Method for research of parametric control schemes by asynchronous motor

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Abstract
Asynchronous motor, in stator and rotor chains of which there used converters for control, is suggested. These convertors have resistors and thyristors, which are turned on between themselves in different ways, creating resistor- thyristor modules.
Scientific novelty is that while using these modules, generalized scheme of induction motor control is obtained. The scheme allows to get various models of parametric control, which may be used for investigation of different motor operating conditions on computer.
Key words: ASYNCHRONOUS MOTOR, THYRISTOR, RESISTOR, MODULE, GENERALIZED SCHEME

The problem and its connection with scientific and practical tasks

The choice of power control circuit of asynchronous motor (AM) determines the possibility of electric motor of industrial plant on implementation of various modes. Technical and economic indicators of the power circuits play a primary role in the choice of the application area of asynchronous electric drives and show feasibility of their industrial application. Thought there is no exact thought where and in which case one should use this or that power schemes of parametric control of electric drive, and insufficiently substantiated choice of power scheme may lead to significant economic losses.

Analysis of research and publications

Choice of rational scheme has the task of optimizing its quality. One solution to this problem is to analyze the existing domestic and foreign practice different options schemes of thyristor power switches using experimental research. However as it was shown in [1-4] this way does not give an unambiguous answer to this task. Besides it may lead to wrong results, because using of this or that power scheme is determined by technical and economic terms regarding to mechanism [5-16].

Statement of the problem

Comprehensive analysis of power management schemes and research of main modes of electric drive in order to choose from the electric power circuit switch and the technical requirements to Common mechanisms associated with the large volume of analytical calculations and experimental research. Therefore, for systematic analysis, finding or obtaining rational options of power schemes of asynchronous electric drive most convenient to use generalized (total) induction motor control circuit and its mathematical description, which allows creating general algorithm for management and to use it effectively during research of electronic computer.

Materials and results

Modular way is suggested to build generalized scheme of control of AM. To implement this method basic modules should be used for building the scheme. Thus, the power module (PM) contains usually controlled valve and passive elements (resistors of active resistance R, capacitors C or inductance L). There are only passive elements in a communication module (CM). In PM instead of thyristor diodes triacs or other semiconductor devices can be used. Options R, C and L of elements that are in PM and CM are managed by impulsive, widely impulsive or other methods. Models become more complicated as parameters of the PM and CM should change with additional controlled devices and special management schemes.

To get general structure for researching of electric drive work, such generalized control scheme is necessary, which has enough quantity of simple modules to get maximum quantity of variants of power scheme of switches included in both stator and rotor induction motor circuit. Considering this, it is proposed to use a simple power module, where one part includes: two resistors, thyristor, and simple communication module, which contains only one active resistance resistor.

In schemes of converters for parametric control by stator and rotor chains of asynchronous electric drive various elements (devices with complete and incomplete handling) can be applied. Moreover, controlled elements are included both in the AC circuit and rectified current. They are included at output phase bridge rectifier.

Generalized scheme of parametric control of asynchronous motor with the help of these modules is obtained [12]. The power circuit is shown in the Fig.1.

Series connection of power thyristor and active resistor, where additional resistor is connected in parallel, forms a CM that is called resistor-thyristor (RTM).

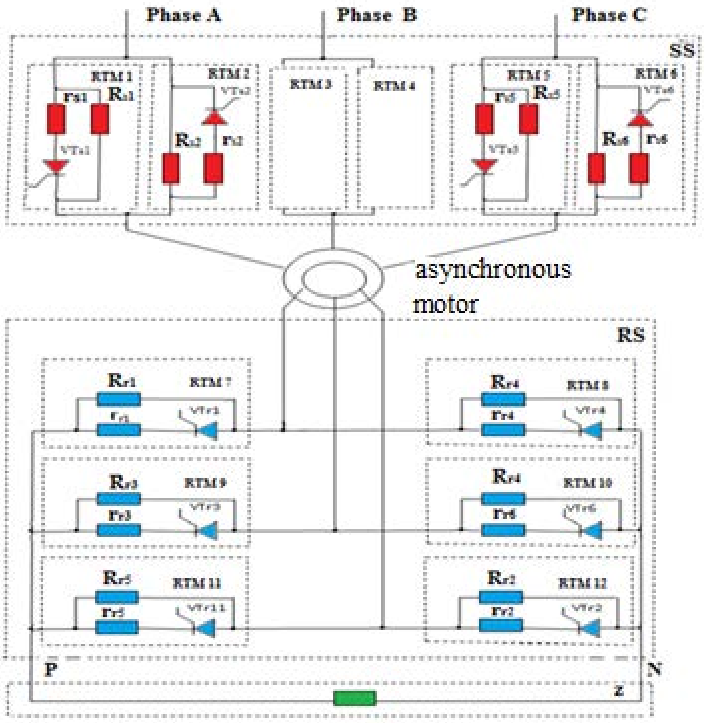

Figure 1. Generalized scheme of AM parametric control

Each RTM is not only individual functional element, but also constructive complete unit (module). Generalized scheme of parametric control of asynchronous motor includes stator irreversible (SS) and rotary (RS) switches formed with RTM. In each phase induction motor includes a stator-to-parallel connected RTM and spinning - consists of six

RTM included on the bridge circuit. Between P and N points rotary switch (Fig. 1) communication module of Z type is connected, which forms the DC link.

Communication module of Z type has three different devices: *Z₀, Zs, Zi* forming the groups of RS. The first group Z_0 is created by devices that short circuit. The second group Zs has devices that let discretely change the parameter elements included in the communication module Z. Third group Zi has devices that fulfill pulse adjusting of these parameters. In the generalized scheme of parametric control by asynchronous motor there used communication module of Z type, which provides change in law the value of active resistor included between P and N points. CM are made of two types, which has non-contact switching device or thyristor AC voltage. Contactless switching devices have only two states (on and off) and that is why are called uncontrolled or unregulated.

Controlled or adjustable SM consisting of thyristors (triacs) are supplemented by electronic protection equipment, entrance control circuits, impulse makers to control the thyristors, there is also systems of pulse-phase control (SPPC) and computer aided starting and stopping of electric drive systems necessary for control implementing of induction motor.
Generalized scheme of parametric control of asynchronous motor provides a power scheme both common and separate management of stator and rotor circuits. Under the joint control we mean control with the help of SS and RS simultaneously in the stator and rotor, and under separate - only using the SS in the stator or just using the RS in the rotor asynchronous motor.
Let us consider the possibility of the proposed generalized scheme of asynchronous motor with active resistor in the stator chain, indicated in RTM1- RTM6 as: R_{si} *i* r_{si} and RTM7-RTM12 rotor as R_{ri} *i* r_{ri}, provided that:
$R_{si} = R_s;\ R_{ri} = R_r;\ r_{si} = r_s\ ; r_{ri} = \ r_r,$
where i = 1, 2, ... for the boundary (0, ∞) and intermediate values of variables Rs, r_s, Rr and r_r and three devices Z_0,Z_s,Z_i, connection module Z. In accordance with accepted restrictions in Table. 1 and 2 there shown the possible circuits respectively for the SS and RS, which are marked by: S_{ij} i Z_{kij}. Indices ij indicate the serial number of the relevant row and column in the table, and index K is set to 0, s, i, that is, it indicates the type of communication module Z.

AM control schemes containing SS and RS types:
S_{11},S_{21}, S_{31}, and Z_0R_{11}, Z_0R_{21}, Z_0R_{31}, Z_sR_{11}, Z_sR_{21}, Z_sR_{31}
$Z_iR_{11}, Z_iR_{21}, Z_iR_{31}$,, are separate control schemes in the stator and rotor. Despite restrictions, proposed generalized scheme covers many well-known circuits of parametric control of asynchronous motor, as it is illustrated by the following examples.

So the analysis and description of separate parametric control circuit using thyristors in stator type S_{13} are shown in [9, 14, 15].

Table 1. Variants of SS

r_{si}	R_{si}		
	0	const	∞
0	S_{11}	S_{12}	S_{13}
const	S_{21}	S_{22}	S_{23}
∞	S_{31}	S_{32}	S_{33}

Table 2. Variants of RS

Z_k		R_{ri}		
		0	const	∞
Z_0	const	Z_0R_{11}	Z_0R_{12}	Z_0R_{13}
	∞	Z_0R_{21}	Z_0R_{22}	Z_0R_{23}
	0	Z_0R_{31}	Z_0R_{32}	Z_0R_{33}
Z_s	const	Z_sR_{11}	Z_sR_{12}	Z_sR_{13}
	∞	Z_sR_{21}	Z_sR_{22}	Z_sR_{23}
	0	Z_sR_{31}	Z_sR_{32}	Z_sR_{33}
Z_i	const	Z_iR_{11}	Z_iR_{12}	Z_iR_{13}
	∞	Z_iR_{21}	Z_iR_{22}	Z_iR_{23}
	0	$Z_{31}R_{11}$	Z_iR_{32}	Z_iR_{33}

In [4, 6] as RS there used scheme of $Z_iR_{11}\ t$ type. Schemes Z_0R_{13} and two parallel circuits Z_iR_{13} are given in [6-11]. Operation of separate parametric control circuits in the rotor of $Z_0R_{12,}, Z_0R_{33}, Z_sR_{13}$types is considered in [1, 4, 5] and Z_iR_{13} – in [11-14]. The analysis and experimental research of scheme Z_sR_{13} for Z, including R_r i $r_r = const$, are given in [9], and parametric control circuit of common types $S_{13}Z_sR_{ij}$ i $S_{13}Z_iR_{ij}$_- [12, 14] and the type $S_{13}Z_0R_{32}$ - [1, 2, 9-11].

Numerous application options of SS for obtaining not only rotating but still fields AM and other modes are considered in [1-16].

Generalized scheme for irreversible SS allows to obtain nine options for various types of power circuits. Two schemes S_{12} and S_{13} that are shown in Fig. 2 are of great interest for comparative analysis. Scheme of S_{12}type (Figure 2, a) is provided for the case when $R_{si} = const\ and\ r_{si} = 0$, and the structure of the circuit of S_{13} type (Figure 2, b), for - $R_{si} = \infty$ и $r_{si} = 0$. Stator winding of asynchronous motor in circuit of S_{12} type is connected to the mains via RTM, and the circuit of S_{13}type , - via thyristor module (TM). The circuit of S_{12} type RTM includes a resistor of resistance R_{si}, which is parallel to connected thyristor VT_i Moreover, each phase of induction motor stator includes two RTM, interconnected-to-parallel.

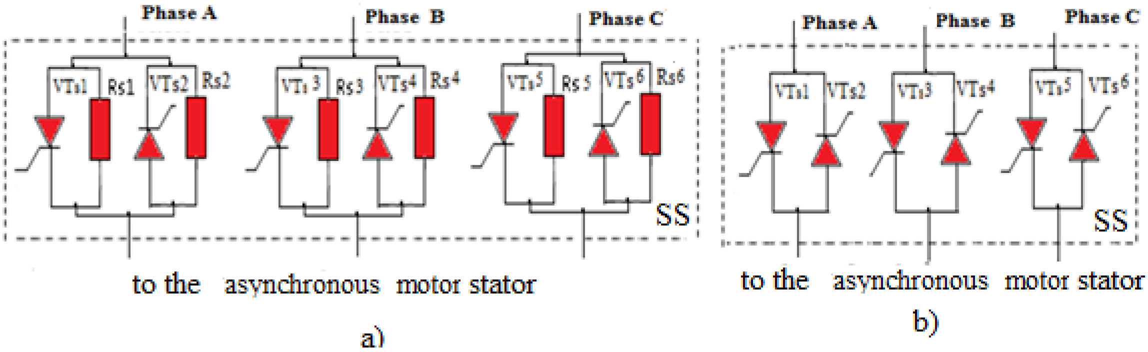

Figure 2. SS Power schemes of S_{12} (a) i S_{13} (b) types

Scheme of S_{13} type consists of thyristors and resistors $R_{si}\ and\ r_{si}$ in this module are not available. In each phase of AM stator AM, there included two thyristors, which are interconnected-to-parallel circuit, and form irreversible known thyristor voltage regulator (TVR) [14, 15]. Please note that the converters that have some kind of valve elements with incomplete handling (thyristor or triac) are included in AC circuits, work in natural mode switching. This converter type implements the so-called phase control in stator or rotor, as it will be shown below, the asynchronous motor circuits [14, 15].

There are twenty-seven different power control schemes of rotor chain of asynchronous motor in the Table 2. Options for power control schemes of AM rotor circuit:
$Z_0R_{11}, Z_0R_{21}, Z_0R_{31}, Z_sR_{11}, Z_sR_{21}, Z_sR_{31}, Z_iR_{11}, Z_iR_{21}, Z_iR_{31}$
$R_{ri} = 0$ provides only locking of circuit rotor winding to the common connection point, thus turning the rotor in short-usual one.

Let us consider the power circuit of RS, which have included RTM in rotor circuits, with the help of which starting and brief regulation of AM rotor speed is provided. Under the scheme of generalized parametric control of asynchronous motor (Fig. 1) at $R_{ri} = const\ and\ r_{ri} = const$ in each phase induction motor rotor parallel to resistance R_{ri} there included series-connected circuit between a resistor r_{ri} and thyristor $VT_{i\_}$ when $R_{ri} = \infty\ and\ r_{ri} = const$ there is only connected in series circuit with these items. All this leads to different power circuits. Thus, when $R_{ri} = const$ there formed different types of schemes Z_kR_{12}, Z_kR_{22} i Z_kR_{32}, while $R_{ri} = Z_kR_{13}, Z_kR_{23}, ZkR_{33}$ and a number of other schemes listed in the table. 2. Scheme of Z_kR_{13}type (Fig. 2.3, a) when $r_{ri} = 0\ is$ known as Larionov bridge circuit [16, 17], where communication module of Z_k type is suggested in the constant current circuit. Two other schemes such as Z_kR_{22} (at $R_{ri} = const, r_{ri} = const\ and\ Z_k = \infty$) and Z_kR_{23} with $R_{ri} = \infty\ and\ r_{ri} = const\ and\ Z_k = \infty$) don't have DC open circuit, and can be used independently.

Using the communication module of Z type, appropriate Z_0 the schemes of Z_kR_{22} type will be converted into a type scheme Z_0R_{32}, and scheme of Z_kR_{23} type in accordance with $Z_0\ R_{33}$ type. In addition, from scheme of Z_0R_{32} type at $R_{ri}=\infty$ and $r_{ri} = const$ there is a new type of scheme Z_0r_{13}, while $R_{ri}=const$ and $r_{ri}=\infty$, scheme of $Z_0\ r_{22}$ type is widely used in industrial environments. It contains only additional resistors in the rotor circuit. When R_{ri}=const and r_{ri}=0 the output of Z_0R_{32} type (Figure 3, c) and at R_{ri}=const, r_{ri}=0 - type Z_0r_{33} (Fig. 3, d). Similarly, from the scheme of Z_0R_{33} type at r_{ri}=0 there created another scheme of Z_0r_{33} type, where the rotor windings are connected in "stars" circuit and consistently connected to the thyristors and resistors locked together in the zero point. The above-mentioned power circuits are shown in the Fig. 4. The power structure will change significantly for the scheme of Z_0R_{32} type, if in circuit DC circuit there will be devices of Z_s or Z_i type. From the scheme of $Z_{s(i)}R_{32}$ type there obtained rotary switch, which thyristors are connected in triangle.

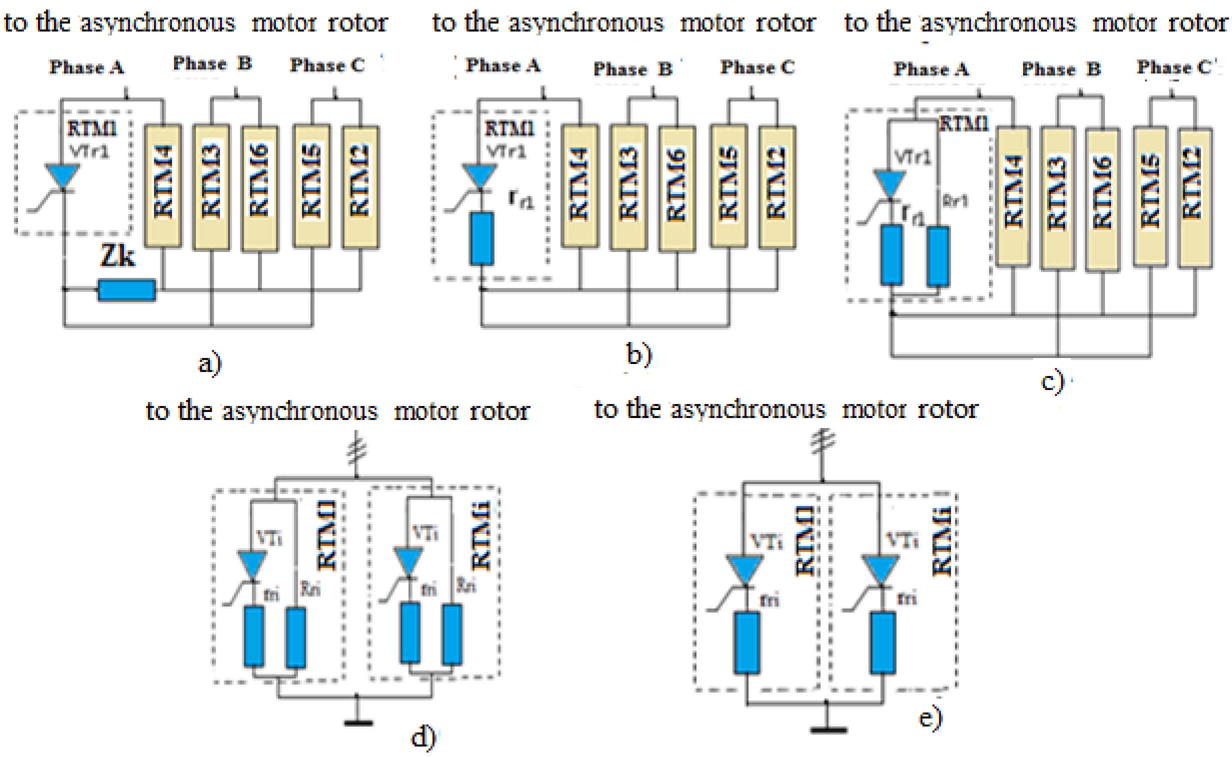

Figure 3. Power schemes of RS types Z_kR_{13} (a), Z_kR_{23} (b), Z_kR_{22} (c), Z_0R_{32} (d) i Z_0R_{33} (e)

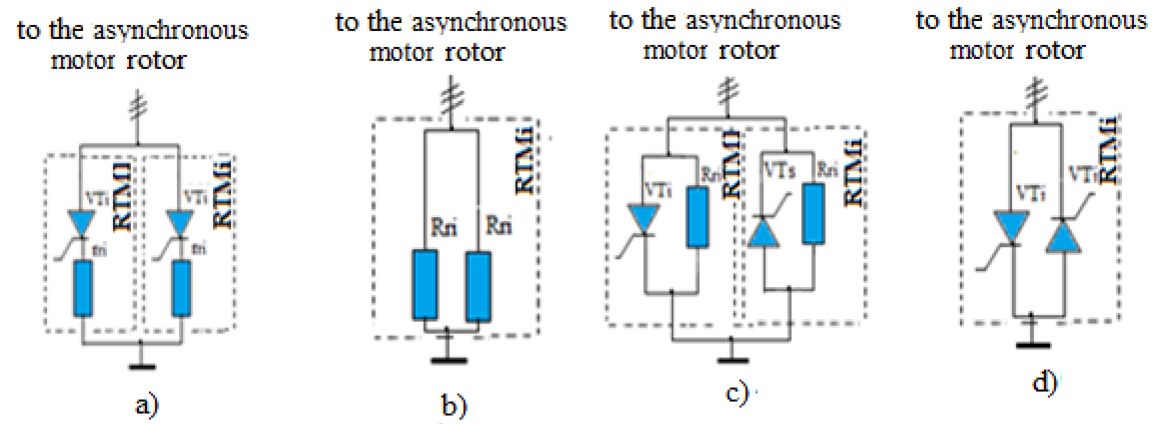

Figure 4. Power schemes of RS types Z_kR_{32} with connection modules $Z_{0(i)}$: Z_0r_{13} (a), Z_0r_{22} (b), Z_0r_{23} (c) i Z_0r_{33} (d)

In this case, device Z_s or Z_i is only one thyristor included into direct current circuit. If we accept that the generalized scheme of $Z_{s(i)}R_{32}$ type (Figure 5, a) resistor: $R_{r1} = R_{r2} = R_{r3} = R_{r4} = R_{r5} = R_{r6} = \infty, r_{r2} = r_{r3} = r_{r5} = r_{r6} = \infty = r_{r2} = const,\ r_{r1} = r_{r4} = 0$, we find that the triangular switch is included in the zero point connection of rotor of induction motor and there is power circuit of Z_1R_{32} type (Fig. 5, b).

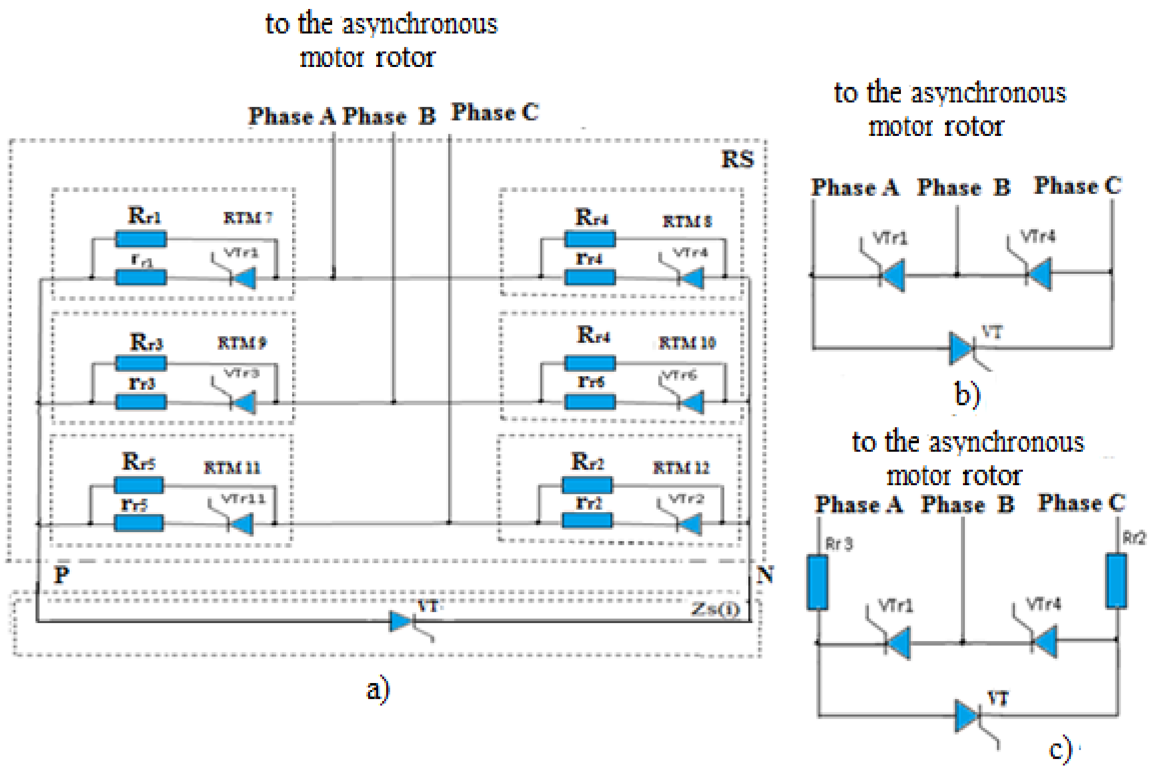

Figure 5. Power schemes of RS types: $Z_{s(i)}R_{32}$ (a), Z_1R_{32} (b) i Z_2R_{32} (c)

As it is seen from the scheme provided in Fig. 5, there is no resistor in the rotor circuit. If we take in circuit of $Z_{s(i)}R_{32}$ type, that $R_{r1} = R_{r4} = R_{r5} = R_{r6} = \infty = const, and\ r_{r1} = r_{r4} = 0\ r_{r2} = r_{r3} = r_{r5} = r_{r6} = \infty = r_{r2} = const$, then the switch will be turned on according to the scheme Z_2R_{32} (Figure 5, c).In the obtained scheme only in phases B and C resistors R_r3 and R_r6 are included, but in phase A they are missing. For getting resistor of all three phases of rotor induction motor, it is necessary to add generalized scheme with a new RTM and to change the structure of connection module of Z type.

The above-mentioned schemes have practical application in many common industrial electric drives of mechanisms, including conveyor installation, drawing, wire, tube-drawing bench [5-15]. If you select the power scheme from generalized scheme, there should be considered that the thyristors RTM, included into the SS and RS work with the same angles of (α) opening. If for one group of thyristors, for example, in the scheme of S_{13} type one takes angels of opening of SC $\alpha_s = 0 \wedge 0$ (open state), the thyristor modules are converted into equivalent thyristor - diode modules (TDM).

Similarly, if in the circuit RS to assume that one group of thyristors $VTr_2, VTr_4\ and\ VTr_6$ will be fully open (opening angle of thyristors $\alpha_r = 0°$), then the rotor circuit there will be turned on consisting of the equivalent TDM.

This property of generalized scheme of asynchronous motor can be used for the selection, analysis and study of power switching circuits using ECM. All the power schemes of asynchronous motor with SS and RS derived from generalized parametric control schemes can be divided into two main groups: with phase and impulse control switches. In the first group the control is fulfilled due to the natural switching valves RTM. Schemes of phase control valves for conventional circuit rotor are more complicated than general ones, applied for stator asynchronous motor circuits. The main distinguishing feature of them is in terms of synchronization blocks operation that should consistently run the application in a wide range frequency and amplitude of the rotary voltage.

Conclusions

Thus, using the most simple resistor-thyristor modules and elementary communication modules made it possible to obtain a generalized scheme of induction motor control. This scheme brought together a variety of known schemes and schemes of parametric control previously not considered. The structure of the scheme can be used in the analysis and study of starting, braking, energy and other operating modes of series of power circuits of asynchronous electric drives control. Changing parameters of RTM resistor and communication modules in the structure of generalized scheme of induction motor, it is possible to obtain almost any version of power scheme for electric motor control necessary for research or manufacturing application.

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