Solutions of reducing an influence of converter-fed AC-drives on vicinity

Abstract. The paper discusses the negative impact of power converters on mains and vicinity. Higher harmonics of current and voltage, energy losses, electromagnetic radiation, and high level of noise are considered as examples. The preventive measures are discussed. The effectiveness of the low-pass filter applied between inverter and motor was investigated and results are presented.

Minimization of drives’ influence on electric power system

Nowadays, the ac-motor is the fundamental final control unit of industrial drives due to the fast progress in power electronics. Since many years there is a possibility to set up ac-drives with technical parameters (static, dynamic and energetic) competitive with converter-fed dc-drives, whereas the well-known advantages (higher reliability, high rotational speeds, lower dimensions and moments of inertia) of ac-motors are kept. The fundamental disadvantages such as hunting and falling out of step of synchronous motors and stalling of squirrel-cage motors have been eliminated by the appropriate control. The range of application of ac-machines covers first of all high powers and rotational speeds, where dc-motors are not produced. Moreover, the application of ac-motors is necessary if special working conditions e.g. inflammable, caustic or dust ambiance are required [1].

The intermediate frequency converter, which feeds three-phase winding of motor, includes voltage source inverter (VSI). The electronic switches are applied for setting up the bridge of inverter. They are made of semiconductor power devices (transistors, thyristors and diodes) and they have similar properties to the electric semiconductor power devices (transistors, thyristors and diodes) and they have similar properties to the electric circuits fed with the distorted currents and voltages, an application of passive filters has to be preceded by thorough analysis and gives the best results when load parameters of distortion sources are constant.

Minimization of noise and losses in electric motors

The commutation of the electronic switches in converter-fed drives at non-zero voltage and non-zero current causes disadvantageous phenomena, such as:
- losses of power and limitation of switching frequency as a consequence of losses,
- electromagnetic radiation as a result of switching high currents which causes the radio-noise,
- high level of the noise produced by motors fed with deformed currents and voltages.

The disadvantageous phenomena caused by the commutation of the electronic switches could be avoided if the resonance converters containing the switches interrupted at zero voltage or zero current will be applied. In order to minimize losses in motor and noise emitted by motor fed with distorted currents and voltages, an application of passive filters between inverter and motor may be considered. The structure of the test stand including this kind of filter is presented in Figure 2. The points where currents were measured by digital oscilloscope with memory are also shown.

The test stand consisted of: the prototypical specially designed induction motor of 7.5 kW fed from the frequency converter, the passive filter, the current probe and digital oscilloscope [4], [5]. The intermediate frequency converter consisted of: three-phase bridge 6D, the voltage source inverter and the dc-circuit between rectifier and inverter. The dc-circuit contained battery of capacitors. The voltage source inverter was set up as a bridge containing six transistors IGBT plus one transistor to brake the motor. The frequency converter included control panel based on direct torque control (DTC) method [6], [7].

The laboratory investigations into specially designed induction motor fed from the frequency converter were made with the application of the following equipments:
- the transistor-based frequency converter with rated parameters: power – 7.5 kW, input voltage, current and frequency – 3 x (380 + 460)V, 25.5 A, 50Hz, respectively, output voltage and frequency – 3 x (0 + 400) V, 0 – 120 Hz, respectively, switching frequency – 3.3 kHz.
- the induction motor with rated parameters: 7.5 kW, 3 x 380 V, 50 Hz, 15.4 A, cos ϕ = 0.85.
- three choking-coils with the magnetic core: 500 V, 50 Hz, 50 A, 5 mH.
- the battery of capacitors setting up as delta-connection: 3 x 500V, 8µF.

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Fig. 1. The conception of application and simplified structure of the parallel active filter

Fig. 2. The structure of the test stand

Fig. 3a. The current pattern versus time at frequency of 2 Hz; the current and time scales are 1 A/div and 100 ms/div (filter input)

Fig. 3b. The current pattern versus time at frequency of 2 Hz; the current and time scales are 1 A/div and 100 ms/div (filter output)

Fig. 4a. The current pattern versus time at frequency of 10 Hz; the current and time scales are 2 A/div and 20 ms/div (filter input)

Fig. 4b. The current pattern versus time at frequency of 10 Hz; the current and time scales are 2 A/div and 20 ms/div (filter output)
Fig. 5a. The current pattern versus time at frequency of 50 Hz; the current and time scales are 2 A/div and 5 ms/div (filter input).

Fig. 5b. The current pattern versus time at frequency of 50 Hz; the current and time scales are 2 A/div and 5 ms/div (filter output).

Fig. 6. The current patterns versus time of reversed motor from 50 Hz to -50 Hz; the current and time scales are 5 A/div and 200 ms/div.

Fig. 7a. The current pattern versus time of braked motor from 50 Hz to 0 Hz; the current and time scales are 5 A/div and 100 ms/div (filter input).

Fig. 7b. The current pattern versus time of braked motor from 50 Hz to 0 Hz; the current and time scales are 5 A/div and 100 ms/div (filter input).
Results of experimental investigations

The drive including an inductive-capacitive filter with parameters 5 mH / 8 µF was investigated.

The measured currents were registered by digital oscillo-scope and current probe with amplifier. The patterns of the phase-current of the motor and the current in the single filter branch versus time were measured for supply frequency 2, 5, 10, 30, 40 and 50 Hz, respectively. Selected results of experimental investigations into the specially designed induction motor fed from the frequency converter are presented in Figures 3 to 8.

Recap

The application of the energy-saving semiconductor devices allows to save the electric energy but it introduces distortion into the power grid. As a consequence of the distortion higher harmonics in power voltage appear what results in a number of negative effects. In order to minimize the abovementioned consequences the active filter applied between the grid and the converter may be considered. In order to minimize losses in motor and noise emitted by motor fed with distorted current and voltage, an application of passive filters between inverter and motor may be considered.

Selected results of experimental investigations into the induction motor fed from the intermediate frequency converter are presented in the paper. As a consequence of application of the low-pass filter between converter and motor the significant reduction of the distortion level can be observed in the patterns of the phase current. It results in minimization of disadvantageous phenomena described in the paper.

REFERENCES

[4]. Rusek A. et al., Development of the prototypical technological line for complex finishing of the precise pipes for Steelworks Buczek S.A. in Sosnowiec (in Polish), the scientific-research project for the industry no. 7 7814 95C2313, unpublished study
[5]. Rusek A. et al., Development and setting up the specially designed induction motor with the frequency converter equipped with a modified control system for starting up the production of the main drives for polymerization reactors (in Polish), the scientific-research project for the industry no. 6 T10 2003C/06105, unpublished study

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