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Analysis Of Frequency Control Systems For Asynchronous Electric Drive

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Abstract — *This article discusses the analysis of frequency control systems for asynchronous electric motors*

Keywords —asynchronous motor, half-phase operation mode, vector control of the electric drive, torque control, direct torque control.

Introduction

The asynchronous electric drive is by far the most popular among the entire range of drives used in the industries of industrial, military, agricultural production and transport. It won its popularity due to its high performance and energy performance, as well as lower cost in relation to its competitors, namely, synchronous, valve drives and even more traditional DC drives [1, 3]. In electric drives, where it is required to provide maximum speed along the torque contour, accurate control of output coordinates, reliability, reliability, acceptable technical and economic indicators, long-term operation without constant maintenance, asynchronous electric drives with squirrel-cage rotor motors are used, which have an impressively lower moment of inertia. weight and dimensions, along with contactlessness, as well as high overload capacity at the best cost on the market [5].

Materials and methods

In the XX century, there was a sharp leap in the development of asynchronous electric drives and automated electric drives in general. Electric drives with frequency control began to be used, one of the founders of which is our compatriot M.P. Kostenko, who created the basic law of frequency control. In the 60s of the XX century, methods of frequency-current (as a kind of scalar control) and vector control of an electric drive were invented. Subsequently, vector control has supplanted scalar frequency-current control abroad. Vector systems of frequency-current control also appeared. The first patents for vector control of electric drive belong to the company "Siemens", the system had the name "Transvektor" and meant the regulation of the current vector in the coordinate system associated with flux linkage, with the implementation of coordinate transformations [4,8]. A huge impetus in the development of vector control of an electric drive was the emergence and rapid modernization of a new element base - powerful single-chip microcontrollers, three-phase transistor converters, implemented on the basis of high-speed intelligent transistor switches (IGBT - transistors). In general, the rapid development of semiconductor elements and computer technology has contributed to the further improvement of complex vector control systems requiring a large number of mathematical calculations [2, 6, 7].

The next major step in the development of vector control of the electric drive is the direct torque control system. For the first time the theory of direct torque control (DTC - direct torque control) was presented in 1971 by German and Japanese researchers M. Depenbrock, I. Takahashi, T. Noguchi. The direct torque control method was originally developed for use in electric drives, where the direct torque control of traction motors and high power servo motors is realized. The structure of direct torque control, which is now considered traditional (with a switching table), was first published by I. Takahashi in 1984 in an IEEJ journal article. And ten years later, ABB (Asea Brown Boveri Ltd) began the serial production of complete electric drives based on the principle of direct torque control. The first series of electric drives were ACS-6000, ACS-800, ACS-1000 [9].

From the mid-90s of the XX century to the present day, among all types of electric drive control systems, the most relevant and promising are:

1. Scalar control.
2. Frequency-current control (scalar and vector).
3. Classical vector control.
4. Direct torque control.

All of the above systems are actively used for asynchronous electric drive. The original method of controlling an asynchronous motor (AM), implemented on the simultaneous regulation of the frequency and amplitude of the stator voltage, called scalar AM control, is still widely used and is popular in many industries and transport [10].

Discussion

The principle of operation of scalar control of an asynchronous motor is to maintain a constant ratio of the amplitude and frequency of the supply voltage. Depending on the type of load of the electric drive, the ratio can undergo changes, so with a fan load, the ratio of the voltage amplitude to the square of the voltage frequency must be kept constant. Frequently, the voltage frequency acts as an independent influence, while the voltage is calculated from the mechanical characteristic at a given frequency, critical and starting torque. A constant overload capacity of an induction motor, which does not depend on the voltage frequency, is ensured when implementing scalar control, however, at low frequencies, a serious drop in the electromagnetic moment of the induction motor can occur. The maximum range of speed control of an electric drive when using scalar control does not exceed 1:10, in rare cases 1: (10 ... 25) (with a fan load), provided there is no decrease in the electromagnetic moment on the rotor shaft of the electric motor [11].

Scalar control of an asynchronous motor is quite simple to implement, but at the same time there are two drawbacks that do not allow the use of this system to solve a wide range of problems. Firstly, in the absence of a speed sensor on the electric motor shaft, it is impossible to control the shaft rotation speed, due to its dependence on the load acting on the electric drive. The solution to this problem is to install a speed sensor on the motor shaft. However, this system has one more drawback - it is practically absent the ability to control the torque on the motor shaft. This can be realized when installing a torque sensor, but the price of such sensors can exceed the price of the electric drive itself [2]. Even with a torque sensor in the system, the process of controlling this very moment turns out to be very inertial. It should also be noted that scalar blood pressure control can be characterized by the impossibility of implementing simultaneous speed and torque control. As a consequence, it is necessary to stop at the regulation of the value that is most necessary for the implementation of the required technological process.

Control systems that use direct measurement of controlled quantities have an advantage, since the parameters of the electric motor during operation can seriously deviate from the rated values and have high instability, which can lead to large inaccuracies in calculations and, as a consequence, reduce the quality of control of the coordinates of the electric drive. However, it should be noted that the active development of computer technology makes it possible to build complex structures of control systems, including a large number of mathematical calculations, without much damage to the quality of the required static and dynamic characteristics of the electric drive [12].

As you know, the current of the IM rotor when constructing a control system is very difficult to observe and it is very laborious to accurately determine, therefore, it is preferable to use the stator current in the control system as a torque generating one. When choosing a flux linkage, one of the determining factors is the ability to calculate it without using sensors. The stator flux linkage and the main flux linkage can be determined from the instantaneous values of the stator current and voltage, which just satisfies the desired requirements, but when choosing these flux linkages as moment-generating ones, the mathematical description of the control system turns out to be laborious, due to the high complexity and problems of using the obtained transfer functions in practice when implementing specific tasks.

Conclusion

Systems based on the traditional control of the controlled coordinate vector are inferior in a number of important parameters to DTC systems, which in many sources are positioned as a continuation of the development of vector systems and continue to be called vector systems. The main differences between traditional vector control systems and the direct torque control system are that the DTC system does not imply multiple coordinate transformations, separate for each component of the stator current of the relay controller, links that implement cross-coupling compensation. In addition, it should be noted that the DTC system is less susceptible to inaccuracies in the data on the observed parameters of the control object and disturbances in the process of coordinate control. Next, the structure of the basic speed control system of an electric drive with direct control of the torque of an induction motor in the internal loop will be considered in more detail.

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