REDUCTION OF HARMONICS BY 18-PULSE RECTIFIER

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Summary: operation of such electrical devices as data processing and electronics devices, adjustable speed drives or uninterruptible power supply can cause problems by generating harmonic currents into the network, from which they are supplied. Effects of these harmonic currents are various, they can get worse the quality of supply voltage in the network or to have negative influences on devices connected to this network. There are various technical solutions for reduction of harmonics. One of them is using of multi-pulse rectifiers, whereas the 18-pulse rectifier in the structure of adjustable speed drive is briefly presented in this paper including some results of its behaviour. The examined experimental measurements confirmed its very good efficiency in the harmonic mitigation.

1. INTRODUCTION

Harmonics can be reduced by various ways, from which these are used in technical practice as AC or DC reactors, passive series *LC* filters, broad-band harmonic filters, active filters, active front end rectifiers or multi-pulse rectifiers. As regards the multi-pulse rectifiers, the 12-pulse, 18-pulse and 24-pulse systems can be created and each of them in various kinds of connection. These types of rectifiers usually require special multi-winding transformers, or autotransformers. In the case of the 18-pulse rectifier presented in this paper, four-winding transformer is required, it is with one primary winding, and three secondary windings, whereas each of them is connected to the standard 6-pulse diode rectifier. These three rectifiers are connected either in series, or as the case may be, in parallel. The series connection of them was used for the construction of two 18-pulse rectifiers located in the laboratory of Department of Electrical Engineering in VŠB-TU Ostrava. Output of thus connected 6-pulse rectifiers was connected to the voltage-fed inverter including capacitor of the frequency converter. Three-phase asynchronous motor was used as the load. Some results from experimental measurements performed on one structure are shortly presented in this paper.

2. 18-PULSE RECTIFIER

As it is known from the theory, the harmonic spectrum of current drawn by non-linear load, e.g. the adjustable speed drive, from the mains depends on the type of used input rectifier in the drive structure. Only harmonics of certain orders appear in the harmonic spectrum, which satisfies an equation as follows:

$$h = k \cdot p \pm 1, \tag{1}$$

where h= harmonic order, k= integral number, p= pulse number of the rectifier. So in the case of the 18-pulse rectifier only harmonics of following orders will be in the harmonic spectrum of drawn current:

$$h = 17, 19, 35, 37 \ldots, \tag{2}$$

which means that the dominant harmonics of the 5., 7., 11. and 13. order are theoretically eliminated. The input current drawn by the adjustable speed drive with such kind of rectifier should already be rather close to the sinusoidal one. For this harmonic elimination it is necessary to construct the special transformer (or autotransformer as the case may be) with three secondary windings with phase shift among their voltages of 20 electrical degrees as it can be seen in Figure 1. These measured voltages and all following figured outputs of experimental measurements were performed on the 18-pulse rectifier in series connection Dy1z1+20^0z1-20^0.

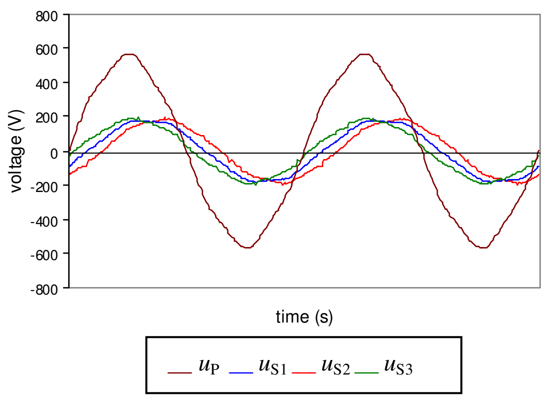

Fig. 1. Voltages of the supply transformer in the structure of 18-pulse rectifier in connection Dy1z1+20^0z1-20^0

3. HARMONIC ANALYSIS

In this chapter some results of experimental measurements including harmonic analysis of currents are briefly presented. The mentioned 18-pulse rectifier in series connection Dy1z1+20^0z1-20^0

was implemented into the structure of adjustable speed drive with three-phase asynchronous motor. Current drawn by the drive from the network, i.e. the primary current of the supply transformer including its three secondary currents are in Figure 2 and their harmonic spectrum in Figure 3. This measurement was performed under nominal loading of the supply transformer and distorted supply voltage in the mains with the level of total harmonic distortion THD_u= 4,02%. The connected asynchronous motor was supplied with voltage at frequency 50Hz. The levels of total harmonic distortion THD_i of all transformer currents are showed in Figure 4.

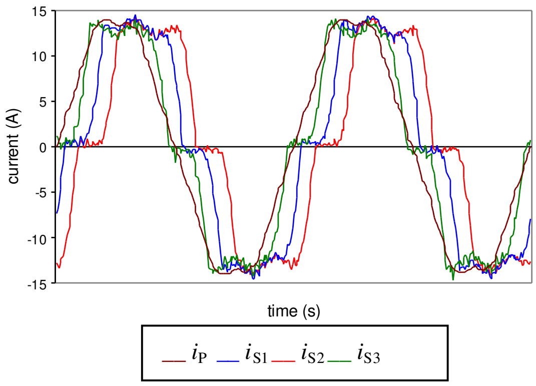

Fig. 2. Currents of the supply transformer in the structure of 18-pulse rectifier in connection Dy1z1+20^{0}z1-20^0

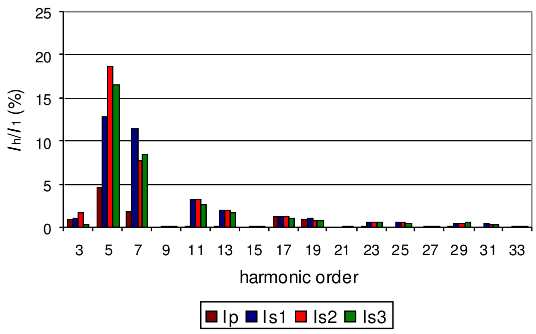

Fig. 3. Harmonic spectrum of currents from Figure 2

THD_{iP} (primary current)	5,23%
THD_{iS1} (1. secondary current)	18,11%
THD_{iS2} (2. secondary current)	20,88%
THD_{iS3} (3. secondary current)	19,32%

Fig. 4. Table of THD_i of currents from Figure 2

From the Figures 3 and 4 can be seen the efficiency of the tested 18-pulse rectifier in the sense of the harmonic mitigation. Theoretically the harmonics of orders 5., 7., 11. and 13. should be eliminated. In the practice from various reasons it is not quite possible and some levels of these harmonics are presented in the current harmonic spectrum, even if small. One from the reasons is the voltage distortion represented by the factor THD_u, which affects considerably the problem of harmonic elimination. Even if the voltage distortion is relatively higher in the supply network in VŠB-TU Ostrava, so the 18-pulse rectifier ability to reduce mentioned harmonics remains rather high as it presented in Figure 3. This rather high ability to markedly reduce relevant harmonics has its influence on the level of THD_i of primary current, thus current drawn by adjustable speed drive from the network. The level of 5,23% is very low resulting in favourable waveform of the drawn current shown in the Figure 2, already rather close to the sinusoidal one. All these measured values were got from measurements under the nominal loading of the 18-pulse rectifier. If the level of loading is variable, an impact on the rate of harmonic reduction will be obvious as it is shown in following figures.

In the figure 5 THD_i of all four currents of supply transformer in the structure of the 18-pulse rectifier versus its loading is shown. With load decreasing it is obvious the rising of THD_i levels, especially of the input primary current (THD_{iP}), which is in terms of harmonic reduction and reverse influences of the drive into the supply network the most important. The reason is increasing of dominant harmonics and their rate in the harmonic spectrum of input current if loading of the 18-pulse rectifier cuts down as seen in figures below. In Figure 6 for 5th, in figure 7 for 7th, in figure 8 for 11th and in figure 9 for 13th.

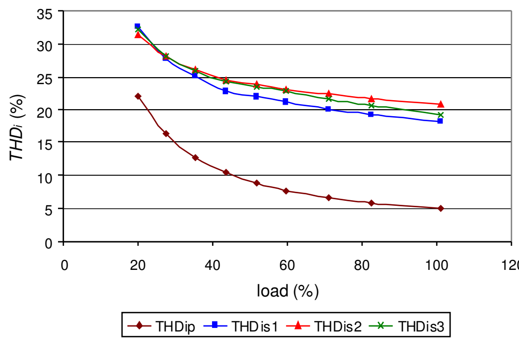

Fig. 5. THD_i of currents of 18-pulse rectifier in connection Dy1z1+20^{0}z1-20^0 versus its loading

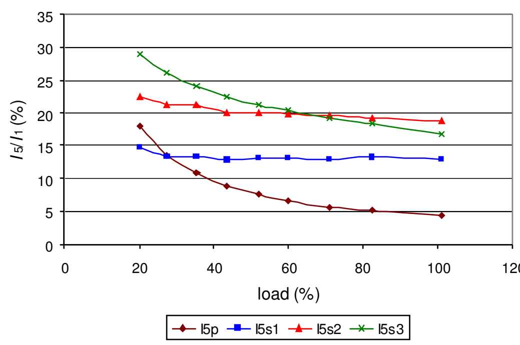

Fig. 6. 5th harmonic of currents of 18-pulse rectifier in connection Dy1z1+20^{0}z1-20^0 versus its loading

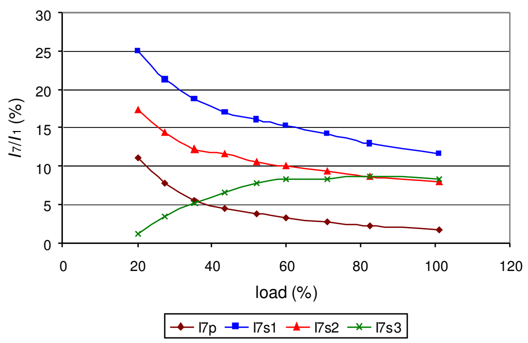

Fig. 7. 7th harmonic of currents of 18-pulse rectifier in connection Dy1z1+20⁰z1-20⁰ versus its loading

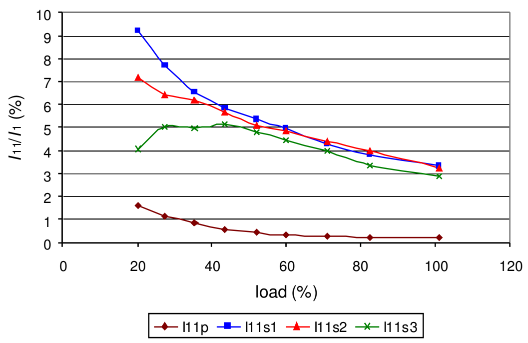

Fig. 8. 11th harmonic of currents of 18-pulse rectifier in connection Dy1z1+20⁰z1-20⁰ versus its loading

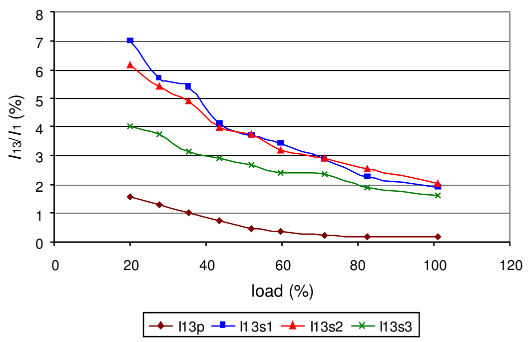

Fig. 9. 13th harmonic of currents of 18-pulse rectifier in connection Dy1z1+20⁰z1-20⁰ versus its loading

Nevertheless it can be said that above mentioned increasing of THD_i of the input primary current, i.e. the current drawn from the network, is not so high and THD_i levels under lower degrees of loading remain quite low.

4. CONCLUSION

Various electrical devices and instruments fitted by semiconductor converters are produced and operated on a mass scale. By their connection to the supply network they act as sources of harmonic currents generated into it. To minimize the levels of these generated harmonic currents, various technical solutions of variant levels of harmonic mitigation efficiency are accepted and implemented into structures of such electrical devices or instruments. The tested 18-pulse rectifier represents the very good solution for harmonics reduction as it can be seen from the presented results. The levels of harmonic currents generated by the adjustable speed drive fitted by this type of rectifier are rather strong reduced and remain on low levels. But it is necessary to bear in mind that the harmonics reduction efficiency of tested 18-pulse rectifier, and other used devices in the practice, depends on a level of loading, voltage unbalance and supply voltage distortion rate and a construction of the device.

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