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Nerubatskyi V. P., Kharkiv, UkrSURT
Hordiienko D. A., Kharkiv, UkrSURT

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DETERMINATION OF ADDITIONAL THERMAL LOSSES FROM HIGHER HARMONICS IN AC MOTORS WINDINGS

Improving energy efficiency is a priority for the development of asynchronous and synchronous electric drives. To achieve maximum energy efficiency, a clear numerical understanding of the components of power losses and methods for their elimination is required. In particular, it is necessary to understand the contribution to power losses from higher current harmonics by the amount of total losses. This is due to the fact that the power and regulation of most induction motors is by means of frequency converters based on IGBT or MOSFET-transistors (Fig. 1) [1].

The peculiarity of the frequency converter is that the sinusoidality of the output current of the frequency converter depends on the switching frequency of the power transistors. There is a dilemma, the higher the switching frequency of the transistors, the higher the sinusoidal current of the induction motor and, accordingly, the lower the power loss in the induction motor from higher harmonics [2].

The increase in the number of general industrial switching consumers of electricity significantly affects the distortion of the form of voltage in the power supply network. Thus, even under the condition of direct power supply of the induction motor from a three-phase general industrial network higher harmonics will take place. All this determines the urgency of the problem of determining additional power losses in the windings of AC motors from higher harmonics [3].

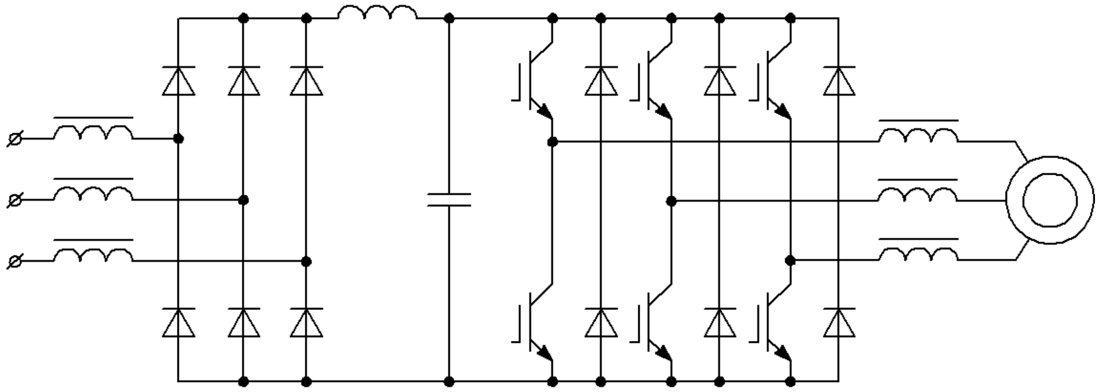

Fig. 1. Power circuit of a frequency converter with an induction motor

Considerable attention has been paid to the negative influence of higher harmonics and inactive components of load currents. However, it should be noted that the results of calculations of additional losses in the active resistance of electrical networks from higher current harmonics in a number of publications differ significantly.

Additional losses of active power in three-phase load, due to the flow of currents of higher harmonics, are determined by the action of the skin effect and can be defined as the sum of losses from each harmonic.

The skin effect makes the active resistance of the network frequency-dependent and the resistance of the network increases with increasing frequency, which causes an increase in power losses in the power supply system. From the above characteristics it is seen that at the same frequency of the higher harmonic, the larger the radius of the conductor, the greater the power loss. Thus, taking into account power losses from higher harmonics under the action of the skin effect is especially important for single-core power supply systems with large wire radii, for example, for single-core contact wires of the railway power supply system. At the same time, the use of a multicore cable eliminates the negative impact of the skin effect on the losses in the conductors of the power supply system from higher harmonics of currents in a fairly wide range of frequencies. However, even in the absence of the effect of the skin effect, higher harmonics cause an increase in additional power losses in the network conductors due to an increase in the RMS current.

A method for determining additional heat losses from higher harmonics in the windings of electric motors of alternating current, which are uniquely determined based on the resulting value of the coefficient of harmonic distortion of the motor current. This method can be used in the case when the effect of the skin effect on the resistance of the windings of motors with a limited range of higher harmonics of the current is insignificant. In this case, the additional losses in the windings from the higher harmonics can be calculated based on the value of the root mean square value of the current, and, consequently, the increase in losses in the square depending on the value of the RMS value of the current.

These ratios allow to determine the additional losses in the power supply system from the value of the harmonic distortion coefficient (THD) of the load current. Distortion of mains current with a harmonic distortion coefficient of 50 % causes an increase in power losses in the electrical network by approximately 25 %. In the case when the spectrum of higher harmonics is limited and the increase in the active resistance of the network in this frequency range increases insignificantly, the effect of the skin effect can be neglected. In this case, the influence of higher harmonics of the load current on the power loss in the resistance of the windings can be determined based on the root mean square value of the load current.

The dependence of additional power losses in the active resistance of windings on higher harmonics as a function of the coefficient of harmonic distortions of the load current is established. It is shown that in the range of THD values of the input current from 0 % to 30 %, the additional losses in the electrical network will increase from 10 % to 48 % relative to the electrical resistance of the DC conductor.

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Nerubatskyi V. P., Kharkiv, UkrSURT
Hordiienko D. A., Kharkiv, UkrSURT

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DETERMINATION OF POWER LOSSES IN SEMICONDUCTOR CONVERTERS BY COMPUTER SIMULATION

Power losses and efficiency are one of the most important indicators in semiconductor power converters [1]. "Manual" calculation of power losses in semiconductor converters with different types of modulation is a rather difficult task and requires the search for a new technique.

Programs for automatic calculation of power losses in power IGBT-transistors, such as MelcoSim, Semisel, Iposim, etc. are quite common [2]. These programs are a very convenient tool, but they allow you to perform automatic calculation of power losses only for "standard" topologies (up and down DC converter, three-phase stand-alone voltage inverter) with "standard" control algorithms (pulse-width modulation) (PWM) with DC fill factor, sinusoidal PWM, spatial-vector PWM) [3]. The disadvantages of existing programs are the inability to model "non-standard" topologies, such as power active filters, active rectifiers with power factor correction, multilevel converters and many other topologies, or standard topologies with non-standard control algorithms.

Matlab / Simulink is one of the most popular programs for the study of semiconductor converters, which allows you to simulate almost any converter topology with any control system. However, the disadvantage of this program is the lack of consideration of dynamic power losses in IGBT transistors. In addition, the volt-ampere characteristic of IGBT-transistors is presented as a linear function (Fig. 1).

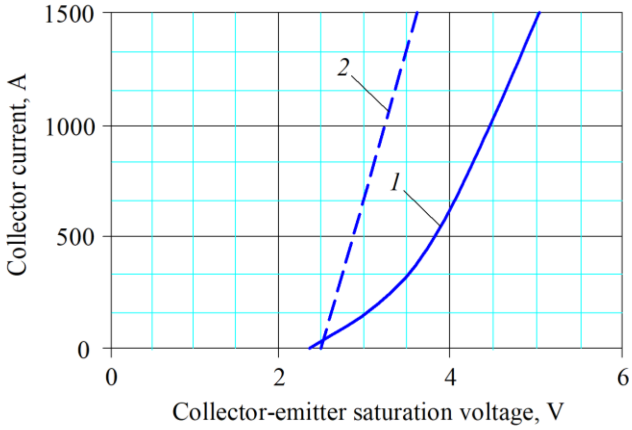

Fig. 1. Volt-ampere characteristic:
1 – real transistor; *2* – transistor in the Matlab/Simulink program