NEGATIVE INFLUENCE OF FREQUENCY CONVERTERS ON POWER DISTRIBUTION NETWORK

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Summary This paper deals with low-frequency analysis of the phase current taken by frequency converters from a power distribution network. Problems concerning with characteristic harmonic currents are relatively well-known. Therefore the main emphasis of this work is focused on the investigation of factors which influence arising of non-characteristic and interharmonic current components.
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1. INTRODUCTION

Nowadays a big attention is given to the negative effects of semiconductor devices on the distribution network from the electromagnetic compatibility point of view. As the power electronics devices find their wide application in power systems, power quality is becoming a more important issue to consider. Operation of indirect frequency converters with IGTB (Fig. 1) brings a lot of advantages, but is often accompanied by some unfavourable effects. The converter adversely influences power distribution network due to non-sinusoidal taken current, fed motor by transient motor overvoltage [1,2] and also converter control circuits.

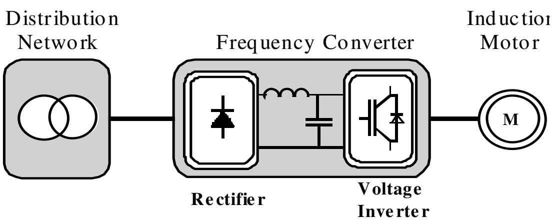

Fig. 1. Block diagram of the drive with frequency converter

The problems concerning with characteristic harmonic currents of indirect frequency converters, causes of their arising, negative effects in power distribution network and ways of their minimization, are relatively well-known [3, 4]. There is a less attention concentrated on non-characteristic and interharmonic current components in practice and literature [4, 5]. The frequency converter takes away from distribution network a non-sinusoidal current wave which contents higher frequency components. These harmonic components are transferred to power distribution network where they can arise a distortion of supply voltage, disturbance of connected equipment (e.g. ripple control devices, tuned power filters, compensation units).

2. SYSTEM MODELLING

In the case of frequency converter with voltage source inverter (Fig. 1), we can divide the circuit into inverter part and rectifier part supplying capacitor in the DC Bus.

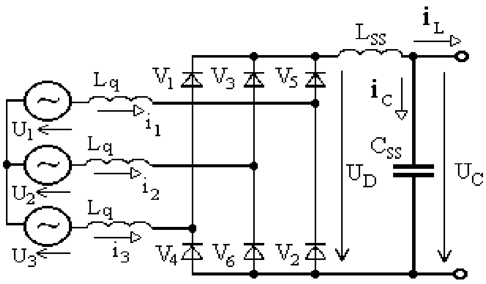

Fig. 2. Three-phase bridge rectifier configuration

Three-phase bridge rectifier as an input part of the static converter (Fig. 2) is modeled with the focus on the calculation of all harmonic components presented in the current taken by rectifier from a power distribution network.

Typical waveform of taken phase current under ideal operating conditions (symmetrical power supply, indefinite short circuit power etc.) is on the Fig. 3. The non-sinusoidal waveform of phase current creates higher frequency current components. For the harmonic components calculation of phase current it is necessary to simplify the phase current.

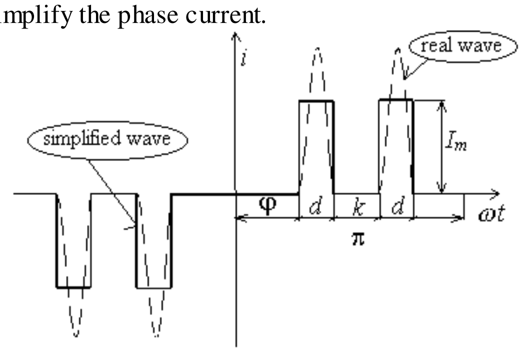

Fig. 3. Real and simplified phase current wave

3. NON-CHARACTERISTIC HARMONICS

Under real conditions, unbalanced power source (amplitude or phase non-symmetry), the considered problem becomes more complicated and we can find also non-characteristic components in frequency spectrum. In contrast to characteristic harmonics for calculation of non-characteristic harmonic amplitudes we can not use well-known "*1 over h rule*" and we have to apply numerical Fourier analysis (DFT or FFT) [6] for investigation of frequency spectrum of taken current. Voltage and current circumstances at single phase voltage power source non-symmetry you can see on the Fig. 4. Power source non-symmetry causes distortion of phase currents and drift of basic harmonic wave of phase current against phase voltage [7].

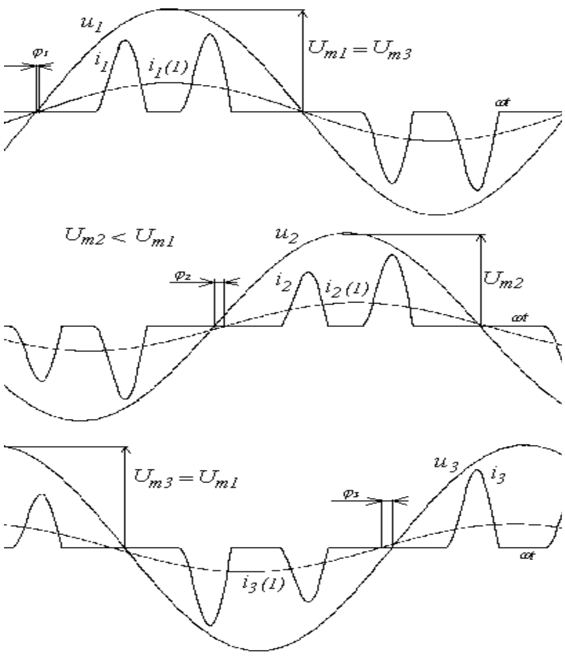

Fig. 4. Voltage and current waveforms at single phase voltage source non-symmetry

The frequency spectrum of phase current from contains non-characteristic harmonics of odd multiple of three only (Fig. 5) and their amplitudes depend on the value of voltage source non-symmetry (Fig. 6).

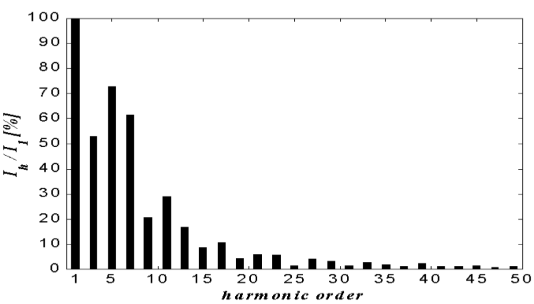

Fig. 5. Frequency spectrum of taken phase current at 3% power source non-symmetry

Value of non-characteristic harmonics increases with voltage non-symmetry rising and it results in low decrease of characteristic harmonics. Drop of dominant harmonics has influence on coefficient *THDi* low decrease, but then increasing of third harmonic causes low rising of coefficient *THDi* (Fig. 8). In following figures you can see comparison of simulation and experimental results. The measurement of harmonic components was made according to Standard IEC 1000-4-30 and has been measured by frequency analyzer.

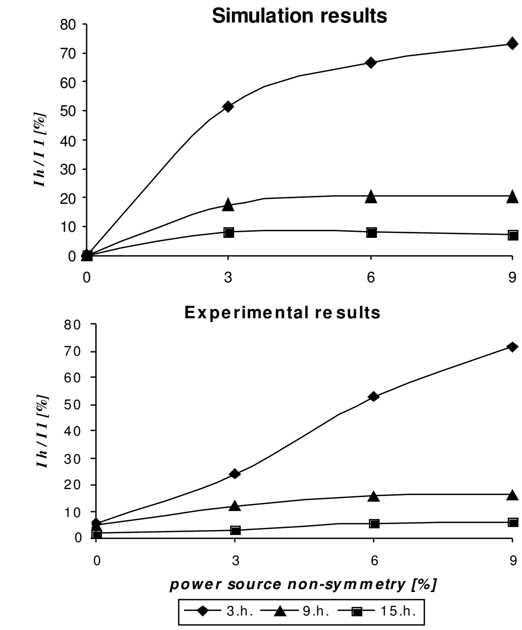

Fig. 6. Non-characteristic harmonics in dependence of voltage power source non-symmetry

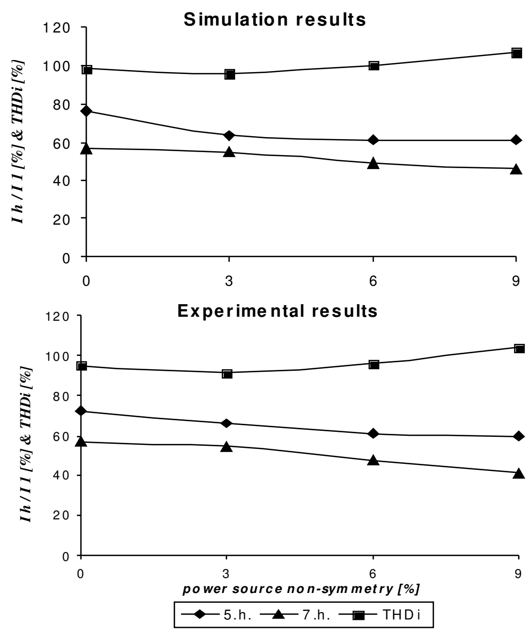

Fig. 7. Characteristic harmonics and THDi in dependence of voltage source non-symmetry

Waves of quantities on Fig. 6-7 are displayed for definite circuit configuration (*Lq*, L_{SS}, C_{SS}, diode voltage drop etc.). It is obvious, that change of these circuit parameters influence phase currents and consequently values of harmonics. Dependence of non-characteristic harmonics on circuit parameters L_{SS} and C_{SS} is shown on Fig. 8.

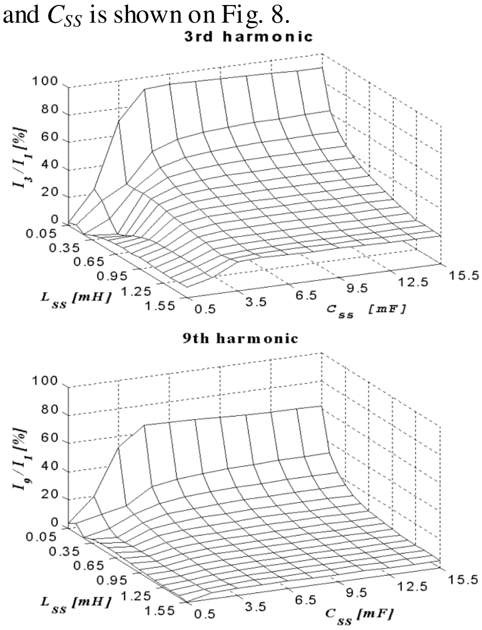

Fig. 8. Non-characteristic harmonics in dependence of parameters Lss and Css

4. INTERHARMONICS

Many factors influence the harmonic spectrum under real conditions. In this case except characteristic harmonics and non-characteristic harmonics (previously paragraphs) we can find also interharmonic components in frequency spectrum. The interharmonic current magnitudes are relatively small in comparison with the characteristic and non-characteristic harmonic components but they may cause the interference in neighbouring electronic equipment, for example the interference of ripple controls and tuned power filters.

Waveforms of taken currents are affected by combinations of many influences:

- change of phase supply voltage (single phase, three phase)
- change of phase supply frequency

Interharmonic values are dependent on dynamic changes of these quantities. The distribution network is relatively hard and frequency changes are minimal, therefore we will discuss supply voltage changes further. Voltage changes can be making by connecting and disconnecting equipment to distribution network and load changes of connecting equipment. At the first we will discuss case of three phase voltage change for interharmonic components arising.

Waveforms of circuit quantifies are shown on the Fig. 9 and appropriate frequency spectrum you can see on the Fig. 10. Size of voltage change ΔU has major influence on interharmonic value (Fig. 11) and it is determined in percent of phase voltage amplitude during the calculation window T_W=200 ms (it means voltage decrease during ten basic periods).

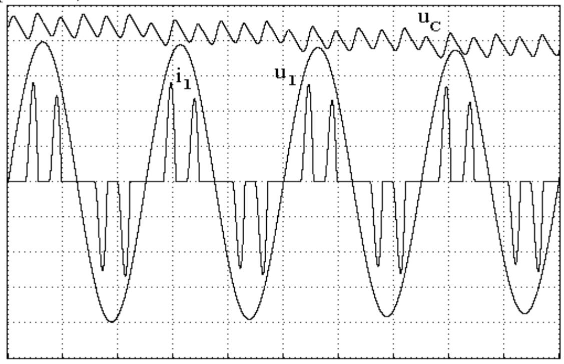

Fig. 9. Voltage and current waveforms at three phase voltage source change (ΔU = 15,5 % ≅ 50 V)

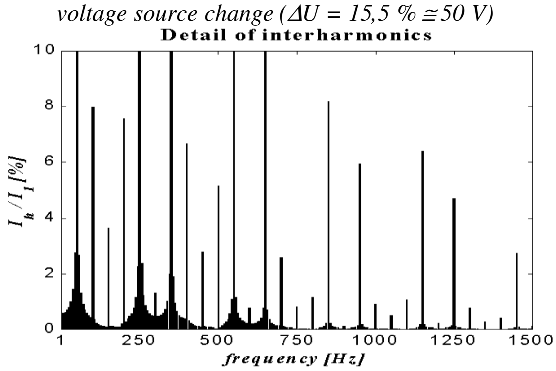

Fig. 10. Detail of interharmonics at three phase voltage change (ΔU = 15,5 % ≅ 50 V)

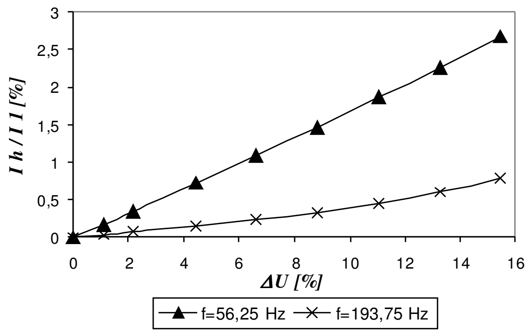

Fig. 11. Dependence of interharmonics on voltage decrease at three phase voltage change

It is evident that value of interharmonics increases with *ΔU* rising. The case of three phase voltage change causes creation of all interharmonic currents in frequency spectrum.

Now we will discuss case of single phase voltage change and we will change amplitude of the second phase (Fig. 12) and appropriate frequency spectrum is on the Fig. 13. Due to single voltage change phase current waveforms are heavily distorted that appears at frequency spectrum of interharmonics which are much bigger than in case before. Also the voltage of capacitance C_{SS} is distorted, it has bigger waviness and lower pulse (from six pulses it floats to four pulses).

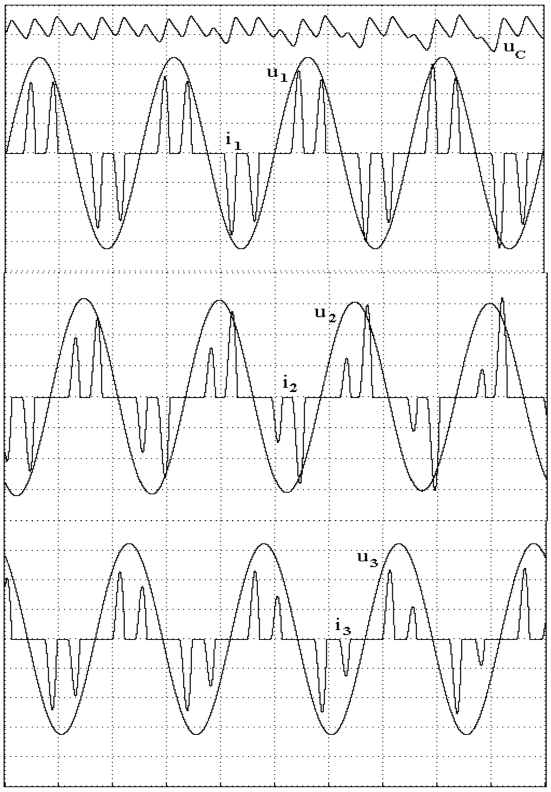

Fig. 12. Voltage and current waveforms at single phase voltage source change (ΔU = 8.8 % ≅ 29 V)

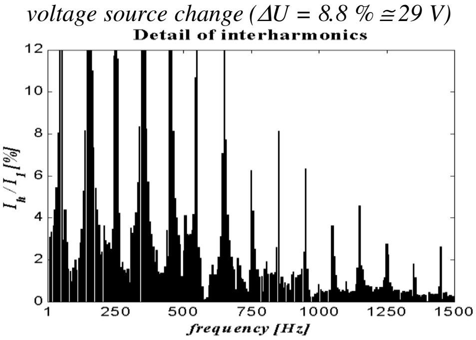

Fig. 13. Detail of interharmonics at single phase voltage change (ΔU = 8.8 % ≅ 29 V)

For lower ΔU dependence of interharmonics is the same as for three phase voltage change (the paragraph above) but for higher ΔU interharmonic components decrease (Fig. 14).

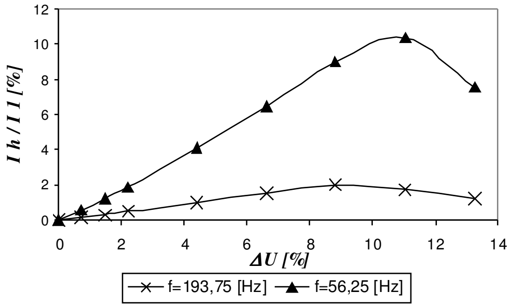

Fig. 14 Dependence of interharmonics on voltage decrease at single phase voltage change

For higher value of ΔU distortion of phase currents is so high that the classical double pulse waveform of phase current (Fig. 3) is changing to single pulse waveform (Fig. 12 – second phase). This pulse change of phase current has good influence on interharmonic components (amplitudes decrease). On other hand it has unfavourable effect on harmonic components, mainly on the third non-characteristic harmonic, which essentially increase.

5. CONCLUSION

Unfavorable effects of frequency converters on power distribution network have been presented. Unbalanced power source causes arising of non-characteristic harmonic which order is odd multiple of three only. Their amplitudes depend on value of voltage source non-symmetry. Non-characteristic harmonics increase with rising of voltage non-symmetry and it results in low decrease of characteristic harmonics. In frequency spectrum we can find also interharmonic components which are caused by changes of phase voltage of power source.

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