Application of impedance method for research the dynamics of asynchronous motors

*Boris D. Khastsaev**, and *Dmitry V. Merkushev*

North-Caucasus mining and metallurgical Institute (state technological University), Vladikavkaz, Russia

Abstract: One of the possible fields of application of the impedance method based on the use of impedance and its components as an informative parameter is considered. This area of work is the study and diagnosis of asynchronous motors in dynamic mode. The paper presents both a T – shaped scheme of replacement of an asynchronous motor and one of its possible mathematical models, on the basis of which conclusions were made about the feasibility of applying the impedance method for the study and diagnosis of asynchronous motors and the need to develop hardware for this method. In this regard, the main part of the work is devoted to the consideration of measuring transducers necessary for both the technical implementation of the method as a whole, and the instrument support of the method. The option to build transmitters that use the basis four-armmeasuring bridge circuit known as a Wheatstone bridge. The first converter is easier to implement because it is implemented on the basis of the Whitstonbridge with one feedback, but is characterized by less functionality. The second converter is implemented more difficult, as it is also implemented on the basis of the Whitstonbridge, but with two feedbacks. However, this version of the converter has more functionality.

Introduction

There is a wide application of the impedance method in medicine and biology for scientific and diagnostic studies. At the same time, the effectiveness of these studies largely depends on the technical support of this method, since the method provides the formation of primary information related to the properties of the studied and diagnosed objects and the changes occurring in them [1-4]. A similar problem is set and solved in the work, but for the study of the dynamics of technical objects. At the same time, an asynchronous motor (AM) is considered as an object of research and diagnosis, the high value of which in the national economy is not in doubt.

The application of the impedance method for the study and diagnosis of AM is an important problem, since the practical application of the method involves providing with high reliability the identification of a number of am defects. It is very economically profitable.

Thus, the work devoted to the use of the impedance method for the study and diagnosis of AM, the development of means of technical support of this method is actual work.

* Corresponding author: bordsamchas@rambler.ru

1 Theoretical part

It is known that in its performance AM has great advantages over other types of electrical machines, as it is characterized by high reliability, the absence of any switching elements, a large interval of time between preventive maintenance. However, AM is the most complex engine and is a complex nonlinear control object. But with the advent of microprocessor technology, electric drives based on AM successfully displace direct current electric drives. This shows the importance and necessity of research and diagnosis of hypertension, the study of dynamic characteristics with high reliability, for the implementation of which there is currently no technical provision with high user characteristics. Therefore, the purpose of this work is to fill the gap and the development of technical means for the study of the dynamics of AM with improved characteristics.

The analysis of literary sources showed the necessity of creating a mathematical model of AM and examining the equivalent circuits of the AM. It also showed the existence of a large number of both models and the substitution scheme, so the authors chose the most popular replacement scheme of AM, shown in fig.1.

Fig. 1. The variant of the equivalent circuit AM.

For fig.1 applied the following notation: U_1 – the voltage vector of the stator; I_1 – the vector of stator current; I_0 – is the vector of the magnetizing current; I_2' – is the vector of the rotor current; r_1, r_2' – active resistance of stator and rotor; x_1, x_2' – inductance dissipation of the stator and rotor; x_m is the mutual inductance; s is the slip of the motor. Now we present one of the variants of mathematical models of AM.

The system of equations describing AM with a short-circuited rotor in a fixed system, given in [5], has the form:

$$\begin{cases} \overline{u}_s = r_s \cdot \overline{i}_s + \frac{1}{\Omega_s} \cdot \frac{d\overline{\Psi}_s}{dt}; \\ 0 = r_r \cdot \overline{i}_r + \frac{1}{\Omega_s} \cdot \frac{d\overline{\Psi}_r}{dt} - j\omega \cdot \overline{\Psi}_r; \\ \overline{\Psi}_s = (l_m + l_{s\sigma}) \cdot \overline{i}_s + l_m \cdot \overline{i}_r; \\ \overline{\Psi}_r = (l_m + l_{r\sigma}) \cdot \overline{i}_r + l_m \cdot \overline{i}_s; \\ m = \zeta_N \cdot k_r \cdot (\Psi_{r\alpha} \cdot i_{s\beta} - \Psi_{r\beta} \cdot i_{s\alpha}); \\ m - m_\infty = T_j \frac{d\omega}{dt}. \end{cases}$$

Without stopping at a detailed analysis of the equivalent circuit and a detailed description of the above system of equations, we note that all physical quantities contained in both the equivalent circuit and in the system of equations that provide the study of AM dynamics can be measured and controlled by measuring converters of impedance parameters (IPC).

It is possible to use sensors with their connection to the input of these converters. Thus, the development of IPC for the study of am dynamics is an important task and the development of IPC with improved characteristics will serve as the basis for the widespread use of the impedance method for the study of AM dynamics. The relevance and importance of a highly effective method for the study and diagnosis of AM to the present time remain at a high level, which is confirmed by scientific publications [6-10]. This determined both the relevance and the purpose of the work devoted to the promotion of the impedance method for the study of AM dynamics and the issues of IPC construction necessary for the practical application of the method in question.

2 Converter for measuring inductance and active resistance

The IPC scheme is shown in fig.2, from which it can be seen that IPC is built on a four-arm bridge measuring circuit (BC) with the supply voltage of the unbalance and the supply voltage of the BC power supply to the BC branch with an adjustable element [6]. This is the upper branch of BC, and the lower branch of BC contains an object with the parameters L_x and R_x .

Fig. 2. Scheme IPC to measure DKH and KKH with intelligent control block (ICB).

Used in the scheme designations: L_x and R_x – respectively, the inductance and resistance of the object; R_O – resistance of the sample element; R_3 – resistance of the shoulder of the comparison branch resistor, which provides the choice of the value of the conversion R_x ; C_3 – capacitance of the comparison branch capacitor, which provides the choice of the converted value R_x ; R_4 – the resistance of the adjustable resistor of the comparison branch, which ensures the achievement of the quasi-equilibrium state; DA1-differential amplifier, which provides the formation of the unbalance signal BC-Ub; DA2 is a differential amplifier, forming part of the main voltage – U_O ; PSD-phase sensitive detector, providing a signal for adjusting the resistance value of adjustable resistor; U_O – the reference voltage for the power BC; U_2 – the voltage generated at the shoulder of a branch comparison (the voltage drop across adjustable resistor) at the time of quasireverse and proportionally one of the converted values of L_x and R_x ; K – key.

In addition, we note that the controlled (adjustable) resistor R_4 serves as an adjustable element. If the key K is in position 2, then the inductance is converted, and if in position 1,

then the active resistance R_x . In the latter case, when applying to the input of the adder SB, the constant voltage on the isarm is formed by an analog value proportional to resistance R_x . The reference voltage is the voltage drop on the resistance R_o . The expression for the output voltage U_b IPC in general can be represented as:

$$U_b = U_o \frac{Z_x G_0 - R_4 G_3}{1 + Z_x G_0}$$

The expression for the output voltage U_b in the position of the key 2 will have the form:

$$U_b = U_o \frac{(j\omega L_x + R_x)G_0 - R_4 j\omega C_x}{1 + (j\omega L_x + R_x)G_0}$$

and the expression for the same voltage in the position of the key 1 will have the form:

$$U_b = U_o \frac{(j\omega L_x + R_x)G_0 - R_4 G_3}{1 + (j\omega L_x + R_x)G_0}$$

From the last two expressions it can be seen that when the inductance of the object is converted, its value is determined from the following quasi-equilibrium condition:

$$R_4 = L_x G_o / C_3$$

and the analog value U_2 equal to the expression:

$$U_2 = U_o L_x G_o / C_3$$

will be proportional to L_x .

In the conversion of the resistance R_x , the value of the resistance is determined from the following quasi-equilibrium condition:

$$R_4 = R_x G_o / R_3,$$

the analog value U_2 in this case is equal to the expression:

$$U_2 = R_x U_o G_o / R_3,$$

will be proportional to R_x .

IPC capabilities can be significantly improved if it is supplemented with a block of intelligent control (ICB), designed to solve a number of problems arising in the study of objects not previously studied and electrical circuits which have not yet been known. Such a block is also important for the processing of research results, their accumulation and effective use.

3 IPC for multi-point measurement of AM

Multipoint measurement of impedance parameters involves the use of a large number of electrodes connected to a single measuring circuit, as in IPC used BC with a linearized output characteristic [10]. Another important property of the measuring circuit used is its use in the quasi-equilibrium mode to ensure high accuracy of measurement of the main component of the impedance and lower accuracy of the secondary.

A structure scheme of IPC, designed to measure two impedance parameters at many points of the object, is shown in fig.3, which shows that the number of electrodes is n . The electrodes should be located at some distance from each other. IPC also contains the shaper of the rectangular impulses (RIS), a binary pulse counter (BC), BC built using two

The lower branch consists of the shoulder with the impedances Z_3 and Z_4 , and the top of the shoulder with the impedance Z_l and of the shoulder with the impedance plots of the investigated object from Z_{x1} to $Z_{x(n-1)}$.

SMS provides BC with different shapes of measurement signals and different frequencies, resulting in enhanced IPC capabilities and applications. For linearization of the output characteristic BC, operational amplifiers with negative feedback circuits are used. The output voltage of the used BC corresponds to the expression:

$$U_b = U_o(Y_1Z_{xi} - Y_4Z_3),$$

The impedance between two electrodes, i.e. the measured value is most often: $(ReZ_{xi} + jImZ_{xi})$. For these cases, the output voltage OA2, respectively, can be represented as: $U_b = U_o [Y_1 (ReZ_{xi} + jImZ_{xi}) - Y_4 Z_3]$.

From the expression it is seen that the impedance Z_3 should be an active resistance and its regulation achieves the state of quasi-reverse BC, and thus receive par $-Y_1 ReZ_{xi} = Y_4 ReZ_3$, which is easily determined value ReZ_{xi} .

Simultaneously, the voltage at the output OA2 becomes directly proportional to the reactive component of the measured impedance, i.e $U_{bg} = jU_o Y_1 ImZ_{xi}$.

IB in IPC is designed to determine other informative parameters of the impedance, and IDM provides a visual display of the controlled information. Switching of information inputs Ms_1 and Ms_2 is provided by signals from BC, which receives pulses from RIS. In turn, RIS receives signals from SMS, from which RIS provides the formation of short rectangular pulses. One of the important properties of IPC is also the ability to eliminate the impact on the measurement accuracy of a number of uninformative parameters shown in general in the figure as $Z_{ki} \dots Z_{kn}$. These parameters can include impedance of connecting wires, impedance of contacts and electrodes, as well as impedance of boundary layers, etc.

Conclusion

The paper notes the importance of using the impedance method for the study and diagnosis of objects. In this regard, the aim of the study of the capabilities of the impedance method for the study and certification of the dynamic characteristics of AD and the results were obtained, which are of significant practical importance. To a certain extent, the work contributes to the promotion of an important method of research and diagnosis in the field of electrical machines. Hence, the expediency of developing a technique for conducting studies of the dynamic characteristics of AD, which will be implemented in future works of the authors. It is important to note that it is essential to create a bank of mathematical models and equivalent circuits of AD. This is necessary, first of all, to assess the dynamic characteristics of AD. The paper proposes two options for building IPC to study the dynamics of AD. Developed IPC are characterized by improved properties and capabilities compared to analogues.

The work is of interest to students and graduate students, researchers involved in the development of experimental facilities. The work is of interest to the developers of electronic equipment.

References

1. B.D. KhastsaeV, Kh.Sh. Dryaeva, I.P. Maksimova, M.B. KhastsaeV, Devices and systems. Management Control Diagnosis, **2**, 25 (2010)
2. B.D. KhastsaeV, M.B. KhastsaeV, *Application information properties of the impedance in medicine and biology*, Monograph (LAP LAMBERT Academic Publishing, 2013)
3. B.D. KhastsaeV, M.B. KhastsaeV, Devices and systems. Management Control Diagnosis, **5**, 36 (2010)
4. B.D. KhastsaeV, V.A. Sozaev, A.L. Korolev, V.A. Kodzasov, Science and Technology, Scieuro, **222-29** (2016)
5. A.A. Emelyanova et al., Molodoi ushenyi, **13**, 20 URL: <https://moluch.ru/archive/93/20907/> (2015) (date of circulation: 15.07.2018)
6. B.D. KhastsaeV, M.B. KhastsaeV, MATERIALS for the IX international scientific practical conference "SCIENTIFIC POTENTIAL FOR LIGHT-2013", **21**, 91 (2013)
7. B.D. KhastsaeV, L.M. Dedegkaeva, A.L. Korolev, A.I. Abaev, Science and Technology, **2**, 14 (2016)

8. B.D. Khastsaev, V.A. Sozaev, A.L. Korolev, V.A. Kodzasov, Science and Technology, **2**, 22 (2016)
9. M.A. Gavriluk, E.P. Sogolovsky, *Chetyrechplechie mosty peremennogo toka*, (Izd-vo "Vishashkola", L'vov, 1975)
10. B.D. Khastsaev, T.S. Kataev, Patent 2104668 C1 RF, MPK⁶A 61 B 5/05. *Mostovoe ustroystvo dlya mnogotochechnogo opredeleniya impedansnykh harakteristik bioob'ektov*, №96121545/09, Zayavleno 01.11.1996.