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FREQUENCY CONVERTER WITH A CURRENT REGULATOR AND A CURRENT-CONTROLLED INVERTER IMPLEMENTED IN A STATIONARY COORDINATE SYSTEM

Muzaffarov F. F.
Bafoyeva G. U.
Bukhara State Technical University
Bafoyevagulrux072@gmail.com

Abstract:
In this article, various types of invertor-based frequency converters incorporating current regulators and current – controlled operation are examined. special attention is given to the implementation principles of current-controlled inverters and their integration into vector control-based speed regulation systems for asynchronous motors. the main objective of this study is to analyze the funcsional structure and control schemes of such convertrs, emphasizing the interaction between current regulation and vector controlinenhancing drive performance and dynamic response.

Keywords: current-controlled inverter, frequency converter, current regulator, rotating coordinate system, PWM invertor.

Introduction

In electric drives, in addition to the autonomous voltage inverter-based converters discussed in earlier sections of our textbook, converters with a DC link and a current-controlled autonomous inverter are also widely used.

The structure of the converter known as an Autonomous Current Inverter (ACI) is shown in Figure 24. Its main difference from a voltage inverter-based converter lies in the fact that the inverter is powered not by a voltage source, but by a current source. As such a source, a controlled rectifier (CR) is used, which, by forming a current regulation loop for the rectified current, acquires the characteristics of a current source – known as the Rectifier Control System (RCS).

A current regulator is present in the current control loop, which compares the actual value of the rectified current with a reference signal. Thus, this signal determines the current value at the input of the autonomous inverter, and accordingly defines the motor stator current formed by the switching of the inverter. The stator current frequency, as well as the voltage frequency in controlled rectifier and ACI-based

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converters, is determined by the frequency of the signal provided at the input of the Inverter Control System (ICS).

A specific feature of the ACI-based converter is the difference in circuit structure compared to voltage inverter-based converters: instead of using a capacitor as the main component of the smoothing filter designed to eliminate ripples in the rectified current, an inductor (choke) is used. Furthermore, reverse current diodes are not present in ACI switches. This is due to the fact that when the inverter switches are turned on, current—not voltage—is formed in the stator windings of the motor. The voltage in the windings is formed under the influence of the resulting phase current. The phase shift between current and voltage is not due to the lag of current behind voltage, but rather the lag of voltage behind current.

As a result, there is no time interval during which the current must continue to flow in its previous direction due to the inductive nature of the load after the switching process of the inverter has completed. The frequency-based control mode of the asynchronous motor powered by ACI is referred to as frequency-current control. [1]

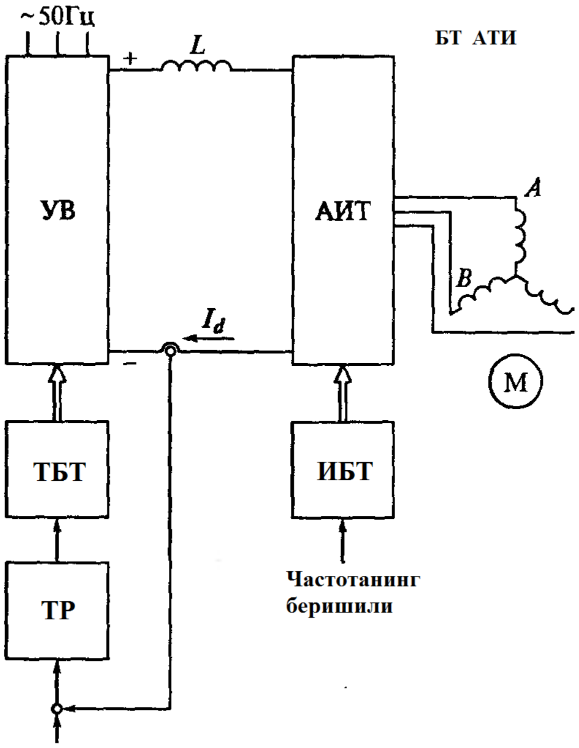

Figure 1. Structure of a Frequency Converter with a DC Link, Controlled Rectifier, and Autonomous Current Inverter

In frequency-current control, the components of the stator current are typically controlled along two perpendicular axes. This enables regulation of the motor torque and the establishment of the desired excitation current mode. Therefore, in further analysis of current-controlled converters, a speed regulation system is implemented within the inner control loops. The outer control loops — relative to these inner loops — are the speed and flux regulation loops.

When the reference signal at the input of the closed speed loop changes or the motor load changes, the output signal of the speed controller adjusts accordingly. This leads to the required change in the stator current components, which form the motor torque.

Currently, the frequency-current control principle associated with the use of DC-link frequency converters is generally implemented using a pulse-width modulation (PWM) autonomous voltage inverter. The PWM autonomous voltage inverter includes direct feedback on the output current — specifically, the stator current of the motor. Thus, the input signal for the converter is the current signal applied to the motor, and the frequency converter acquires the characteristics of a current-controlled converter.

In source [2], cases of both indirect and direct current control have been proposed. In the first case, the inverter operates with a conventional PWM control system, supplemented with simple proportional-integral current regulator loops implemented either in a stationary or rotating coordinate system. In the second case, the inverter switches are directly controlled as a function of the difference between the reference and actual current values.

One of the implementations of indirect control of current regulators in the stationary coordinate system is shown in Figure 2. The converter uses an autonomous current inverter (ACI) with its own control system. Each phase includes current regulators, which compare the sinusoidal reference signals (representing the desired phase currents) with the instantaneous values of the actual currents in the stator windings. The amplitude of the currents is defined by the reference signal amplitude, and the frequency is defined by the reference frequency. The sinusoidal signals from the output of the current regulators serve as input signals for the inverter control system. This type of converter forms part of the electric drive speed regulation system. The external loop of speed and flux linkage regulation is typically implemented in a rotating coordinate system.

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The output signals of the flux linkage and speed controllers define the currents along the d and q axes, which are then transformed into signals representing the instantaneous values of the phase currents.

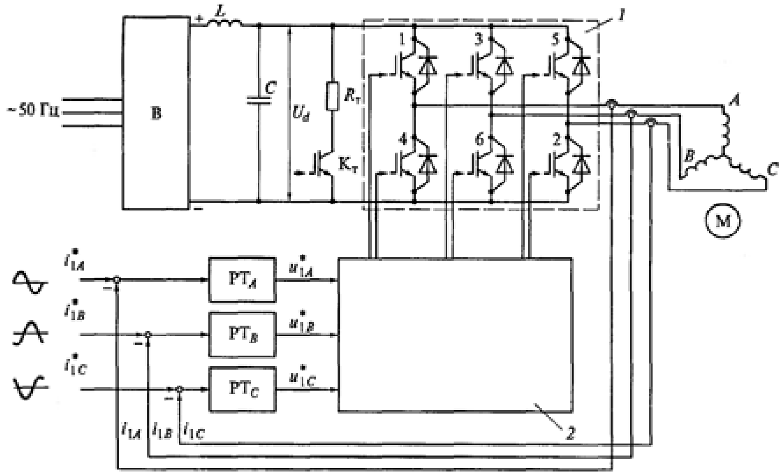

Figure 2. Frequency Converter with a Current Regulator and Current-Controlled Inverter Implemented in a Stationary Coordinate System

1 – Autonomous Voltage Inverter;

2 – Control System of the ACI

A system with a current regulator implemented in a rotating coordinate system operates on the same principle. The only difference is that the measured stator phase currents are first transformed into the components of the stator current space vector in the rotating coordinate system. Then, the output signals of the regulator loops — which are external relative to the current control loops — are compared with the reference signals.

The output signals of the current regulators along the d and q axes are considered the input signals for the converter. After coordinate transformation, they are supplied to the input of the ACI control system in the form of ABC signals.

The principle of such an application of a current-controlled inverter, as well as the vector control-based speed regulation scheme for an asynchronous motor, is illustrated and analyzed.

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