Operation features of silicon controlled rectifiers of rotor commutator of the asynchronous electromotor

Karina Lobova

Student of Department of Automation and Control Systems
State Higher Educational Institution "Kryvyi Rih National University"
Ukraine

Oleh Boiko

Student of Department of Automation and Control Systems
State Higher Educational Institution "Kryvyi Rih National University"
Ukraine

Abstract
Phase and impulse operation modes of silicon controlled rectifiers in the rotor commutator are considered using the example of $S_{13}Z_0r_{32}$ type force diagram taken from the generalized diagram of parametric control by the asynchronous electromotor. Boundaries of valves operation modes are determined by graphical analytic method via change of a rotor phase current.

Key words: ASYNCHRONOUS ELECTROMOTOR, ROTOR, COMMUTATOR, RESISTOR AND SCR UNIT, SILICON CONTROLLED RECTIFIERS, PHASE MODE, CURRENT

Asynchronous electromotors with parametric phase control (AEM), in the stator circuits of which the voltage thyristor converters (VTC) or frequency transformers are used, and the resistor and SCR unit (RSCRU) are the most widespread in practice in rotor commutators (RC), their operation will be applied in the future for electric drives of low and medium power [1 - 5]. Using RSCRU, the general diagram of parametric control by the asynchronous motor was obtained [6].

Commutation of grounding resistors in RSCRU is carried out by controlled silicon controlled rectifiers using phase or impulse methods. Phase control, which means change of an angle of silicon controlled rectifiers opening in relation to sine curve of power voltage for VTC or EMF of a rotor for RC, represents a kind of parametric control. It allows regulating of value of the alternating voltage applied to AEM or rotor current. Changes of such parameters determine a type of mechanical and speed characteristics of the electric drive. The principle of the discrete change of the RSCRU parameters is the cornerstone of an impulse method of the asynchronous electric drive control. Such method of control leads to the change of values of current, flow and electromagnetic moment of the electromotor from the value exceeding the static moment to smaller value of the static moment. Mean value of electromagnetic moment in the static mode is equal to the static moment [1, 2]. Existence of controlled elements in RC and NC (network commutator), absence of smoothing element with inductance, and the considerable duration of commutation in case of valves phase control in comparison with a duration of intercommutation intervals, in case of parametric control, lead to variety of operation modes of silicon controlled rectifiers in commutators.

Let us consider the possible operation modes of SCR on the example of $S_{13}Z_0r_{32}$ force diagram; the commutator with RSCRU contains them in a circuit of the asynchronous machine rotor [6]. Let us assume that in this diagram, the phase control of valves is carried out, and the angle of opening changes in the range of 0≤α_r≤π; thus, we will consider that:

1) the control system provides reliable synchronization of opening moments of silicon controlled rectifiers;

2) reading of angles of silicon controlled rectifiers opening is carried from phase voltage of rotor circuits;

3) control impulses are fed in SCR with the identical angles of opening in each phase; they are shifted to each other by 120 electrical degrees;

4) loads on the motor phases are symmetrical;

5) the value of the equivalent resistors of RSCRU resistance in the rotor circuit for each phase of the electromotor was selected considering condition of providing of the minimum static moment with value equal to 0.1;

6) the current transient component in a rotor phase from switching on of thyristors is absent.

Although the last assumption reduces an accuracy of the obtained analytical results, but makes it possible to evaluate the silicon controlled rectifiers operation in the RC at first approximation. The fact that inductivity of rotor circuit is not considered enters the greatest distortions in case of determination of a harmonica of current of the electromotor. Besides, we accept that valves of VTC are completely open in case when α_S = 0° and do not distort electromotive force (EMF) of rotation of electromotor;rotor. So, it is possible to mark the following operation modes of valves in RC:

0-1 if $2/3\pi \le \alpha \le \pi$ - one SCR is opened or all the SCR are closed;

1-2 if $\pi/2 \le \alpha \le 2/3\pi$- one or two SCR are opened;

2-2 if $\pi/3 \le \alpha \le \pi/2$- two SCR are opened;

2-3 if $0 \le \alpha_r \le \pi/3$- two or three SCR are opened.

Curve of a phase current (phase α) for the mode 0-1 on the interval from zero to

T / 2 (T – EMF period of rotor circuit) contains the first section in the range $0 \le X \le \alpha_r - 2/3\pi$ (Figure 1a). The ranges for the following sections:

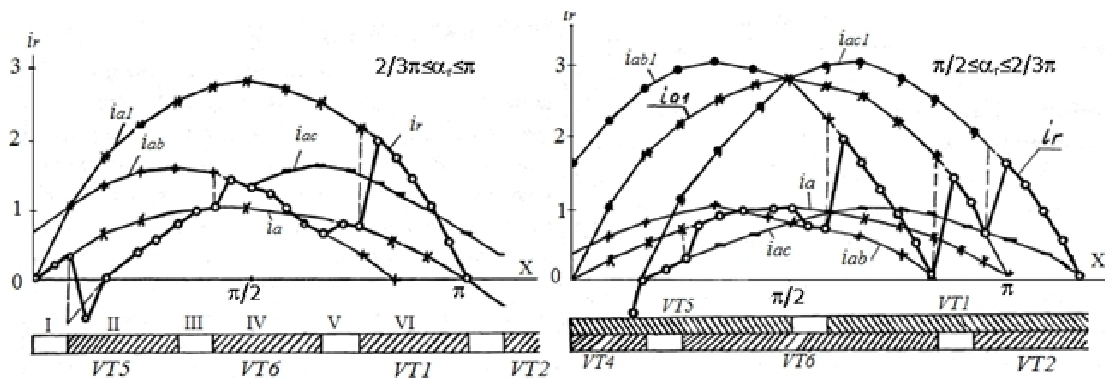
2nd section- $\alpha_r - 2/3\pi \le X \le \pi/3$

3rd section – $\pi/3 \le X \le \alpha_r - \pi/3$;

4th section - $\alpha_r - \pi/3 \le X \le 2/3\pi$;

5th section - $2/3\pi \le X \le \alpha_r$;

6th section - $\alpha_r \le X \le \pi$.



(a) (b)

Figure 1. The oscillogram of a phase current of rotor of AEM in case of parametric control (a - the mode 0-1, b - the mode 1-2)

In the given expressions $X = \omega_r t$ is accepted. The silicon controlled rectifiers operation in the mode 0-1 for the diagram $S_{13}Z_0r_{32}$ is characterized by the fact that SCR of RC work either one at a time or all of them are closed. The opening angle of SCR for this mode is in the range from 2/3 π to π. Therefore, the silicon controlled rectifiers of RC are closed in the first section of current curve of a rotor from 0 to $\alpha_r - 2/3\pi$; it means that current does not flow through them. The value of this current is insignificant and is determined only by values of grounding resistor of RSCRU and electromotor rotor winding. As is seen from the diagram (Figure 1a), the silicon controlled rectifier VT5 is opened in the 2nd section of a phase current of rotor, and the main part of this current flows through the opened silicon controlled rectifier VT5. In this section, the maximum value of phase current of rotor is reached in case of $\alpha_r = \pi/3$, and minimum one is reached in case of $\alpha_r = \pi/6$. All the silicon controlled rectifiers of RC are closed in the 3rd and 5th sections. In this case the rotor current flows only through the grounding resistor of RSCRU and electromotor winding. Unlike the 3rd and 5th, in the 4th and 6th sections, the 6th SCR VT6 and the 1st one VT1 and RC thyristors are switched on respectively; through these silicon controlled rectifiers, the AEM rotor current flows with a bigger amplitude.

Three modes 0-1, 1-2 and 2-3 have in sixes sections of SCR operation, and the mode of 2-2 has only four such sections. Boundaries of operation modes of silicon controlled rectifiers in RC for $S_{13}Z_0r_{32}$ diagram are determined by graphical analytic way of a rotor phase current. The diagrams of RC silicon controlled rectifiers operation for other operation modes are of the form shown in Figure 2.1, where the following designations are accepted:

X - rotor phase currents i_a, i_{a1}, flowing through the grounding resistors and thyristors of RSCRU in phase α of the rotor;

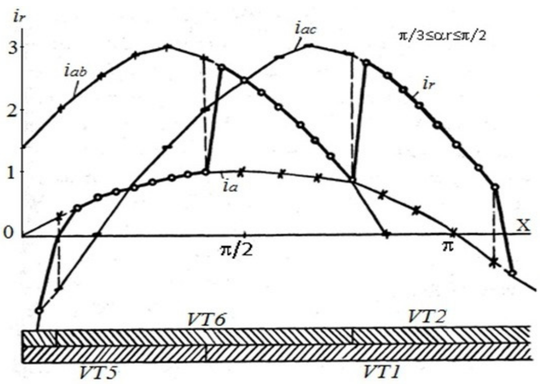
+, ·, -, '- linear currents $i_{ab}, i_{ab1}, i_{ac}, i_{ac1}$, flowing through the grounding resistors and thyristors of RSCRU;

0 - rotor phase current i_r.

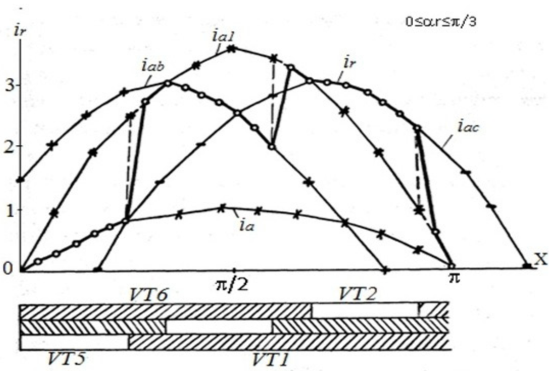
In the axis of abscissa and ordinates in the presented oscillogram, the values of phase currents of rotor and running time are pointed. And currents values are noted in the relative units. The nominal current of AEM is selected as basic current. Design values of rotor current i_r are marked on oscillograms by a solid line, and the experimental ones by dashed line. The results of experimental studies are presented for the electromotor MTKF 411-8, which nominal power is P_N= 18 kW and speed is n_{rN}= 700 rpm. Besides, RC are crosshatched in the diagrams of operation zone of thyristors.

As is seen from the oscillogram shown in Figure 1a, three thyristors come into operation sequentially in case of opening angles $2/3\pi \le \alpha_r \le \pi$ in each half-wave of phase EMF of rotor. In the positive half-wave of this EMF, the thyristors VT5, VT6 and VT1, and in the negative one, the thyristors VT2-VT4 are opened. If the opening angle of RC silicon controlled rectifiers is in the range from π/2 to 2/3π, in the positive half-wave of phase voltage of rotor, the thyristors operate either one at a time VT5, VT6 and VT1, or by two, namely VT4 and VT5, VT5 and VT6, VT6 and VT1, VT1 and VT2 (Figure 1b). The third mode is characterized by operation of valves by two. Thus, such thyristors are turned on: VT4 and VT5, VT5 and VT6, VT6 and VT1, VT1 and VT2 (Figure 2a). If the angle α_r is in the range from 0 to π/(3) two participate in operation or three thyristors. Apparently from the oscillogram (Figure 2b), in this mode, the following thyristors work: Vt5i VT6; VT1, VT6 and VT5; VT1 and VT6; VT6, VT1 and VT2; VT1 and VT2; VT2, VT1 etc.

In force diagrams $Z_LR_{32}, Z_LR_{33}, ZkR_{32}$ and of other types, operation modes of the auxiliary silicon controlled rectifiers VT_{vi} can be various in case of an impulse method of control of commutators valves.



(a)



(b)

Figure 2. The oscillogram of a phase current of rotor of AEM in case of parametric control (a - the mode 2-2, b - the mode 2-3)

Valves can be switched on either randomly at any moment, or only at those timepoints when there are dips in case of phase control in current curve of rotor of the asynchronous machine (Figure 3).

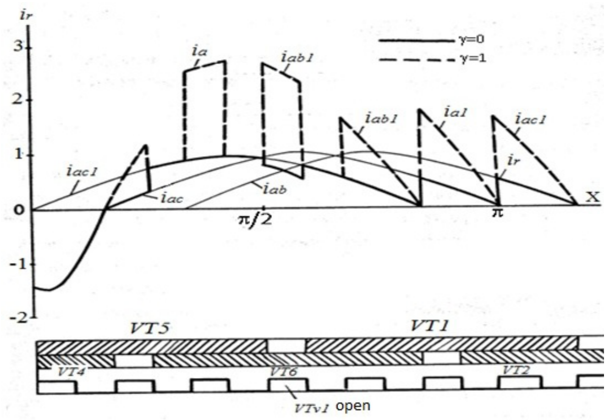


Figure 3. The oscillogram of a phase current of rotor of AEM in case of impulse control

By means of change of the relative turn-on time Y of r_{ri} grounding resistors from zero to one in case of impulse control of commutator SCR, mean value of rotor current of its maximum value to minimum is regulated. As a consequence of this, mean value of electromagnetic moment and rotational speed of AEM are changed. Frequency of thyristors commutation is specified depending on admissible rotation frequency pulsation. Rational commutation frequency value is usually in the range from 50 to 500 Hz [1]. In case of on-off time Ɣ = 1, silicon controlled rectifiers VT_{vi} of schemes $Z_L R_{32}$ and $Z_L R_{33}$ are completely opened.

If the thyristors VT_{vi} are closed, the phase current flows along the rotor chain of AEM; this current is determined by equivalent resistance value of RSCRU and operation mode of silicon controlled rectifiers of RC in case of phase control.

References

1. Braslavskiy I.Ya., Ishmatov Z.Sh., Polyakov V.N. Energosberegayuschiy asinkhronniy elektroprivod. [Energy saving asynchronous electric drive]. Moscow, Akademiya, 2004. 256 p.
2. Petrushin V.S., Yakimec A.M., Bangula V.B. (2012). Analysis of starting of asynchronous engine by means of the thyristor voltage transformer. *Elektrotekhnika i elektromekhanika*. No 6, p.p. 31-33.
3. Figaro B.I. (2011). Application of devices of the smooth start and braking of asynchronous electromotors with short-circuited rotor in electric drives of crane travel mechanism. *Elektrotekhnicheskie i kompyuternye sistemy*. No4, p.p. 30-38.
4. 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.
5. Lobov V. (1981) Modeling an induction motor with a thyristor- controlled rotor circuit. *Electronic simulation*. No 4, p.p. 88-92
6. Lobov V. (2015) Method for research of parametric control schemes by asynchronous motor. *Metallurgical and Mining Industry*. No 6, p.p. 102-108.
7. Morkun V., Morkun N., Tron V. (2015). Distributed closed-loop control formation for technological line of iron ore raw materials beneficiation. *Metallurgical and Mining Industry*. No 7, p.p. 16-19.
8. Marynych I.A. (2014) Reason for application of intelligent systems for disintegrating complex control. *Metallurgical and Mining Industry*. No 6, p.p. 25–29