switchboard or on terminals of high-load cables.

Automatic compensation is usually implemented using automatically regulated condensers unit, which are divided into a number of sections, each of which is controlled by a contactor. The switching on of the contactor switches on corresponding section simultaneously with other sections already in operation. This allows stepwise increasing or decreasing the capacity of the unit by switching the control contactors on and off.

2. Methods

The model for automatic compensation of the reactive component of consumed current of asynchronous motors operating at powers lower than the nominal values has been proposed as a model. This model includes the following units:

- Unit of current generator.
- Unit of current meter.
- Unit of intermediate relays.
- Unit of condensers.

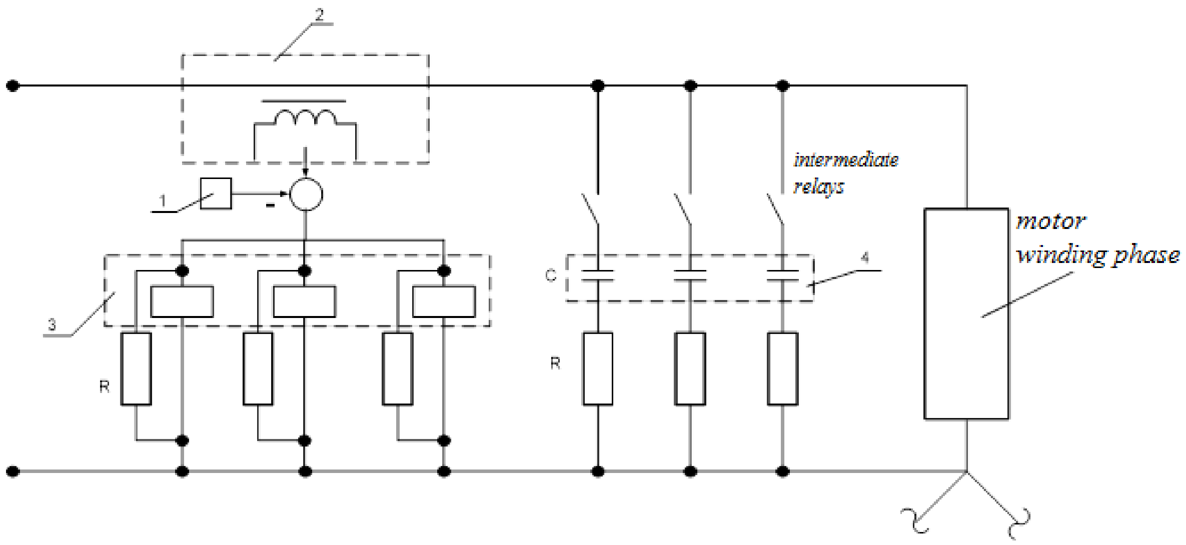

Figure 1. Model for automatic compensation of reactive component of consumed current of asynchronous motors operating at powers lower than the rated values.

The operating principle of the model is as follows.

The operation of asynchronous motors at powers lower than the rated values is characterized by a low power coefficient of its windings. This causes a significant increase in the consumed current due to an increase in its reactive component of the consumed power. The value of the consumed current, determined by the current meter 2, is compared in the comparing device CD with the rated current value for the given motor, set by the current generator 1 (figure 1). If the current consumption exceeds its nominal value, the difference enters the unit of intermediate relays 3, the operating current of which is regulated by the shunt resistors R. When the corresponding relay is triggered, the corresponding closing contacts are closed, connecting the required number of condensers C of condenser unit 4. In this case, the shunt resistors R are selected as so that the activation of the next relay does not change the state of all other relays of the unit [2]. This provides parallel connection of condensers to provide the necessary compensation for the phase shift by reducing the reactive component of the consumed current. This algorithm of operation provides a general reduction in the current consumption of each phase of the motor, and hence a decrease in the energy consumption of the technological process. Additional resistances R ensure the matching of the rated voltage of the condensers with the phase voltage of the power circuit of the electric motor. The number of intermediate relays and condensers determines the number of compensation steps for the reactive component of the consumed current.

The model for automatic compensation of the reactive component of the consumed current of asynchronous motors operating at powers lower than the rated values, containing a condenser for each phase of the motor stator windings, the first terminal of which is connected to the ends of the stator windings, switching device and intended for connecting condensers to the stator windings, differing in that that several parallel-connected condensers are connected to the ends of the stator windings, the second ends of which are connected to the closing contacts of intermediate relays, the windings of which are shunted by resistors, and the ends of the windings are connected to the end of the stator winding, and the beginning of the windings are connected to a device that determines the difference between the real current consumed stator winding, which is determined by the current meter, and the specified current set by the current generator [3, 4].

3. Results

The proposed model is an analog implementation of the developed algorithm for the functioning of the automated control system for energy saving of technological processes [5]. Its advantages over the implementation of the algorithm by means of programmable controllers include:

- Lack of discreteness of measurements of control parameters.
- Higher system reliability due to fewer and simpler building units.
- Lower cost in comparison with the system based on programmable controllers.

Experimental implementation of the proposed automated control system for the energy intensity of mechanical engineering technological processes for automatic control of energy consumption in asynchronous motors of machine tool equipment that implement the technological process of cutting showed a general decrease in the current consumption of each phase of the motor, and hence a decrease in the energy intensity of the technological process [6] The decrease in the value of the consumed current during the implementation of technological processes reaches 2-3 times value, which means that the energy consumption of these processes decreases 3-4 times.

The following are the equivalent values of the power consumption parameters obtained because of several series of experiments. In this case, the process of making a product of the “hairpin” type is presented as the technological process under study. During several series, nine products were manufactured. The results are shown in table 1.

Table 1. Experimental data on the values of energy consumption parameters.

No.	Characteristic of energy consumption				
	Consumed current I, A	Active component of consumed power P, W	Reactive component of consumed power Q, VAR	Apparent power consumption S, VA	Power coefficient Cos φ
1	7.58	1997	4435	4920	0.41
2	7.83	2000	4405	4858	0.42
3	7.84	2075	4404	4898	0.44
4	7.86	1984	4415	4917	0.42
5	7.74	2010	4408	4856	0.42
6	7.76	2065	4401	4873	0.44
7	7.66	2062	4333	4837	0.42
8	7.90	2062	4352	4787	0.42
9	7.84	1948	4350	4876	0.44

After that, a series of experiments were carried out to determine the parameters of energy consumption of mechanical engineering technological processes using an automated system for controlling the energy intensity of technological processes. In this case, a part of the “Hairpin” type was also made. An equal number of experiments were carried out to obtain reliable data. The results are shown in table 2.

Further, in a graphical form in figure 2, the equivalent values of the total power consumption of the series of experiments are presented

Table 2. Experimental data on the values of energy consumption parameters.

No.	Power consumption characteristics taking into account reactive power compensation				
	Consumed current I, A	Active component of consumed power P, W	Reactive component of consumed power Q, VAR	Apparent power consumption S, VA	Power coefficient Cos φ
1	3.58	2030	778	2185	0.91
2	3.53	2085	807	2170	0.91
3	3.62	2098	742	2200	0.93
4	3.18	2025	772	2103	0.90
5	3.19	2045	766	2100	0.93
6	3.58	2095	771	2112	0.89
7	3.57	2085	803	2102	0.91
8	3.53	2092	805	2046	0.90
9	3.26	1997	804	2165	0.89

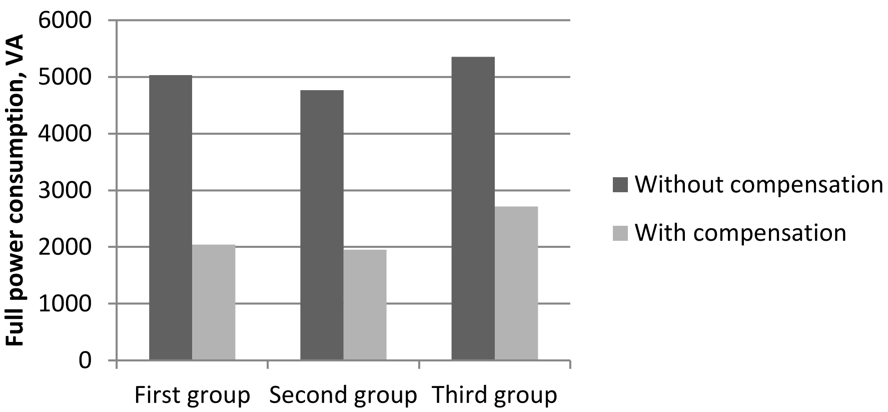

Figure 2. The results of the experimental implementation of automatic control system for the energy intensity of mechanical engineering technological processes.

As an additional example, the characteristics of energy consumption of mechanical engineering technological processes of cutting are given, which were implemented on a universal vertical drilling machine model 2P135 with and without the use of an automated control system for the energy intensity of mechanical engineering technological processes. As the process under study, the operation of longitudinal turning of the shaft is presented (table 3).

Table 3. Power consumption characteristics for lathe turning using the compensation method.

Characteristics	Without compensation	With compensation
Cos φ	0.42	0.93
P (W)	2010	1918
Q (VAR)	4408	766
S (VA)	4856	2100
I (A)	7.74	3.19

4. Discussion

From the above results it can be seen that the use of the proposed automated control system for the energy consumption of mechanical engineering technological processes allow reducing the amount of current consumption by 2.5 times, and the amount of power consumption by 2.3 times. Similar results were obtained for other mechanical engineering technological processes.

An automated control system for the energy consumption of mechanical engineering technological processes allow significantly increasing the energy efficiency of these processes.

The use of this system is advisable on machine equipment that implements mechanical engineering technologies of shaping, and operates in the underloading mode. The proposed system allows effectively controlling the energy intensity of the technological process with practically any spread of the range of loads on the motor, with an appropriate selection of the range of compensating devices.

5. Conclusions

The proposed automated control system is designed for individual compensation of the reactive component of the consumed power and is connected directly to the asynchronous electric motors of machine tool equipment [7].

The use of an automated control system for the energy consumption of mechanical engineering technological processes is possible for the following types of machine tools:

- Lathe machines.
- Milling machines.
- Drilling machines.
- Grinding machines.

It is also possible to use this system in other technical systems, where asynchronous electric motors (for example, pumps or hoists) are used as a drive or other device.

Since the process of energy control occurs in a discrete mode, it is necessary to reasonably approach the determination of the number and capacity of the compensator batteries.

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