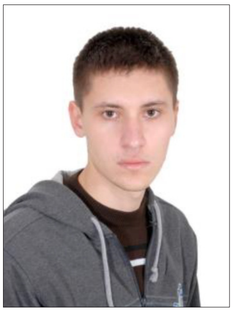
Field of asynchronous electric drive application with parametric control

Vyacheslav Lobov

PhD, Associate professor of Computer Science,
Automation and Control Systems department
Kryvyi Rih National University
Kryvyi Rih, Ukraine

Bogdan Shatrovoy

PhD - student of Automation and Control Systems department
Kryvyi Rih National University
Kryvyi Rih, Ukraine



Anton Gavenko

PhD - student of Automation and Control Systems department
Kryvyi Rih National University
Kryvyi Rih, Ukraine

Abstract
The article shows that to determine the field of application of electric drive with parametric control, generalized scheme of parametric control of asynchronous motor must be used. Asynchronous electric drive is considered. It includes the electric motor, in the stator and rotor circuits of which, there used switches to control the commutators, which contain modules consisting of thyristors and resistors.
Keywords: ELECTRIC DRIVE, ASYNCHRONOUS ELECTRIC MOTOR, GENERALIZED SCHEME, THYRISTORS, RESISTORS, FIELD OF APPLICATION

The problem and its relation to scientific and practical tasks

Starting and breaking modes of asynchronous electric drives (AED) with parametric control the most fully meet the requirements of different mechanisms and units. On practice, simple parametric control is the most widespread and they will be implemented for AED of different power in future. Bellow we'll consider only the AEDs, which are based on changing of value of supply voltage, which connects to asynchronous electric motor (AEM), active (inductive) resistors in the stator (rotor) circuits, or stator (rotor) current [1-8].

Choice of the power control circuit of AEM defines the AEM possibilities of implementation of different working modes. Technical and economic indicators of power circuit play the main role in the selection of the application area of asynchronous electric drives and identify the feasibility of their industrial application. All of this indicates on relevance of this problem as there is still no clear idea where and in what case one or another power circuit of AEDs for specific industrial machinery should applied, and insufficiently proved choice of power circuit can lead to significant economic losses.

Analysis of researches and publications

A characteristic feature of the modern development of AEDs is a development of simple, economical and reliable systems. They should provide starting, breaking and other modes of AED. So these AEDs are the most widely used in electric drives fans, compressors, pumps, conveyor and lifting plants, drawing, wire, rolling mills and many other common mechanisms [8-10]. It should be divided into two main areas of development. The first direction is associated with the development of wound-rotor slip recovery system (SRS), Permanent Magnet Synchronous Motor and the creation of frequency-response asynchronous electric motor (TFC), providing infinity and deep speed control [1-3]. The second trend is the use of switches for switching circuits of AED. Thus for implementation starting and braking modes of AED developers often use in the stator and rotary switches together with additional support thyristors (active, inductive and capacitive), opening additional possibilities of forming the required characteristics of AEDs [4-10].

Most of the work performed under this theme is devoted to research of electromagnetic processes occurring at AEP thyristor control. At the same time, these issues require detailed study when starting and braking electric power circuits with different ways to control valves and switches, both included in the stator and rotor AED. On the solution of these issues depends largely the efficiency, cos φ, reliability, economy and other indicators of drive.

There are certain research methods developed in relation to start-up and braking modes of AED made using SRS or TFC. Research methods for such drives may be partially used to analyze these operating modes at AEP. The main differences are caused here as a feature of the current value of regulation through controlled gates and possible schemes connection resistances, thyristors, stator and rotor windings of the asynchronous machine [4-8].

During implementation of the braking mode, it is natural to use thyristor rectifier elements. The first solutions to this problem are reduced to the supplement of starting thyristor by controlled rectifier switches of different type [7]. Well-known solutions were suggested mainly the replacement of relay-contactor circuits and thyristor blocks by their counterparts without creating molded AED mode. However, more rational and better in this case is the establishment of such methods of control undertaken without additional power components in the stator switch. Therefore, according to information above, the first developed vector – impulse way of dynamic braking (VIDB) of induction motor. The essence of this method is explained by the description given in the author's testimony. This method provides a sufficiently effective braking of AED. It is implemented using simple control methods that allowed to implement it into complete thyristor control units in various series TSU-2, 4-TSU, TSU-D. Because of abovementioned, deep and full AED study with switches, which consist of a thyristors and resistoris is impossible without these features in determining the static modes and the flow of electromagnetic transients in AEP. [1, 2, 5-8].

Statement of the problem

Defining the application of electric parametric management is impossible without a comprehensive analysis of power management schemes and studies of major modes of AED. The choice of power circuit switch for AED is carried out with the technical requirements to common mechanisms. This choice is also associated with a large volume of analytical calculations and experimental research. The selection process for the rational scheme switch of AED is considered as the optimization problem of quality. One of the solutions to this problem is the use of existing research results in domestic and foreign practice of different variants of power circuits. However, this way, as shown in [2], does not give a clear answer to this problem. Moreover, it can lead to incorrect results because the use of a power circuit is determined by technical and economic conditions in relation to specific technological mechanism.

Therefore, for systematic analysis, finding or receiving rational variants of security schemes of AED, the most convenient to use generalized (total) scheme and its mathematical description, which allows to create total control algorithm and effectively use computers in research.

Presentation of the material and results

To build generalized control scheme of AED there was proposed a modular way, the implementation of which is carried out using switches elementary modules [9, 10]. Thus, the power module (PM) contains a controlled valve and passive elements (resistors of active resistance R, capacitors C or inductance L). Communication module (CM) includes only passive elements. PM may use diodes symistors or other semiconductor elements instead of thyristor. Parameters R, L and C of elements of modules PM and CM can be controlled by pulse, broad-pulse or other method if necessary. In this case, the models become more complex as parameters of the CM and MR should change with additional controlled devices and special management schemes.

To attract the general framework for the study of the electric circuit, there required such generalized control AED that has a sufficient number of the most simple modules in order to create maximum number of variants of power switching circuits from such model, included both into the stator and rotor circuits of AED. According to this, it is proposed to use a simple power module, which consists of two resistors and a thyristor, and the simplest communication module, which contains only one active resistor [10].

In modules schemes for stator and rotor circuits of AED, different elements (instruments with complete and incomplete handling) may be applied. Moreover, controlled elements are included into the circuit of both AC and rectified current, for example, at the output of a three-phase bridge rectifier. Consistent inclusion of power resistor and active thyristor, where the second additional resistor is connected to them in parallel way, forms a CM that is called resistor-thyristor (RTM). Each RTM is not only individual functional element but also designed complete unit (module).

Generalized scheme of parametric control of AED includes irreversible stator (SC) and rotary (RC) switches formed with RTM. Each phase of induction motor stator includes anti-parallel RTM and spinning one- consists of six RTM included on the bridge circuit, at the output of which there connected communication module of Z type, which forms the DC link. Communication module of Z type has three different devices: Z_0, Z_s, Z_i, forming corresponding groups of RC. The first group Z_0 is created by devices that form short DC circuit. The second group Z_s – are the devices that allow discretely to change the parameters of elements included in the device Z, the third group Z_i – are the devices that perform pulse adjusting of these parameters. In the generalized scheme of parametric control of AED there used communication module of Z type, which provides the change in certain law of active resistor value included between points P and N [10]. PM are made of two types, which has non-contact switching device or thyristor of AC voltage. Contactless switching devices having only two states (on and off) are called uncontrolled or unregulated. Controlled PM consisting of thyristors (symistors) are supplemented with electronic devices for protection, control input circuits, pulse shaper to control thyristors, there is also a system of pulse-phase control system, and automated start and stop necessary for AED control.

Complex theoretical and experimental studies to expand the manageability, improvement of energy and dynamic qualities of AED, study of characteristics of starting, braking and other modes. This allowed to create industrial designs resistor-thyristor electric drives, expand the possible application of AED modules that have some kind of thyristors and resistors. Choice of electric drive for any mechanism of general use seems extremely important and challenging. The variety of requirements to electric drives, on the one hand, and considerable amount of power modules schemes on the other, all this leads to the development of concrete recommendations on the use of asynchronous electric drives of such type. The analysis of advantages and disadvantages of various power schemes in AED with modules allowed us to determine the groups of machinery and plants, where the use of this method of control a priori gives positive results. The fulfilled comparative analysis indicates that the AED with modules may in some cases replace DC motors or improve technical and economic performance of electric rheostat or thyristor control. Due to insufficient high-energy performance as compared to SRS and TFC, AED with modules can be recommended for the mechanisms:

1) that require smooth start-up, braking or high frequency of turning on;

2) that are short-lived with resistance moment not higher than nominal one, at reduction of frequency of rotor engine;

3) that are long-lived with fan moment resistance on the axis when reducing the frequency of rotor engine.

In the design of AED with the modules there occurs task of selecting of the power circuit of stator and rotor switches. When choosing the scheme, it is necessary to consider the mechanism of operation, the nature of load, load changes and set capacity of drive. Table 1 represents a number of power circuits with the highest technical and economic parameters for some mechanisms and components. It should be noted that while providing starting and braking modes, and threading speed for low-speed AED (10 kW) with modules it is recommended separate control in circuit of the stator of asynchronous machine. To control electric drives of medium power (10-50 kW) providing the same operating modes, it is appropriate to apply power circuit with separate management in the circle of the rotor. For electric drives of high power (50 kW) it is preferably to use the joint control in chains of stator and rotor of AED. Moreover, power circuits of $S_{11}Z_LR_{33}$ type are more preferable. As can be seen from the table 1, asynchronous electric drives with AED with modules cover wide mechanisms for metallurgical, mining, processing, chemical and other industries.

Proposed drives allow to start smoothly, brake effectively, control the speed, and also it can briefly run at reduced speed, can be used not only for mechanisms that do not impose specific requirements to form of the moment developed on the motor axis. They are widely used to limit and form the transient electromagnetic moments of such responsible mechanisms as cranes, hoisting winches, conveyor installations, drawing mills and others. Significant prospects of AED usage with modules are opened at modernization of existing electrical installations with rheostat and thyristor control. Such settings as drawing mills, wire, calibration and tube drawbenches, hoisting winches and conveyor installations, where AED with slip-ring motors are widely used and may be

Table 1. Power circuit types that are recommended for different mechanisms and assemblies

Mechanisms and assemblies	Power AED, kW	Operation mode of the mechanism	Recommended power scheme
1. Conveyor unit	2.5 - 30	Smooth starting, electrical braking	S_{12}, S_{13}, S_{22}
	30 - 200	Smooth starting	Z_0R_{32}, $Zs(i)\Gamma_{32}$, $S_{13}Z_0\Gamma_{32}$, $S_{11}Z_LR_{33}$, $S_{12}Zs(i)\Gamma_{33}$
2. Presses (toggle, arbor and other)	75 - 200	Smooth starting	$S_{13}Z_0\Gamma_{32}$, $S_{11}Z_LR_{33}$, $S_{12}Zs(i)\Gamma_{33}$
3. Drawbench, wire, Tube drawing, sizing mill	25 - 75	Smooth starting, threading speed, electrical braking	Z_0R_{32}, $Zs(i)\Gamma_{33}$, $S_{12}Z_0R_{32}$, $S_{13}Z_0\Gamma_{32}$, $S_{11}Z_LR_{32}$
4. Ventilating blowers, pumps, compressors, machine-tool electric drive, rotary accelerators	1,5 - 30	Smooth starting, electrical braking	S_{12}, S_{13}, S_{22}
	30 - 200	Smooth starting	$Z_0\Gamma_{32}$, $Zs(i)R_{32}$, $S_{11}Z_LR_{33}$
5. Hoisting mechanisms	4,5 - 30	Smooth starting, electrical braking	S_{12}, S_{13}
		Smooth starting, speed governing, electrical braking	Z_0R_{32}, $Z_0\Gamma_{32}$, $S_{12}Z_0R_{32}$, $S_{13}Z_0\Gamma_{32}$, $S_{12}Zs(i)R_{32}$, $S_{11}Z_0\Gamma_{22}$, $S_{11}Z_LR_{32}$
	30 - 125	Smooth starting, speed governing, electrical braking	$S_{13}Zs(i)R_{33}$, $S_{13}Z_LR_{33}$, $S_{13}Z_0R_{32}$
6. Adjustage mechanisms of rolling mills	1,5 - 30	Smooth starting, electrical braking	S_{12}, S_{13}, S_{22}
	30 - 100	Smooth starting	$S_{13}Z_0\Gamma_{22}$, $S_{13}Z_0\Gamma_{32}$, $S_{11}Zs(i)R_{32}$, $S_{11}Z_LR_{32}$, $S_{11}Z_LR_{33}$
7. Transfer tables	10 - 75	Smooth starting, electrical braking	Z_0R_{32}, $S_{13}Z_0\Gamma_{32}$, $S_{11}Zs(i)\Gamma_{32}$, $S_{11}Z_LR_{32}$
8. Gravity roll carriers	2 - 50	Smooth starting, electrical braking	S_{12}, S_{22}, $Z_0\Gamma_{32}$
9. Straightening units	80 - 200	Smooth starting, threading speed	$S_{12}Z_LR_{33}$, $S_{11}Z_LR_{33}$
10. Coiling apparatus	1,5 - 30	Smooth starting, speed governing, electrical braking	$S_{13}Z_0\Gamma_{22}$, $S_{13}Z_0\Gamma_{32}$, $S_{11}Zs(i)R_{32}$, $S_{11}Z_LR_{32}$
	30 - 100	Smooth starting, speed governing, electrical braking	$S_{13}Z_0\Gamma_{32}$, $S_{13}Zs(i)R_{32}$, $S_{11}Z_LR_{33}$
11. Globe mill	100 - 200	Smooth starting, speed governing	$S_{13}Z_0\Gamma_{32}$, $S_{12}Z_LR_{33}$, $S_{13}Zs(i)R_{32}$, $S_{11}Z_LR_{33}$
12. Lifting winch	100 - 200	Smooth starting, speed governing, electrical braking	$S_{13}Z_0\Gamma_{32}$, $S_{12}Z_LR_{33}$, $S_{13}Zs(i)R_{32}$, $S_{11}Z_LR_{33}$

equipped with thyristors and resistors without changing the basic AED and stop of production. Metallurgical mechanisms may be upgraded in such way: finishing mechanisms, transfer handling gear, roller bed, correct tools and others for control of which, there used induction motors with rheostat control.

AED controlling with switches in phase rotor can be introduced in the SRS schemes for starting modes and limit of current and voltages in rotor circuits in the initial period of the electric drive starting. After the process of acceleration of the electric drive, module control is turned off. Possibilities of such AED control extend the fields of application of SRS.

Despite the disadvantages of parametric method such as diseconomy and costs for electricity in the power elements and windings of AED, it can be widely used in the cases, when smooth starting and braking of mechanisms, regulation with a limited on-time (OT), measured in percentage, is required. In addition, it can be applied in cases when energy rates are not essential and there is a need to improve reliability of AEDs as compared with rheostat or thyristor control at frequent switching cycles and where demands for reducing the size and simplicity of the scheme as compared with SRS predominate.

Basing on the analysis of the survey at a number of industry studies and experimental results there defined field of application of resistor-thyristor electric drives (Fig. 1). Calculation was carried out with the help of the following averages: average load - 50%, average rate - 50%, duration of the regulated mode of the engine (AT) - 50%. The rest of work is fulfilled at maximum speed when drive losses and losses in the AGC circuit are small. For a number of mechanisms, relay contact circuits or oil resistors should be applied, as these mechanisms do not require frequent launches, improvement of dynamic characteristics, etc. Thyristor control is more effective at smaller capacities of AED and when mechanism requires providing of switching modes with a high frequency of switching on and starting, braking modes as well and shallow speed control.

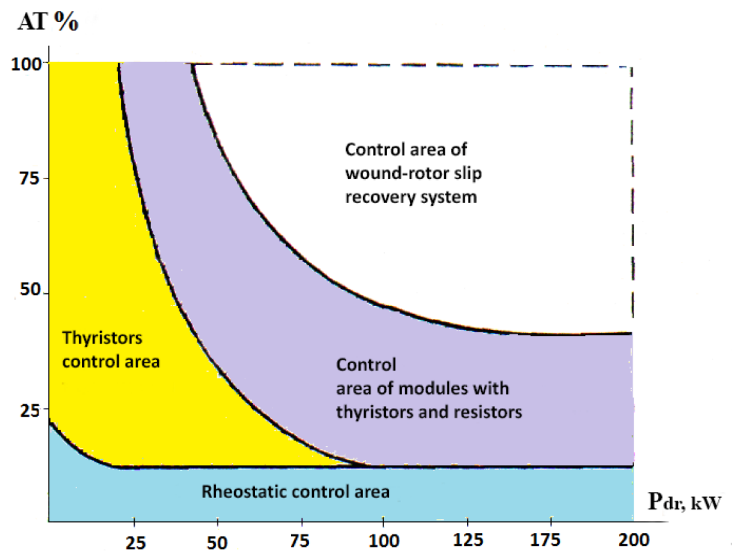


Figure 1. Field of application of AEM

Conclusions

1) To define application field of AEM, it is suggested to implement generalized scheme of AED parametric control. For investigation, it is possible to choose different power control schemes and to get total control algorithm, mathematical description of the electric drive and rationally use computers to select the power switches schemes and carry out effectively their research.

2) Investigations allowed expanding and deepening the understanding of physical processes that occur in asynchronous electric drives at parametric control and allowed defining their application field.

3) Technical solutions on implementation of AEP at electrical, metallurgical and ore mining enterprises are suggested.

References

1. *Avtomatizirovannyj elektroprivod* [Automatic electrical drive]. Under the editorship of N.F. Ilinskiy, M.G. Yunkov. Moscow, Jenergoatomizdat, 1990, 544 p.
2. Braslavsky I.Ya., Ishmatov Z.Sh., Polyakov V.N. *Energosberegayushhiy asinhronny elektroprivod* [Energy-saving asynchronous drive]. Akademiya, 2004, 256 p.

3. Chilikin M.G. Sandler A.S. *Obshhiy kurs elektroprivoda* [Guide line of electric drive]. College textbook. Moscow, Energoizdat, 2007, 576 p.
4. Petrushin V.S., Yakimets A.M., Bangula V.B. (2012). Analiz puska asinhronnogo dvigatelya s pomoshhyu tiristornogo preobrazovatelya napryazheniya [Analysis of launch of the asynchronous engine by means of thyristor converter of tension]. *Elektrotehnika i elektromehanika.* No 6, p.p. 31-33.
5. Figaro B.I. (2011). Primenenie ustroistv plavnogo puska i tormozheniya asinhronnyh elektrodvigateley s korotkozamknutym rotorom v elektroprivodah kranovyh mehanizmov peredvizheniya [Aplication of devices of smooth starting and braking of asynchronous electric motors with the square-cage rotor in electric drives of crane mechanisms of movement.]. *Elektrotehnicheskie i kompyuternye sistemy*. No 4, p.p. 30-38
6. Marenich K.M., Russiyan S.A. (2010). Obgruntuvannya printsipu udoskonalennya sposobu upovilnennya pusku asinhronnogo elektroprivoda girnichoi mashini [Justification of the principle of improvement of a way of delay of launch of the asynchronous electric drive of the mining machine]. *Girnicha elektromehanika i avtomatika.* No 84, p.p. 160-168.
7. Cherny A. P., Gladyr A. I., Osadchuk Yu. G. *Puskovye sistemy nereguliruemyh elektroprivodov* [Starting systems of non-regulated electric drives]. Monography. Kremenchug, "Shherbatyh A.V.", Private Company, 2006, 280 p.
8. Popovich M.G., Lozinsky O.Yu., Klepikov V.B. (2005). *Elektromehanichni sistemi avtomatichnogo keruvannya ta elektroprivodi* [Electromechanical automatic control systems and electric drives]. Study guide. Kyiv, Libid, 2005, 680 p.
9. Nazarenko, V.M., Lobov, V.I., Zhosan, A.A., Nechaeva, S.V. (2004). Universal program for automated choice of control circuit for induction motor drive of conveyer unit. *Promyshlennaya Energetika.* No.1, p.p.42-46.
10. Vyacheslav Lobov (2015). Method for research of parametric control schemes by asynchronous motor. *Metallurgical and Mining Industry*, No.6, p.p.102-108.