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Comparative Analysis of Speed Control Methods of Induction Motors with a Square Rotor

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ABSTRACT: The article presents the results of a comparative analysis of the possibilities of using valve frequency converters based on autonomous current and voltage inverters to regulate the speed of asynchronous motors with a squirrel-cage rotor. It is shown that two-stage converter devices consisting of a three-phase alternating voltage rectifier and an autonomous inverter, despite the fact that their efficiency is slightly reduced, are widely used in adjustable electric drives.

KEY WORDS: frequency converter, asynchronous electric drive, electromechanical system, dynamic mode, electric drive control system.

I. INTRODUCTION

As is known [1, 2], the speed of asynchronous motors is determined by two key parameters: the rotation speed of the stator electromagnetic field ω_0 and slip s. There are two main ways to regulate speed: changing the speed of rotation of the electromagnetic field of the stator and regulation at a constant value of ω_0.

The rotation speed of the stator electromagnetic field is determined by the frequency of the voltage supplied to the stator windings $f1$ and the number of motor pole pairs Zp. Thus, speed control can be carried out by two methods: changing the frequency of the supply voltage using frequency converters and changing the number of motor pole pairs[3-5]. Regulating the speed of an asynchronous motor by changing the number of pole pairs Zp allows you to obtain several fixed operating speed values. For example, asynchronous motors of the 4A-6A series can have two, three or four speeds and are used for crane electric drives. Typically, variable speed control is not used for such machines, which means that multi-speed induction motors are not used in variable-speed drive systems [3].

II. METHOD

As is known [1, 2], Frequency regulation is based on converting AC mains voltage into AC voltage with adjustable frequency, voltage and current. This is carried out by frequency converters (autonomous current and voltage inverters), made on the basis of power semiconductor switches, such as thyristors and transistors. This method has its certain advantages and disadvantages.

The advantages include the possibility of regulation over a wide range, smooth regulation, high rigidity of mechanical characteristics and energy saving due to low motor slip.

Disadvantages include the technical complexity and high cost of frequency converters, especially for high-power drives, as well as difficulties in implementing regenerative braking.

Direct coupled frequency converters:

o Based on reversible thyristor converters.

o Multi-phase output is achieved by using multiple single-phase converters.

o Advantages: one-time energy conversion, high efficiency, possibility of reactive power passing in both directions.

o Disadvantages: complex control devices, low power factor, voltage waveform distortion, limitations on output voltage frequency.

These converters are often used to power low-speed engines of medium and high power, operating in dynamically intense modes with frequent reversal and braking with recuperation [4].

Frequency converters with DC link:

o Includes autonomous current inverters (AIT) and autonomous voltage inverters (AVI).

o AIT contains a rectifier, a power filter and an inverter, which convert direct voltage into alternating voltage.

o Advantages: possibility of energy recovery into the network, output voltage close to sinusoidal, short circuit protection.

o Disadvantages: limitation of the output frequency, switching overvoltages, inability to work with a group load, large size and weight of the filter.

Autonomous voltage inverters, in turn, can use pulse amplitude modulation or pulse width modulation to regulate the output voltage. Pulse width modulation, in particular, allows you to more flexibly regulate the average voltage value and correct its shape.

Today, in variable speed drives with asynchronous motors and frequency converters in the power range up to 50 kW, transistor voltage inverters predominate, while for higher powers and applications with active load braking, current inverters are preferred.

In the key operating mode of semiconductor devices, active power losses $P = UI$ are minimal, since one of the multipliers (current I or voltage U) has a minimum value. This ensures high efficiency (efficiency) of electrical energy converters.

As semiconductor devices switch between off and on states, the voltage and current in the DC load changes, resulting in a significant increase in the product of current and voltage. It is therefore important that these switches occur in the shortest possible time. This condition is successfully implemented in two types of semiconductor devices equipped with internal positive feedback that speeds up switching: IGBT transistors and insulated gate thyristors.

Two-stage converter devices consist of a three-phase alternating voltage rectifier and an autonomous inverter, which converts the rectified voltage into alternating voltage with adjustable frequency and amplitude. Despite the double energy conversion, which slightly reduces the efficiency, frequency converters with a DC link are widely used in adjustable electric drives.

When a motor powered by a stand-alone current inverter enters generator mode, the direction of the inverter's back EMF changes, which can lead to an increase in the DC link current. However, due to the strong negative current feedback, the DC link current remains stable and the inverter switches to grid-driven rectifier operation. This allows energy to be efficiently recovered into the grid while maintaining a constant current in the DC link. Thus, self-contained current inverters are excellent for motor braking modes with energy recovery, which makes them preferable for reversible electric drives.

The well-known circuit of a single-phase bridge parallel autonomous current inverter (AIT) [5], shown in Fig. 1, contains an inverter bridge on thyristors T1-T4, the diagonal of which includes an active-inductive load Zn, and a capacitor C is connected in parallel with it. In the direct current circuit there is an inductor Ld with a sufficiently large inductance. The disadvantage of this device is the inability to operate in idle mode, as well as low switching stability due to the need for the entire load, together with capacitor C, to be capacitive in nature and the current i to be ahead of the voltage un.

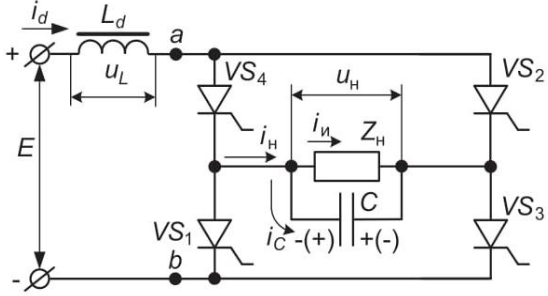

Fig. 1. Diagram of a single-phase bridge parallel autonomous current inverter (ACI)

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A more advanced circuit is an autonomous current inverter with cut-off diodes [6]. In this scheme, the capacitors are isolated from the load using diodes, which allows them to participate in the operation of the inverter only for a short switching time. This significantly reduces their capacity.

Advantages of frequency converters with an autonomous current inverter:

- Possibility of energy recovery into the network.
- Output voltage close to sinusoidal.
- Safety in load short circuit mode.

Flaws:

- Limit the output frequency to 100–125 Hz.
- Switching overvoltages on thyristors, which complicates the power circuit.
- Inability to work under group load.
- Large dimensions and weight of the induction filter.

The second type of DC link frequency converter is a stand-alone voltage inverter (SVI), which contains an LC filter or just a capacitor C. In such inverters, the DC link voltage is directly dependent on the load voltage, making them a voltage source. In voltage inverters, it is preferable to simultaneously operate two valves in one group and one in the other. The presence of capacitor C ensures the exchange of reactive energy between the motor and the DC link.

The well-known circuit of a single-phase bridge parallel autonomous voltage inverter (AVI) [5], shown in Fig. 2, contains an inverter bridge on thyristors T1-T4 and reverse-connected diodes D1-D4. Diodes are designed to pass load current at time intervals when the current is in the opposite direction for thyristors. The load is included in the diagonal of the bridge. The disadvantages of this device are the following: the need to use freewheeling diodes that dump the energy of the inductive element to the power source; the shape of the output voltage differs significantly from sinusoidal; The rate of voltage rise du/dt is very high, so measures must be taken to limit this parameter.

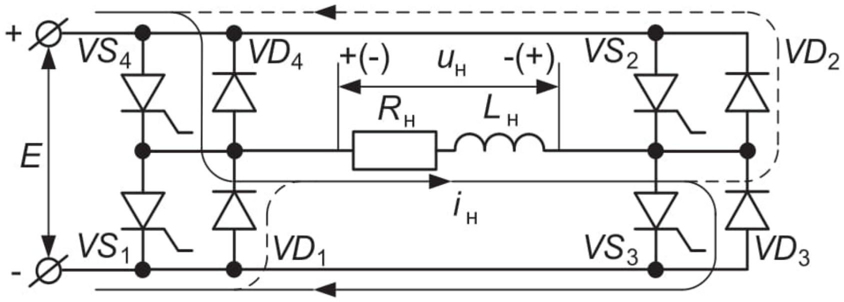

Fig. 2. Diagram of a single-phase bridge parallel autonomous voltage inverter (AVI).

The inverter output voltage can be adjusted in two ways:

- Adjustment of the input voltage in the DC link using a controlled rectifier, while the inverter generates the required frequency. This is called pulse amplitude modulation AIN.
- Pulse-width voltage regulation in the inverter, where the switching frequency of the keys is controlled by a fundamental frequency signal. This is called Pulse Width Modulated AI. In such converters, the rectifier may be uncontrollable

III. CONCLUSION

In modern adjustable electric drives for asynchronous squirrel-cage motors in the power range up to 50 kW, transistor voltage inverters are predominantly used. For higher powers and devices with active braking (for example, centrifuges, test equipment, cranes), preference is given to current inverters [6-8].

REFERENCES

1. Onishchenko G.B. Electric Drive. Textbook for universities. Moscow: RAASN, 2003. — 320 p. P. 143-145.
2. G. C. Diyoke, Okeke C., Uchechi Aniagwu. Different Methods of Speed Control of Three-Phase Asynchronous Motor. American Journal of Electrical and Electronic Engineering, 2016, Vol. 4, No. 2, 62-68
3. Jakub Bernatt; Stanisław Gawron; Tadeusz Glinka. Energy-Saving Electric Drives. 2018 International Symposium on Electrical Machines (SME). DOI: 10.1109/ISEM.2018.8442715
4. Khashimov A.A., Aripov N.M. Frequency-Regulated Asnchron Electric Drive of Silk Potation. Fergana, FerPI Publ., 2000. – 92 p.
5. Pozdeev A.D. Electromagnetic and Electromechanical Processes in Frequency-Regulated Asynchronous Electric Drives. – Cheboksary. 1998. – 172 p.
6. Sh. Umarov, Kh. Sapaev, M. Mirsaidov, A. Ruzmatov.Ensuring Design Reliability of Three Phase Parallel Inverter with Cut-off Valves by Improving the Efficiency of its Mathematical Modeling. AIP Conference Proceedings 2552, 040010 (2023); https://doi.org/10.1063/5.0111343. Publiied Online: 05 January 2023
7. Murot Tulyaganov, Shukhrat Umarov. Improving the energy and operational efficiency of an asynchronous electric drive. III International Scientific and Technical Conference “Actual Issues of Power Supply Systems” (ICAIPSS2023). AIP Conf. Proc. 3152, 030014-1–030014-6; https://doi.org/10.1063/5.0218876
8. Shukhrat Umarov. Dependence of Current Inverter Critical Frequencies on its Load Parameters. 2023 International Russian Smart Industry Conference (SmartIndustryCon) | 978-1-6654-6429-1/23/$31.00 ©2023 IEEE | DOI: 10.1109/SmartIndustryCon 57312.2023.10110751