International Conference on Renewable Energies and Power Quality (ICREPQ'14)
Cordoba (Spain), 8th to 10th April, 2014
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.12, April 2014

IMPACT OF NON-LINEAR SMALL POWER RECEIVERS ON LOW VOLTAGE NETWORK OPERATION CONDITIONS

Julian Wosik, Bogdan Miedzinski, Artur Kozlowski, Marian Kalus
Institute of Innovative Technology EMAG
Str. Leoplda 31, 40-189 Katowice, Poland
wosik@emag.pl bogdan.miedzinski@pwr.wroc.pl, artur.kozlowski@emag.pl, mkalus@emag.pl

Abstract. The paper discusses the causes of distorted waveforms of currents and voltages in industrial electric power systems of low voltage. The ascending contribution of domestic and municipal customers, particularly office and as commercial as well as service and shopping centers where, non-linear loads and load phase unbalance are common, is indicated. Studies of voltage and current waveforms and their harmonics spectra at selected this type of facilities were carried out. The ability to compensate for the negative impact of low power consumer receivers using the active power filter has been demonstrated.

Key words

non-linear load, non-sinusoidal waveform, high harmonics, discharge light source, active power compensation.

1. Introduction

In advanced economies, a significant amount of electric energy (up to 80%) is consumed through the converters of different power. Their characteristic feature is downloading the highly distorted waveforms, especially currents. In the power converter structure one can distinguish three basic units:

- the first-input, which is a rectifier,
- second is a coupling circuit which contains the R, L, C elements,
- third is an output unit that is a voltage source inverter of adjustable (or not) frequency.

In the steady state the distorted current waveforms are periodic and meet requirements of Dirichlet. They can therefore, be represented by a Fouries series:

$$i(f) = I_0 + \sum_{h=1}^{\infty} I_h \cdot \cos(h\omega_1 t + \varphi_h) \qquad (1)$$

where:

I_0 - is a dc component,
I_h - is an amplitude of h-number harmonic,
$\omega_1=2\pi f_1$ - angular frequency of basic harmonic
φ_h - angle shift of voltage and current for h-harmonic.

Depending on the number of pulses of the rectifier system applied, the characteristic feature is the presence of selected current harmonics of h-numbers:

$$h = n \cdot k \pm 1 \qquad (2)$$

where:

n - n-number of pulses of the rectifier,
k - k-integers 1, 2, 3 …

However, detuning of the rectifier can result in the appearance of harmonics with different number that under the eqn (2). Presence of distorted currents (high harmonics) is the cause of a number of negative effects in the electricity network that need to be limited. The receivers resulting in such deformations are called non-linear loads. In practice they are used mainly in industrial applications and are characterized by high range of rated power from a few dozen of kVA to a few kVA. Today, very large role in electric energy consumption and in power system operation play receivers belonging to the group of domestic and municipal load. Although, they have a low rated power but their number is usually considerable high. Over the past several years a specific group of consumers has gained increasing importance if about energy market (large surface offices, shopping centers etc.). They draw from the network a high amount of electric energy, often close to the power demand of large industrial plants. In these objects is usually installed a significant number of non-linear loads [1-4, 6]. These include mainly:

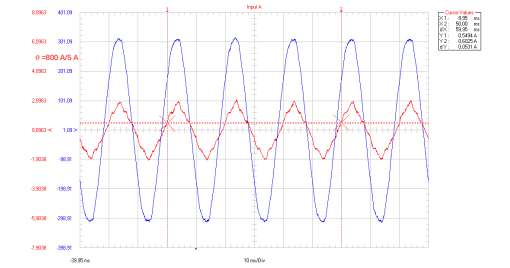
- all kinds of discharge type light sources,
- power electronic equipment containing input rectifiers (computers, monitors, printers, servers, impulse-type power suppliers UPS).

Therefore, for this reason it is important to know the nature of the load for the selection of appropriate technical countermeasures to reduce the negative impact on the supply network.

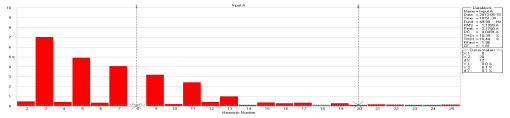
2. Study of the nature of the load in large area objects

For study was chosen office building of area of approximately 5400 m^2 together with laboratory facilities

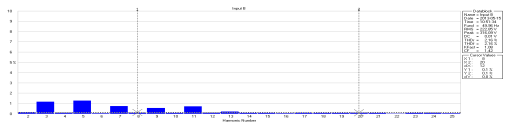
of about 4800 m^2 surface. The main receivers of the office are found to be discharge light sources, computer equipment and air conditioning equipment. In the server room - UPS devices respectively. All the receivers are practically of 1-phase supplied however, fed virtually evenly from all phases. For each of these groups were registered load current and voltage waveforms and an appropriate spectral analysis was performed. From the obtained investigated results (presented as an example in Fig. 1-11) can be observed, known already from the literature [1-4], evident impact of low power receivers on deformation of the current waveform in particular. However, depending on the type of the receiver are generated as odd as well as even high current harmonics (see Fig. 8).



a)

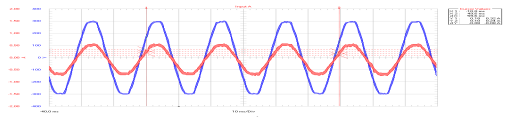


b)

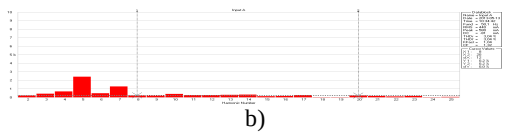


c)

Fig. 1. Voltage and load current waveforms supplied the tested object (a); current harmonics spectrum (b); voltage harmonics spectrum (c).

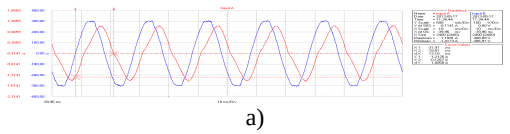


a)

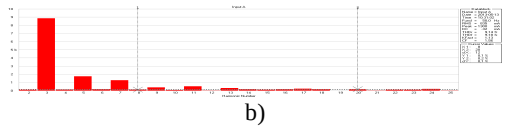


b)

Fig. 2. Voltage and current waveforms for incandescent lamp of 100W (a); current harmonics spectrum (b).

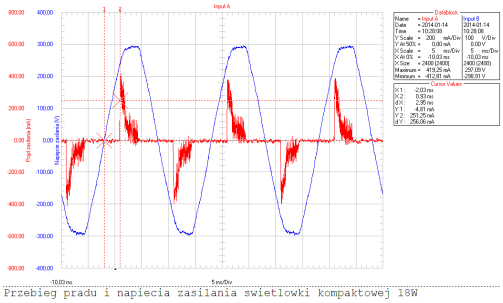


a)

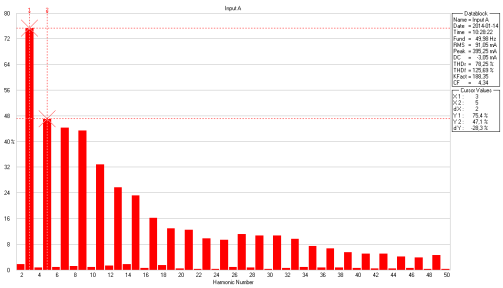


b)

Fig. 3. Voltage and current waveforms for fluorescent lamp LF 2×40 W type (a); current harmonics spectrum (b).

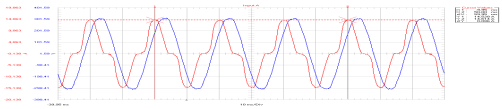


a)

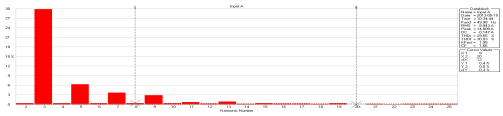


b)

Fig. 4. Voltage and current waveforms for compact fluorescent lamp Brilux 2U 18 W type (a); current harmonics spectrum (b).

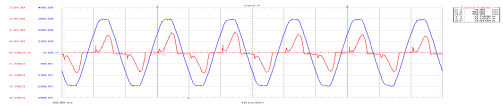


a)

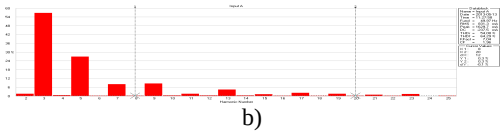


b)

Fig. 5. Voltage and current waveforms for supplying system of 9 high pressure discharge lamps HWL (MBTF) Osram type (a); current harmonics spectrum (b).

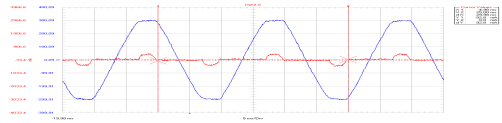


a)

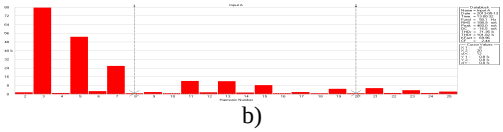


b)

Fig. 6. Voltage and current waveforms when supply computer unit PC-VOBIS (a); current harmonics spectrum (b).

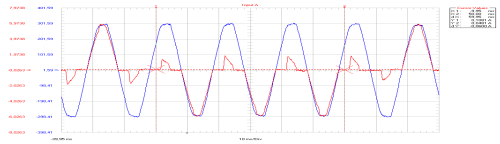


a)

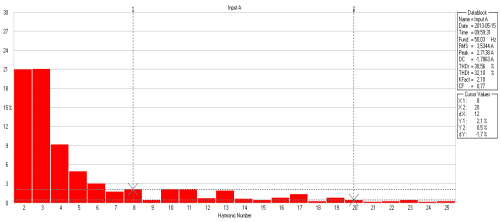


b)

Fig. 7. Voltage and current waveforms when supply monitor SONY 21” type (a); current harmonics spectrum (b).

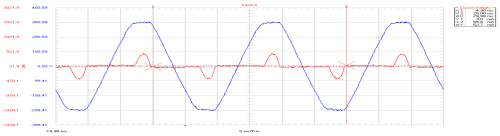


a)

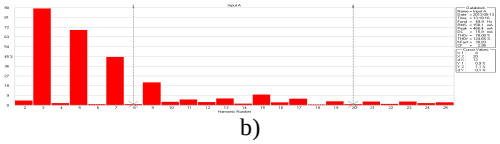


b)

Fig. 8. Voltage and current waveforms when supply printer of HP Laser Jet 2840 type (a); current harmonics spectrum (b).

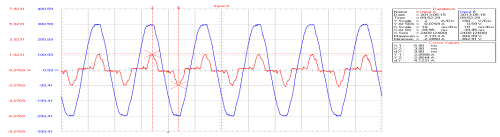


a)

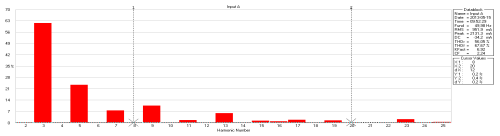


b)

Fig. 9. Fig.9 Voltage and current waveforms when supply scanner of HP Scan Jet 4850 type (a); current harmonics spectrum (b).

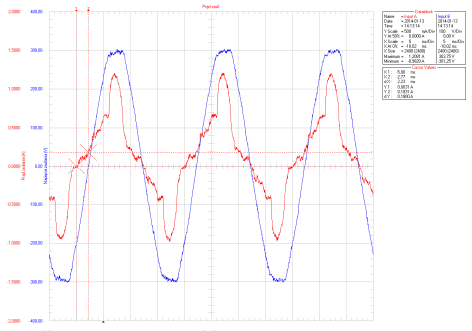


a)

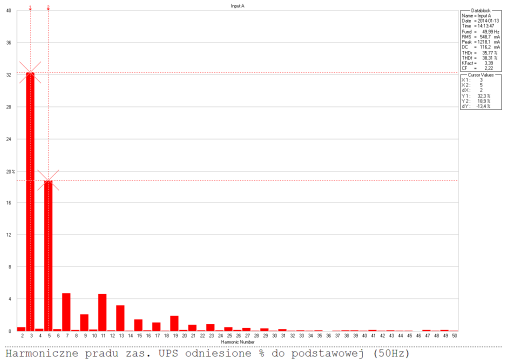


b)

Fig. 10. Voltage and current waveforms when supply a PC kit (computer+monitor+printer) (a); current harmonics spectrum (b).

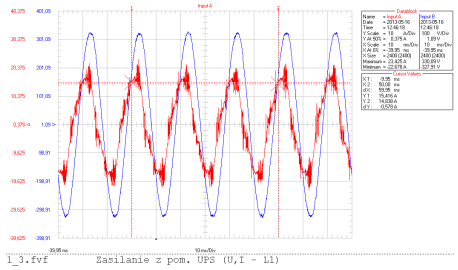


a)

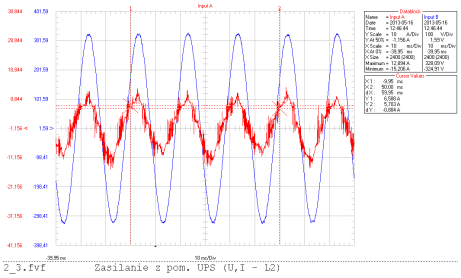


b)

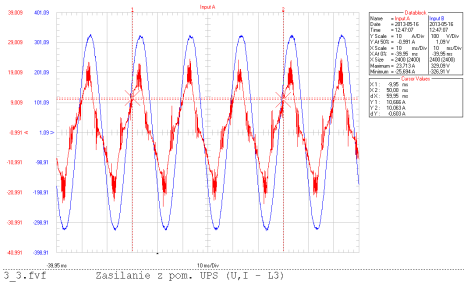
Fig. 11. Voltage and current waveforms when supply a computer unit by means of UPS (Active Power-Model Easy 800 VA) (a); current harmonics spectrum (b).



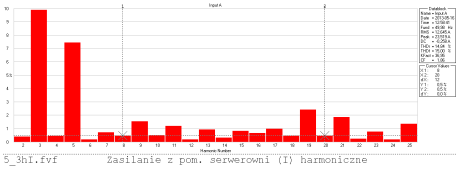
a)



b)

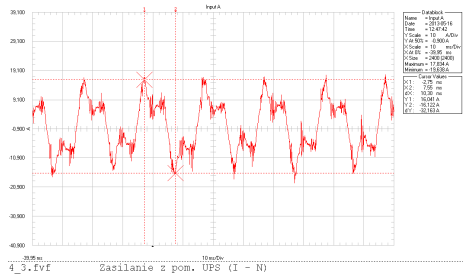


c)

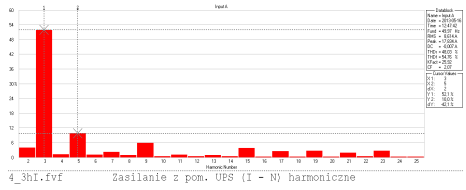


d)

Fig. 12. Voltage and current waveforms in particular phases of the server room; in L1 phase (a); in L2 phase (b); in phase L3 (c) respectively; current harmonics spectrum (d).



a)



b)

Fig. 13. Current waveform in neutral conductor of a 3-phase low voltage network supplying the server room (a); current harmonics spectrum (b).

The values of current harmonics are quite significant and reach about 75% for the third harmonic which, is seen especially when supply the fluorescent lamps type Brilux 2U 18 W (Fig. 4.). It should be noted that the THD_i value exceeds 100%. As a result of application of a significant number of UPS units the nature of the resultant load of the object ,which for example is the server room, can be changed from inductive to capacitive respectively (compare Fig. 11-12) and may also reveal asymmetry of load of particular phase (Fig. 12). It changes significantly the approach to the problem of reactive power compensation for this type of municipal customers in practice. The asymmetry of the load results in current flowing in the neutral conductor of considerable value and highly distorted (Fig. 13). This, in turn, can significantly interfere operation of various important systems like electric shock protection, electrical automation and protection. There were also found various interharmonics both current and voltage which under certain resonant conditions in the network can interfere and sometimes even preclude effective transmission in PLC technology. All this require the application of appropriate remedial measures which could limit or eliminate the negative effects of the impact of non-linear loads of common energy consumer on the quality of electricity and the problems associated with the possibility of reliable operation of the low voltage supply network.

3. Possibility for reduction of nonlinearity and asymmetry of the input current load

Concept to improve the quality of electricity through the use of active power filters has been confirmed by authors both for the simulation model and the laboratory model of active power filter controlled by an algorithm based on the CPC theory (current physical components) [5]. This allows effective elimination of higher harmonics from the load current due to non-linear receiver, effective compensation of reactive power value drawn from the network and suitable symmetrization of network loading as well. For example, below are presented selected results of investigations for the case when the load is both non-linear (controlled rectifier $\alpha=50^o$) and asymmetric (additional resistance value included between L1 and L3 phases) (Fig. 14). As one can see the efficiency of the active power filter application is significant (Fig. 15-16.).

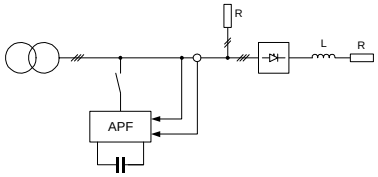
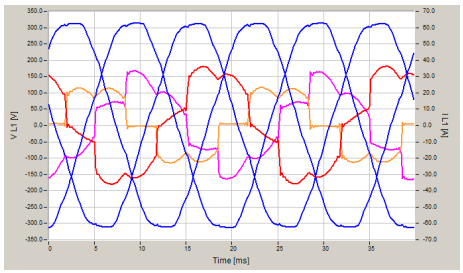
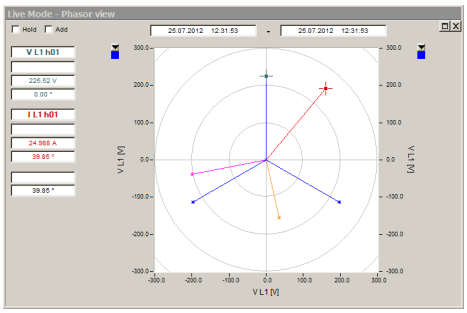


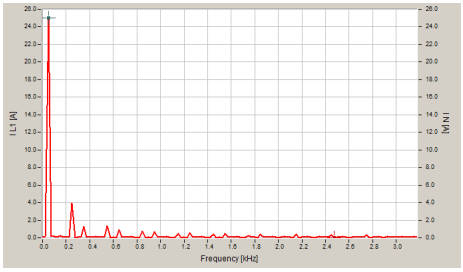
Fig. 14. Simplified electric scheme of system for laboratory testing of operation efficiency of active power filter (APF).



a)

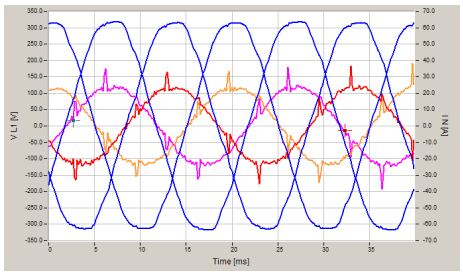


b)

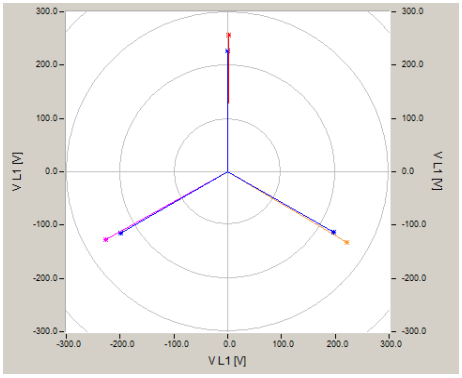


c)

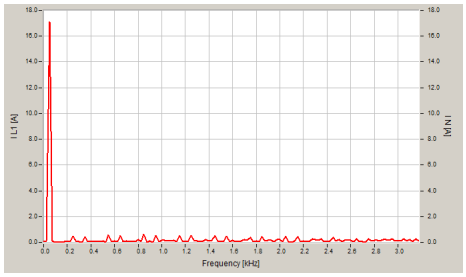
Fig. 15. Current and supply voltage waveforms due to controlled rectifier ($\alpha=50^o$) at involved load asymmetry between L1 and L3 phase (a); phase voltage and current vector diagram (b); current harmonics spectrum in L1 phase (c).



a)



b)



c)

Fig. 16. Current and network voltage waveforms when supply controlled rectifier ($\alpha=50^0$) together with active power filter at involved load asymmetry between L1-L3 phases (a); phase voltage and current vector diagram (b); current harmonics spectrum in L1 phase (c).

4. Conclusion

- Large area objects like administrative offices, service centers and big department stores are now large electricity consumers. Because of significant number of non-linear receivers applied of a low power they draw in general, from the network strongly deformed current.
- Current distortion is mainly due to: the initial deformation of the supply voltage; the use of a large number and diverse quality of discharge type light sources that consume highly distorted current (THD_i over 100%); application of power electronic load (eg. computer hardware) equipped with a rectifier power supply systems.
- Necessity of the use of back- up power supply and the server rooms equipped with buffering UPS units is characterized as a result by a capacitive power consumption with high content of current harmonics.
- The effect of voltage and current waveforms distortion is also responsible for the presence of various interharmonics which may disturb significantly the PLC transmission in the electric networks.
- Due to unavoidable pre-distorted voltage waveforms at supply and due to time-varying share of non –linear loads of a small power only effective way for both reactive power compensation, reduction of high harmonics content in load current and load symmetrization in large area office buildings, commercial and service centers is the use of active power filters.

References

[1] Sarah K. Rönnberg, Mats. Wahlberg, Math H.J.Bollen: Harmonic Emission before and after changing to LED lamps – Field Measuremennts for an urban area. 15-th ICHPQ Conference Hong-Kong, 17-20 june 2012,

[2] Siezinger J., Drapella J., Lamgella R., Testa A.: A New Simplifield Model of Compact Fluorescent Lamps In the Scenerio of Smart Girls. 15-th ICHPQ Conference, Hong-Kong, 17-20 june 2012,

[3] Panas A., Blanco A. M., Parra E.: Analising effective lighting devices impast on Power quality and electrice grid efficiency by means of FBD – poer theory, 15-th ICHPQ Conference, Hong-Kong, 17-20 june 2012,

[4] Matvoz D., Maksic M.; Comparision of LED and CFL Lamp and Their Impact on Electric Power Network, 15-th ICHPQ Conference, Hong-Kong, 17-20 june 2012.

[5] Wosik J., Kalus M., Kozlowski A., Miedziński B.: Improsiement of Electric Energy Quality by use of Active Power Filters. ICREPQ 2013 Bilbao Renewable Energy&Power Quality (Journal Nr 11, March 2013, paper Nr 257).

[6] Arsor L., Cudeva-Blajer M., Ihazi I.. Measurement of Power Qality Effect and Energy Efficiency of Varius Light Technologies. ICREPQ 2013 Bilbao RE&PQ (Journal Nr 11, March 2013, paper Nr 516).