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# Selection Of Flow Diagrams Of The Adjustable Thyristor Asynchronous Electric Actuator With Phase Control

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## ABSTRACT

This article discusses the use of thyristors and the choice of a circuit in the control of adjustable asynchronous electric motors. The theoretical foundations and practical aspects of using various control schemes for asynchronous electric drives are presented.

## KEYWORDS

Adjustable electric drive, asynchronous motor, control systems, reverse, speed control, slip loss, resistance, thyristor, diode.

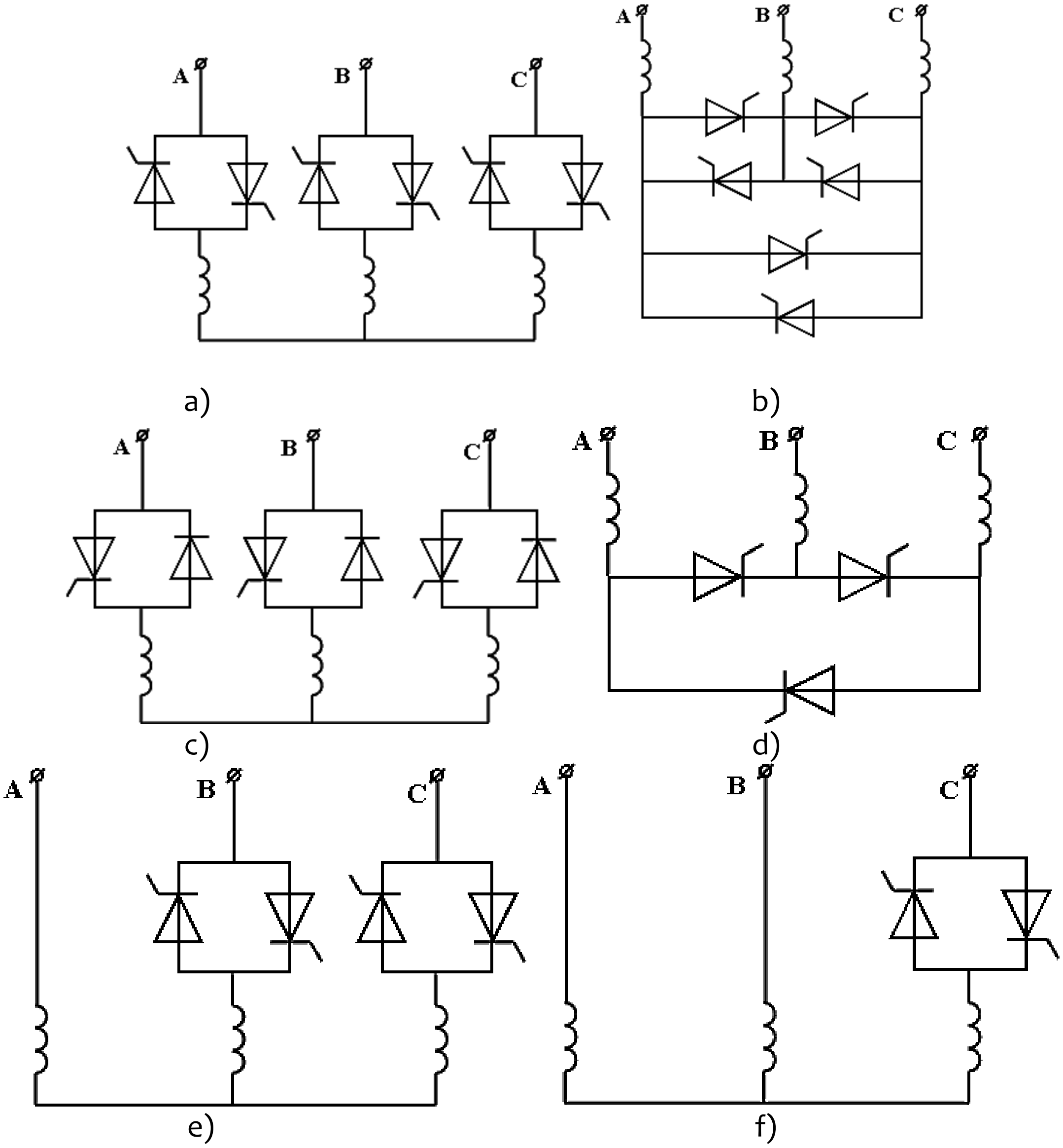
## INTRODUCTION

With the acceleration of scientific and technological progress, an automated electric drive is acquiring significant importance, which constitutes the energy basis of mechanization and automation of various industries and agriculture. At present, the tendency towards the expanded use of variable-speed drives puts forward as an urgent and promising problem the development of variable-speed drives based on AC motors, including asynchronous ones, which prevail in the total volume of produced electric motors and are the main ones for the electric drive of most mechanisms. If we take into account that among asynchronous motors with a capacity of up to 30 kW they account for more than 90%, it will become clear the importance of creating and introducing a mass variable AC electric drive based on asynchronous motors of low and medium power.

The use of thyristors in control circuits of asynchronous electric motors makes it possible to improve the regulating properties of asynchronous electric drives and thus expand their field of application. The simplest method of smooth speed control using thyristors, which require the least number of additional elements, is a change in the voltage supplied to the motor. The latter is easily achieved by changing the opening angle of the thyristors (phase control), connected in a certain way by the motor stator circuit. At the same time, a change in voltage in a closed control system provides stable reduced speeds in motor and braking modes.

## THE MAIN FINDINGS AND RESULTS

It is known that this method of speed control leads to an increase in losses, especially at low speeds, which, of course, limits its use for squirrel-cage motors only for short-term operation. Motors with a phase rotor have great capabilities, since the introduction of additional resistances into the rotor circuit allows you to take out most of the slip losses from the machine and thereby significantly reduce the heating of the engine.



a)

b)

c)

d)

e)

f)

**Figure: 1. Schemes for connecting thyristors to the stator circuit**

The choice of the power circuit of the thyristor asynchronous electric drive [2; 6] with the same technical parameters, the decisive influence is exerted by the efficiency and reliability of the selected option, which in turn depend on the number of power elements and elements of the control circuit. In addition, it is necessary to take into account the overestimation of the total losses, as well as the losses in the motor from the power circuit. The former need to be known to calculate the consumed electricity, and the latter have a significant impact on the choice of engine power.

Many authors have been studying such schemes [1; 3; 4; 5], however, no comparative analysis has yet been made for different indicators. The purpose of the proposed work is to compare these schemes in terms of technical, economic and energy indicators.

All circuits in a speed-closed control system lead to practically the same mechanical characteristics, with the exception of circuit e, which, with fully closed thyristors, does not provide a torque that is almost zero. When using circuits *a* and *e* with the addition of two pairs of thyristors, it is possible to obtain a contactless drive reverse, while the rest (except for *e*) are able to provide only a current-free switching of the contactors during the reverse.

The structure of the power target determines the parameters of diodes and thyristors and, therefore, the cost of the latter. So, the average value of the current through the valves (when the thyristors are fully open) is determined by formula

$$I_{\text{ср}} = \frac{1}{2\pi}\int_0^{\omega t_1} I(t)\,d\omega t$$

In *а, в, ∂, е* $I_{\text{ср}}$= 0,45 $I_{\text{ср}}$; б- $I_{\text{ср}}$= 0,26 $I_{\phi}$ а, в схеме *г*- $I_{\text{ср}}$=0,675 $I_{\phi}$ where $I_{\phi}$ is the effective value of the phase current;

$t_1$- - time of current flow through the thyristor

When the electric drive is operating at setting speeds (not exceeding 10% of the nominal), when it is possible to ignore the emf from the rotation of the electric motor, the maximum voltage applied to the valves is: in schemes b, c, d, d $-\sqrt{3}\,U_{\text{фм}}$, in schemes a, e 1.5 $U_{\text{фм}}$, where $U_{\text{фм}}$ is the peak value of the phase voltage.

For the economic comparison of the circuits, as an example, the calculation of the cost of voltage regulators (valves and control units) was made when working with MTV-311-6, 11 kW, 29 A and MTV-511 40 kW, 100 A. The calculation results are presented in table. 1; it shows the relative cost of thyristor voltage regulators, and scheme a is taken as the basic version. The costs of regulators with three and four thyristors are approximately the same and amount to 60 ... 70%, and the cost of a regulator with two thyristors is 35 ... 50% of the cost of a regulator according to scheme a.

**Table 1**

| Scheme | Rated current motors, A | |
|---|---|---|
| | 100 | 29 |
| A | 1 | 1 |
| B | 0,78 | 1 |
| C | 0,62 | 0,63 |
| D | - | 0,56 |
| E | 0,725 | 0,68 |
| F | 0,5 | 0,34 |

Compared with circuit a, circuit b decreases the current load of the valves, but their class increases, so the cost of the regulator may not change. In some cases, it decreases by 20-25%. In these examples, the comparison was made for circuits with thyristors of the same type.

If, in a circuit where thyristors are selected for a higher current value (for example, g), it becomes necessary to install tablet valves, the relative cost of the regulator turns out to be much higher.

The number of controlled gates in the circuit also determines the number of the least indicator of thyristor control units. That is why this indicator mainly characterizes the reliability of regulators. In addition, some circuits, due to the peculiarities of their structure, have increased reliability. So, in the circuit in, due to the presence of diodes, thyristors are protected from reverse voltage. In circuits b, d, where thyristors are switched on and the zero point is cut, there is no need to protect the valves from short-circuit currents, therefore they are more preferable (when comparing circuits with the same number of thyristors).

The valve switching circuit has a significant effect on the energy performance of the drive. The valve switching processes cause non-sinusoidal currents and voltages, which generally contain a spectrum of different harmonics determined by the number of valves; in circuits e, f, additional losses in the motor are caused not by the symmetry of the applied voltage. Unequal harmonic composition and voltage unbalance lead to different losses in the motor.

In the literature, the energy indicators of the thyristor asynchronous electric drive of the electric drive are considered in detail only for the scheme a / 1,4,6,7 /. However, in these works there is no comparative assessment of the effect of the valve switching circuit on engine losses.

Since the losses depend on the additional resistances in the rotor, we will restrict ourselves to considering the operation of the electric drive of such mechanisms, which, using motors with a phase rotor, operate in a repeated-short-term mode (crane mechanisms). The resistance value, selected according to the starting conditions and providing the specified operating modes of these mechanisms, is (0.5 ... 0.6) $R_H$ on the rise (0.8 ... 1.0) $R_H$ on the descent, when the engine is operating in the counter-switching mode. Here $R_H$ is the nominal resistance of the rotor of the induction motor.

Based on a large number of experiments with crane series motors of different power and different resistances in the rotor at set speeds, the dependences of losses in the motor as a function of the moment at constant slip S for the circuits in Fig. 1 were obtained. Some of them for $R_p$ = (0.5 ... 0.8) $R_H$ and S = 0.8 and 1.2 are shown in Fig. 2, where 11 is the relative value of electrical losses in the motor, and nominal electrical losses are taken as the base value; $M^A$ is the value of the moment referred to the moment on the rheostat characteristic with the same slip S. Note that the nature of the change in losses and the ratio between them remain approximately the same for other resistances.

The study showed that the losses in the engine operating in the schemes a and b and also c, d, e, respectively, are equal. Based on the experimental dependences of losses, as an example, additional equivalent losses were calculated for two motors operating according to a typical crane hoist schedule. When calculating the relative operating time at a reduced speed, 0.1 ... 0.4 of the entire operating time of the drive is taken.

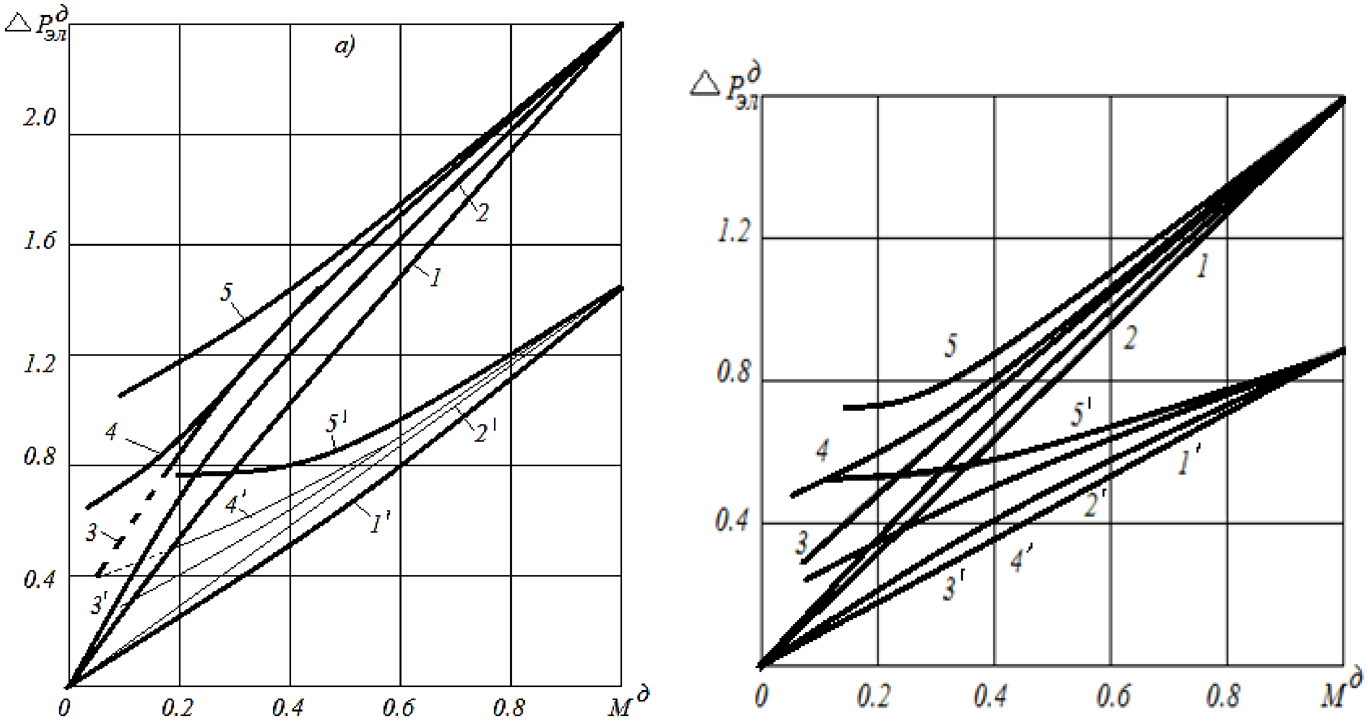


Figure: 2. Addiction

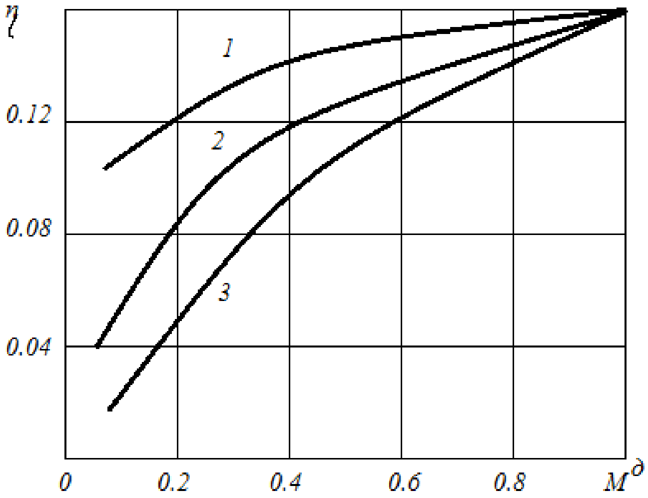


Figure: 3. Dependence of efficiency

The calculation data of which it follows that with 10% of the operating time at a reduced speed in schemes a, b, the average losses increase by 2-4%; in circuits c, d, d - by 6-8% and in circuit e - by 10-15% compared to losses when operating on a rheostat characteristic.

To calculate the cost of consumed energy in a technical and economic comparison of options for electric drives, it is necessary to know the dependence of the efficiency; systems from load. Figure 3 shows the overestimations of the efficiency; on load at constant sliding for different schemes.

Thus, in cases where a reverse is not required or a contact reverse is allowed, it is advisable to use circuits c and d, although they cause a slight increase in losses compared to circuits a and b, however, they are the most reliable and cheap compared to other circuits ( except for e).

At the same time, if the dimensions and weight of the regulator are limited, it is better to use circuit d. In other cases, circuit c, since when the valves are connected to the phase after the motor windings, they are also protected from short-circuit currents, and the electrically connected cathodes of all thyristors simplify the construction of the device management.

Scheme e is even simpler and more reliable, but it is advisable to use it in cases where the static torque is not less than 0.2 of the rated motor torque, and there is also a reserve of engine power. To operate the drive at lower (or even negative) torques, the circuit can be complicated by adding a power capacitor, in which case it is the object of special research.

## CONCLUSION

It is advisable to use the scheme a or d when it is required to provide a contactless reverse (mode mechanisms); the use of the scheme d is preferable if this does not increase the power of the electric motor.

In a limited slip area (0.8 1.2) and resistances (0.5, the given loss data can be used to justify the choice of the power circuit, as well as to calculate the power of electric motors.

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