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THE IMPACT OF THE LARGER NUMBER OF NON-LINEAR CONSUMERS ON THE QUALITY OF ELECTRICITY *

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Abstract. *Theoretically this paper will explain the formation of higher harmonic components in the electricity network, their causes, consequences on consumers and the ways of their elimination. Transformer role in the Dyg connection will be explained on the concrete example. For a specific example the waveform of primary (R) phase at 10 kV voltage level, the current of the secondary (r) phase and the neutral conductor at the 0.4 kV voltage level will be determined as shown in the concrete example in the work. Harmonic content will be determined up to 15 harmonics and the effective value of all these currents (phases R and r). THD for current of primary (R) phase and secondary (r) fase will be calculated. In this paper, the dimensional three-phase filter is set to eliminate the maximum harmonic component of current of the primary (R) phase on the 10 kV side of the transformer. The waveform, the corresponding harmonic content for the current and THD of primary (R) phase will be determined. Additional measures have been proposed to reduce the THD. Another parallel filter has been realized to eliminate the second by size harmonic components of primary (R) phase current. It will also compare THD for primary (R) phase as in the previous cases. For the total duration of the simulation, the used time is Tstop = 0.1 sec. All of the above simulations will be realized in the MATLAB / PSB program package and simulation models will be displayed.*

Key words: *electricity network, higher harmonics, load, transformer coupling*

1. INTRODUCTION

The term quality of electricity was extensively used in the mid-1980s and it is important to pay attention to both suppliers and consumers. Depending on the point of view, there are different definitions of the quality of electricity. The problem of the quality of electricity is related to the end customer [1], ie consumers of electrical energy.

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* An earlier version of this paper was presented at the 4th Virtual International Conference on Science, Technology and Management in Energy, eNergetics 2018, October 25-26, Niš, Serbia [1]

The concept of quality is becoming increasingly apparent as electric consumers become very dependent on the quality of power, since they are increasingly based on electronic or microprocessor components that are very sensitive to power supply disruptions. Also, the quality is additionally updated today with regard to the liberalization of the electricity market, when electric energy becomes a commodity as any other commodity, it must satisfy a certain quality that is defined by the consumers.

Consumers, as well as electricity producers, must meet the appropriate standards regarding the quality of electricity. Normal switching operations with condensing batteries for repairing the power factor, switching on or deactivating low-load transformers or overhead lines, atmospheric discharges, etc. lead to transients that have a significant impact on the quality of electricity. The deteriorating quality of electricity is also affected by an increasing number of non-linear consumers [2] that generates electricity harmonics resulting in voltage deformations.These non-linear consumers are increasingly vulnerable to voltage deformations.

In today's conditions of complex production processes accompanied by a large number of electronic and automatic regulation and control elements, any error in the functioning of a particular system component necessarily leads to very significant economic consequences.In the late fifties and during the sixties, rapid semiconductor components (thyristors and strong bipolar transistors) developed rapidly. Semiconductor energy electronic transducers appeared and completely suppressed those with vacuum elements. Most energy electronic converters are those that connect to the AC mains (rectifiers, network switched inverters, AC voltage regulators, cyclone converters). Due to their interrupt nature, they represent non-linear consumers for the network and cause the distortion of the waveform of the current and voltage [3]. It is shown by mathematical analysis of distorted waveforms, using Fourier series, that these distorted forms can be represented by a series of sine functions of different frequencies. These frequencies are an integer of the basic (dominant) frequency of the analyzed signal and are called higher harmonics [4].

The interest in analyzing the quality of electricity lately has been steadily increasing because:

- Electrical and electronic equipment are becoming more susceptible to voltage disturbances;
- Electrical and electronic equipment are increasingly generating voltage disruptions;
- The quality of electricity is of particular importance in the conditions of the deregulated market; and
- By developing modern measuring devices, today the quality of electricity can easily be measured and memorized.

The two main categories of problems in the analysis are:

a) Disorders:
   Transits
   Decay and increase voltage
   Power supply interruptions
b) Stationary variations:
   Voltage regulation
   Harmonic distortion
   Voltage flickers

2. MODEL OF SOLVING PROBLEMS OF HIGHER HARMONICS

The problem of the quality of electricity is dealt with by experts and scientists from many countries. By raising and expanding the application of electricity and the technology of the operation of the electric energy system, there is a need for standardization of certain solutions for the improvement of quality. The main goal in this period was to provide a reliable supply for consumers, which were linear in nature. Therefore, for many years, the definition of quality was very simple - quality is equal to reliability. However, with the introduction of electronics into banks, business institutions, industrial plants and households, or the emergence of microelectronic circuits and the information revolution in the second half of the twentieth century, the concept of quality has gained a wider meaning. A huge number of sensitive consumers are connected to the network, which require high power quality and voltage. On the other hand, there is a category of non-linear consumers (energy converters), which intensely deforms the waveform of the consumed current. The need for standardization, ie limiting the level of interference, becomes essential for consuming electrical energy.

The initial standards - recommendations related to voltage quality were adopted at the end of the 1960s (the 1967 recommendation and the standard for the limiting of harmonics in Britain and the USSR), and during the seventies and early eighties, by twenty countries [6]. The problem of standardization of the quality of electric energy, ie limiting the influence of energy converters on the environment, and especially the phenomenon of "pollution" of the network with higher harmonics, is dealt by several international organizations. The most important are the International Electrotechnical Commission - IEC, as well as the European Committee for Electrotechnical Standardization - CENELEC. In addition to these international organizations, which are in charge of issuing standards, a number of international organizations are considering this problem as their professional interest, the most influential being the Institute of Electrical and Electronics Engineers – IEEE, and the International Conference on Large Electric Networks - CIGRE

In Figure 1, the example where the three-phase part of electrical energy network is presented, in which non-linear load of a group of PCs is powered through a transformer connection.

Program package MATLAB/Simulink/Powe System Blockset (PSB) is used for modeling, simulation and analization of the dinamic energy system.

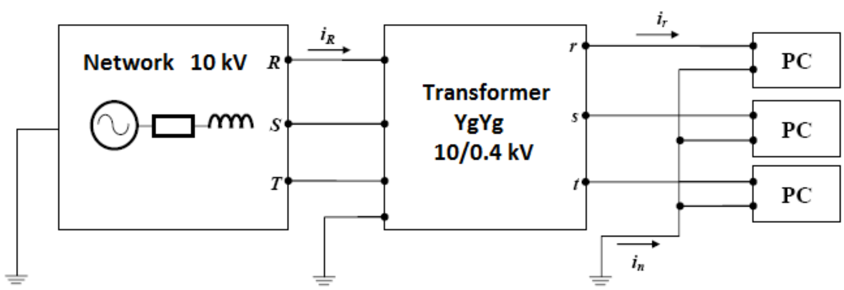

Fig. 1 The analyzed part of the network

In Figure 2, the equivalent nonlinear load model for each phase is presented.

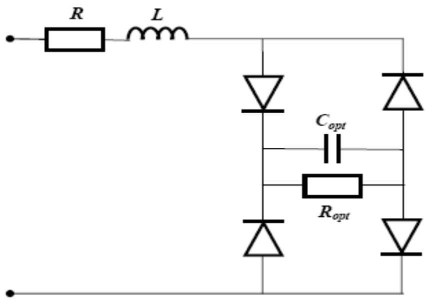

Fig. 2 An equivalent non-linear load model (PC)

The model parameters are:
Network:
Voltage level: Un = 10 kV (line voltage)
Phase angle of the first phase: = 0
Network parameters: Rs = 2.5 Ohm;
Ls = 0.05 H

Transformer (linear model):
Nominal power: Sn = 50 kVA
Transformer Transformer Ratio: 10 / 0.4 kV
Working resistance and primary and secondary winding reactance:
Rp = Rs = 0.0025 p.u .; Xp = Xs = 0.06 p.u.
Magnetization branch parameters: Rm = 500 p.u. ; Xm = 500 p.u.
Nonlinear Load Parameters (PC): R=0.5 Ohm; L=0.004 H Ropt=100 Ohms; Ball=150 uF

Internal diodes parameters:
Resistance Ron (Ohms): 0.01
Inductance Lon(H): 1*10^-6
Forward voltage Vf(V): 0.8
Initial current Ic(A): 0
Snubber resistance Rs(Ohms): 10
Snubber capacitance Cs(F): 0.01*10^-6

The work:

1. Theoretically briefly explains the cause of the formation of higher harmonic components in the electric power network, their consequences on consumers and the ways of their elimination. The role of the transformer in the DYg compound is explained and a concrete example is given.
2. For the part of the electrical network from Figure 1, a waveform of primary(R) phase at 10 kV voltage level and the current of the neutral conductor phase at 0.4 kV voltage level will be determined, as shown in Figure 1. The harmonic content will be determined up to 15. Accordion, as well as the effective value of all these currents. (phases R and r). Also, THD for current of primary(R) and secondary(r) phases will be calculated.

3. The three-phase filter will be set to eliminate the maximum harmonic component of the current of primary(R) phase at the 10 kV side of the transformer. The waveform, the corresponding harmonic content of primary(R) phase current and THD will be determined.
4. Additional measures will be proposed to reduce the THD of primary phase current. Another parallel filter will be realized for elimination of the second one by size harmonic component of the primary(R) phase current. The comparison of THD will be made in cases under 3 and 4 .
5. For the total duration of the simulation, the used time is Tstop = 0.1 sec.
6. The mentioned simulations will be realized with the MATLAB / PSB type program package. The corresponding simulation models are displayed.

3. THE CAUSES OF THE FORMATION OF HIGHER HARMONICS

More *harmonics* in the network are caused and generated by non-linear consumers in the electric power network, which injects more harmonic components of the current into the system. This component through the impedance of the system results in distortion of the supply voltage, that affects the reduced reliability and shortening of the life of electrical equipment [6]. Praxis is interesting to the higher ranks of the order from 0 to 100.

Higher harmonics causes are:

- transformers, due to non-linear Φ - and characteristics of the iron core,
- semiconductor electronic converters that due to their switching nature represent non-linear consumers for the network and cause distortion of the waveform of the current and voltage,
- electric furnaces,
- discharge lamps,
- saturated electrical machines.

The power system components and consumers are designed for sinusoidal forms of voltage and current, and any appearance of higher harmonics brings negative effects.

Some of the side effects are:

- the occurrence of serial and parallel resonance in the network resulting in increased voltage and current,
- impact on condenser batteries which causes an increase in losses,
- the influence on the protection elements, which leads to unwanted activity of the protective devices (protection) or fuse overheating,
- impact on the accuracy of standard measuring instruments,
- additional losses in electrical machines (eg overheating, heating of cables, and the like),
- interference with tt signals (higher har monics from power lines are transmitted by electromagnetic interference to tt cables, thus creating noise and disturbances in telecommunications,
- influence on transformers.

3.1. Reduction of negative impacts

In order to minimize the negative effects of higher harmonics, the following measures are necessary:

Reduce the intensity of harmonic currents
- by installing chokes in series with non-linear consumers,
- transformers in the Yd or Dd connection, since the compound in D retains odd harmonics dividible with three,
- dimensioning of neutral conductors 2: 1 in relation to phase or installation of two with old dimensions,
- installation of 12 pulse converters.

Installation of filters
- passive filters that are split into:

a) Ordinary
  – First row
  – Second row
  – Third row

b) active filters
  – active filters have the ability to generate and manage non-linear currents

Resonant frequency change system

Resonance can occur when there are condensing batteries for compensation of reactive energy in the system or with consumers. Since the resonant frequency of the system, including capacitor batteries, is often close to the frequency of characteristic harmonics of non-linear consumers, there are undesirable effects.

The change in the resonance frequency of the system is realized:
- by changing the size of the capacitor,
- by adding a serial choke,
- moving the capacitor to another location,
- or disconnecting the capacitor.

3.2. The role of the transformer in the Dyg compound

When we look at the magnetization component $i_\mu(t)$ in Figure 1 we see that it is not a sinusoid but a recited periodic function with nulls having maximal values at the same moments as the induction function B (t).

Fourier's analysis of one such function gives data for the amplitude of higher harmonics:

First harmonic	100%
Third harmonic	24,5%
The fift harmonic	3,43%

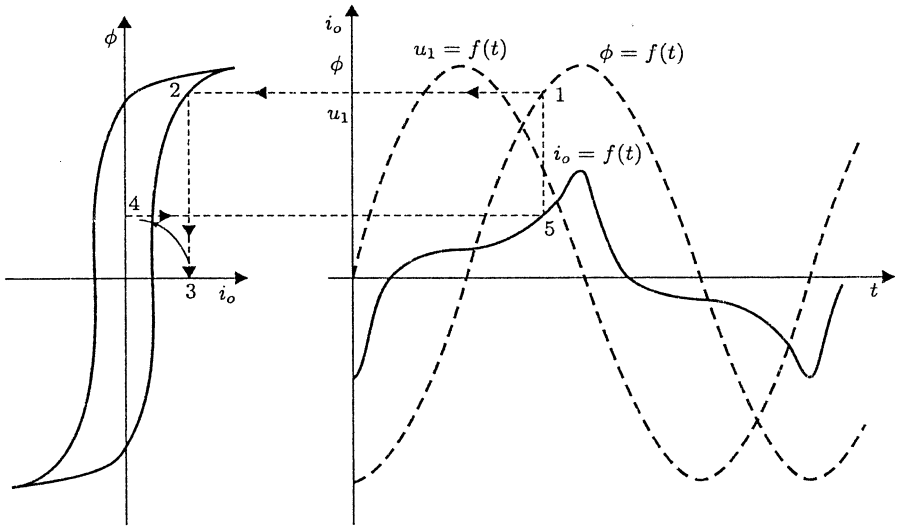

Fig. 3 Hysteresis transformer curve

Figure 3 shows the first, third and fifth harmonics. There is an important influence of the third harmonic (which is a negative sinusoid).

In the first third of the semiperduct, negative values $i_{\mu 3}$ decrease the positive values $i_{\mu 1}$. In the second third of the semiperduct, the positive values $i_{\mu 3}$ are summed up with positive values $i_{\mu 1}$, and in this way a sharpening form occurs $i_{\mu}(t)$.

With zero lead, each single-phase transformer along the basic accordion $i_{\mu 1}$ pulls all higher harmonics.

The magnetization current of the first harmonic is:

$$i_{\mu 1A} = I_{\mu 1A_m} \sin(\omega t)$$
$$i_{\mu 1B} = I_{\mu 1Bm} \sin(\omega t - 120^\circ)$$
$$i_{\mu 1C} = I_{\mu 1Cm} \sin(\omega t - 240^\circ)$$

where m is the mark for the maximum value of the current.

Without zero lead, the magnetization current is sinusoidal, because there is no 0-conductor, so the third harmonics of the current can not be closed.

Flux will have the first and third harmonics Φ_3, so it will be non-sinusoidal.

Because the air has a high magnetic resistance, between the upper and lower yoke, the amplitude of the third harmonic of the flux will be considerably lower.

In the case when the transformer is connected to the DYg compound, the third harmonic component and all others that are its multiplicity are closed in the triangle, but as a result, we have additional heating of the winding.

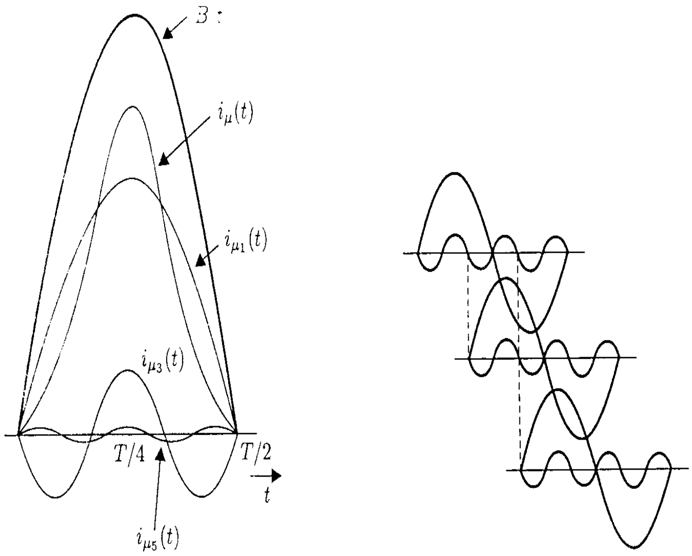

Fig. 4 First, third and fifth harmonics

4. USE OF MATLAB / PSB IN THE SOLUTION OF PROBLEMS

A simulation was performed for the part of the electrical network from Figure 1 with the help of the MATLAB/PSB computer program [7]. The observation time was Tstop = 0.1s and the harmonic currents were counted up to the fifth period [8]. In Figure 6, the wave form of primary(R) phase current is shown on the 10 kV side and here it is clearly seen that due to the influence of higher harmonics, the current does not have a sinusoidal shape.

The rectifiers are the most commonly used single-energy electronic converters and one of the main sources of higher harmonics [9]. The switching mode has the effect of continuously changing the configuration of the active diode of the rectifier, resulting in the waveform of the rectifier current composed of segments and being insufficiently shaped.

The flow of the non-sinusoidal current causes a decrease on impedance of the network, which leads to the distortion of the basic sinusoid voltage, while on the consumer side, the waveform of the voltage consist of parts of the sinusoid, that in addition to the direct component, also have alternating components-higher (steam) harmonics [10].

Most personal computers use mono-phase rectifiers in the power supply section and have the role of generating stable single-voltage with simple design and reliability. For these reasons, most commonly used one are diode rectifiers with a filter capacitor on a one-way side or, more recently, one-way switching power supplies, which also have a capacitor at the output.

In case of need for another voltage level or more stable voltage, a linear or switching power supply is connected behind the capacitor. However, in both cases, this rectifier distorts the network current, and partly the voltage. Due to the charging of capacitor in periods when the network voltage is higher than direct-way, there is a distortion of the current, that is, the voltage at the condenser. The paper analyzes the distortion of the wave shape of the current, as a quality factor, when supplying consumers that generate more harmonic components of the current.

It is possible to filter the source harmonics by using filters and analyze all relevant design parameters [11].

In our case, we have a low voltage installation that is connected via the transformer 10 /0.4 kV to the conventional electricity distribution network 3x10 kV. The load we have is a non-linear set of PCs and is balanced at each stage. The non-linear load for each phase generates more harmonics, whose composition is approximately defined as In = I_1/n where I_1 is the current of the basic and In-n harmonic.

The wave forms of the primary and secondary phase are given in the figures as follows:

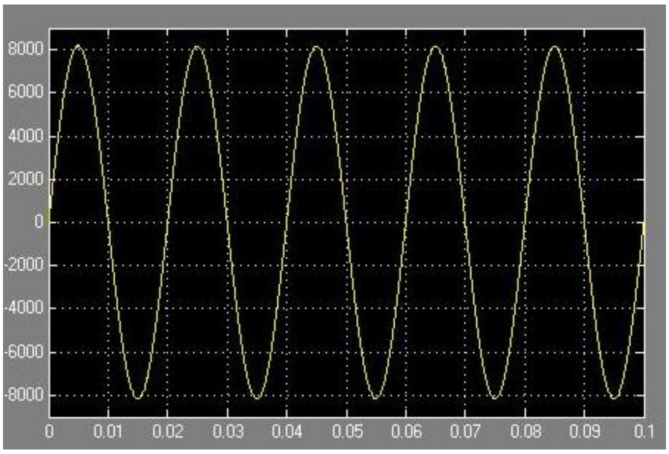

Fig. 5 Voltage waveform of primary(R) phase on the 10 kV side

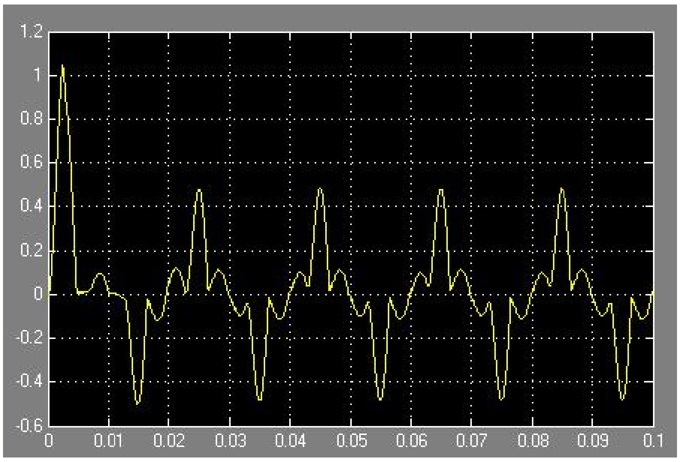

Fig. 6 The wave form of the iRt phase on the 10 kV side

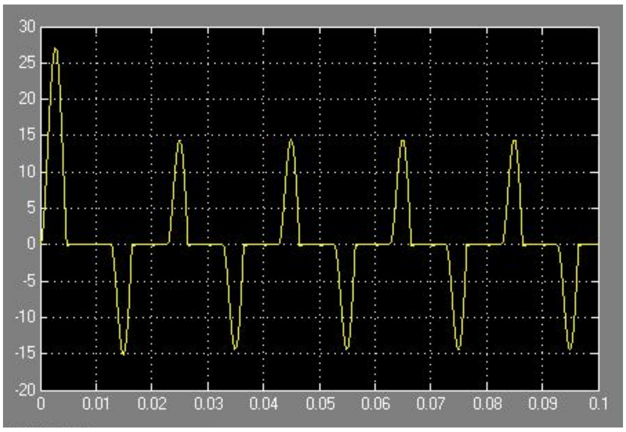

Fig. 7 Wave phase current iRz at 0.4 kV side

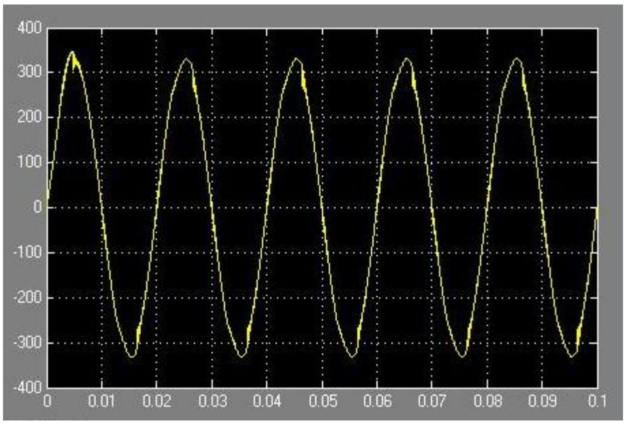

Fig. 8 Wave waveform of phase uRz at 0.4 kV voltage level

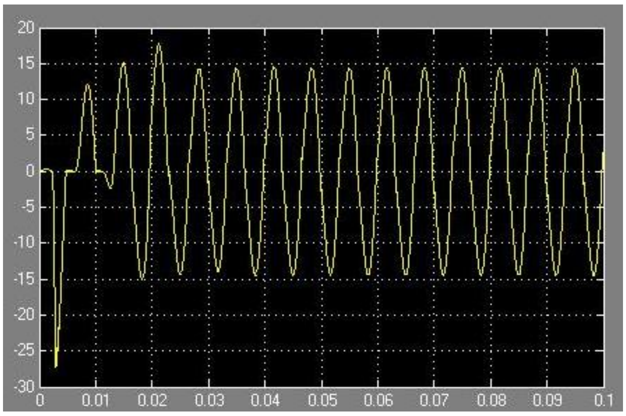

Fig. 9 The current shape of the iN-neutral conductor at 0.4 kV voltage

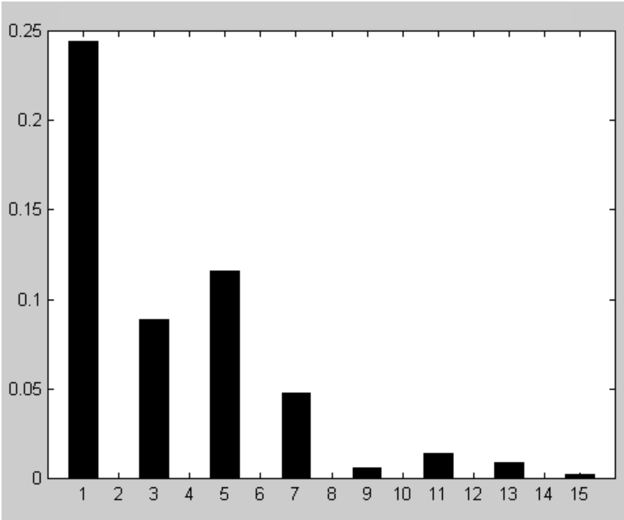

Fig. 10 Harmonic current content iRt on 10 kV side without filter / not installed

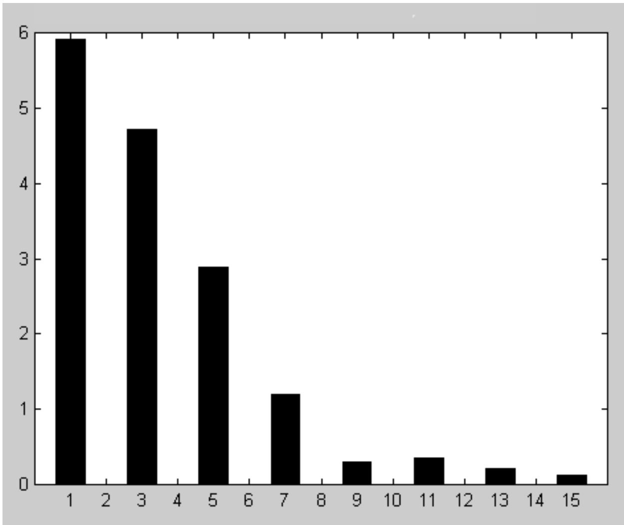

Fig. 11 Harmonic current content iRz at 0.4 kV without filter /not installed

In the power spectrum iRt the odd harmonics are dominant, there are no even harmonics. Measurements of the current of the computer have shown that the shape of the current is very distorted due to non-linear consumer, which generates more odd harmonics (electronic equipment) [12]. THDI is calculated according to the formula below:

$$\mathrm{THDI}_{\%} = \sqrt{\sum_{n=2}^{10} \frac{I_n^2}{I^2{}_1}} \cdot 100\%$$

For primary (R) phase current (on the 10 kV side)

THDI = 268%.

For the current of secondary (r) phase (at 0.4 kV side) is THDI= 279%.

5. Results and Solutions to the Problem

Higher harmonics are constantly present in the network in a higher or lower percentage. But at some point they can become a problem. This happens if the source of the accordion is too large, if the current harmonics path is too long, that is, if the circuit is large, or if the response of the system is such that it leads to reinforcement of harmonics (resonance).

In order to reduce or eliminate the harmony problem, there are several basic solutions:

1. reducing the intensity of harmonic currents,
2. setting the filters,
3. change in the resonant frequency of the system

The methods of reducing the intensity of harmonic currents usually involve changing the mode of operation of the propulsion, which generate harmonics. Such an approach is difficult to implement in practice, as this can affect the entire production process, and it is only possible at the design stage. However, something can be done by matching the transformer.

The coil in the triangle leads to the blocking of the further flow of all the harmonics, which are multiplies of 3. With the introduction of a phase shift of 30 degrees, by twisting the secondary transformers into a star and a triangle, the effect of a 12-pulse rectifier is obtained, that is, the 5^{th} and 7^{th} harmonics[14] are eliminated. Connecting a non-linear consumer to high-power outputs also reduces the effects of harmonics. The goal of setting the filters is to provide a low impedance for the harmonics of the current and thus prevent their spread into the network. Therefore, the filters are most often placed in parallel to the condenser and consist of a condenser with an additional impeller.

The resonant frequency of the filter is calculated always to be slightly below the frequency of the lowest dominant harmonic. This ensures that the filter works properly in case of oscillations of the capacitor parameters due to temperature,etc., and also to avoid the anti-resonant frequency approaching the frequency of the harmonics. The use of serial filters is more rarely applied, and their goal is to represent a high impedance for current harmonics, thus blocking their expansion into the network.

More details about the types and methods of filter design can be found in J. Arrillaga, D. Bradley, P. Bodger: "Power System Harmonics", John Wiley & Sons, Chichester, 1985. These types of filters are called passive, as opposed to the newer ones - active.

Active filters are in fact energy electronic converters, which are programmed to compensate higher harmonics. With such a filter, the "pure" sinusoidal current of the grid is provided. The more complex configurations enable the complete discovery of all disorders that affect the quality of electricity [15].

Changing the resonant frequency of the system is necessary when there are condensing batteries for compensation of reactive energy in the system or with consumers. Their resonant frequency is often close to the frequency of characteristic harmonics, and there are undesirable negative occurrences. Changing the size of the capacitor, adding a serial impedance, moving the capacitor to another bus (location), or simply completely disposing the capacitor (with a pay-off cost without compensation) are the measures that can be resolved.

For example, in the literature J.Toth III, D.Velazquez: "Benefits of an automated on-line harmonic measurement system", IEEE Transaction on Industry Application ,. one such experience is described [16]. Resolving the problem of resonance in the network, which led to the fugging of condenser battery fuses, inaccurate instrumentation, frequent engine failure and communication problems, was found in moving the resonant frequency beyond the range of characteristic harmonics (5^{th} and 7^{th}) by reducing the number of capacitors in batteries. As a specific way of dealing with harmonics, it is an administrative, or economic approach, where special contracts and tariffs discourage the excessive generation of harmonics. For example, in France, a special contract called "Emeraude" was developed, which is a set of technical regulations and obligations for electricity distribution, as well as for consumers, in order to ensure the proper quality. After a year of application, the results released by the EDF show that at mid-voltage, 99% of consumers have complied with the contract, but that compensation is paid $ 150,000, mostly due to short interruptions.

In 1995, a new text of the contract came out, which allowed a considerably smaller number of interruptions, and in 1998 its audit was carried out, which included problems related to voltage failures. More recent research goes not only to determine the state, and to provide a prediction, but also to answer the question of what the cost of degradation of quality (harmonic losses) is, ie what and how to collect additional charges from consumers for the operation of non-linear drives[17].

There is a particularly interesting question of tariffing higher harmonics and how this can be done. The results of the survey show that 46% of the distributions intend to additionally charge the generation of harmonics and flickers, 40% to charge harmonics over apparent power (kVA), and other time of use, that is, the time of "pollution". In addition to this, the question of measuring higher harmonics and the way of expressing their influence is not cleared up.

This section shows the possibility of filtering source higher harmonics using filters as well as analyzing all relevant design parameters.

In our case, we have a low voltage installation that is connected via the 10/0.4 kV transformer to the 3x10 kV classical electricity distribution network. The load we have is a non-linear set of personal computers (PCs) that is balanced at each stage. Non-linear load for each phase generates more harmonics, the composition of which is approximately defined as $In = I_1/n$ where I_1 is the current of the basic and I_n n harmonic.

The dimensioned three-phase filter is set to eliminate the maximum harmonic component of primary(R) phase current on the 10 kV side of the transformer [18].

Also, in this part of the paper, the waveform and corresponding harmonic content of phase R are shown. In this case, THDI is calculated (for phase R current) (10 kV side).

Simulation was performed with the help of the MATLAB / PSB computer program. The observation time was Tstop = 0.1s.

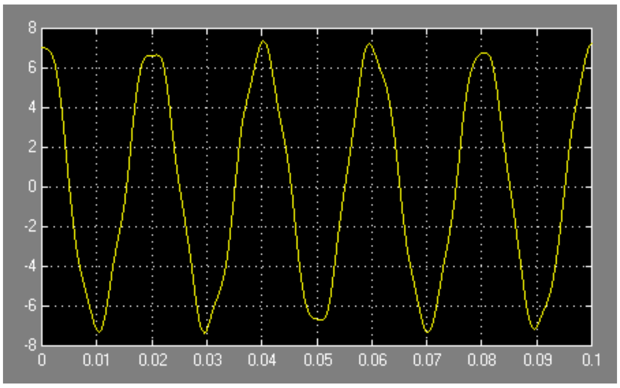

Fig. 12 Primary (R) phase current waveform on a 10 kV side (built-in filter)

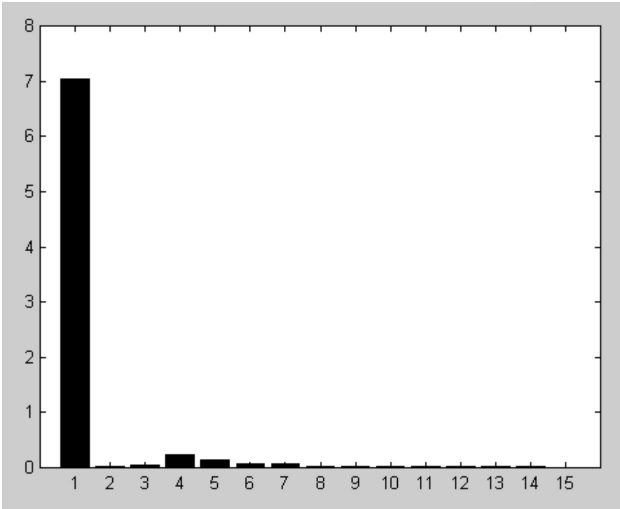

Fig. 13 Frequency spectrum of primary (R) phase current on 10 kV side (with built-in filter)

The value of THDI for primary (R) phase current is:

$$\mathrm{THDI}_{\%} = \sqrt{\sum_{n=2}^{10} \frac{I_n^2}{I^2{}_1}} \cdot 100\% =$$

THDI = 0.239 %

The pictures show the oscillation of the primary (R) phase wave and the spectral composition of the same current.

It turned out that this filter has done a good job of eliminating the third and all other odd harmonics, so that the total THDI of the primary (R) phase current is about .239 %, which is quite satisfactory, given the regulations in this field.

6. CONCLUSION

The components of the energy system, as well as consumers that connect to it, include sine waveforms and currents. Any appearance of higher harmonics brings negative effects, the most important are:

1. The appearance of resonance in the network,
2. Influence on condensing batteries,
3. Influence on elements for protection,
4. Impact on the accuracy of standard measuring instruments,
5. Additional losses in electrical machines,
6. Interference with telecommunication signals.

Business buildings with a large number of administrative and other service workers who can not imagine their work without computers, laser and/or matrix printers, scanners, photocopiers, small telephone exchanges, fluorescent, halogen or energy-saving lamps and other similar small sources of higher harmonics, represent a recognizable consumer group, which must be given special attention. Within these buildings there are often concentrated large groups of small PCs (either as computers in individual departments, or as special computer centers). This group includes faculties and university campuses, which have their own computer centers, as well as a large number of computers in laboratories and cabinets.

In order to further reduce the THDI of the current of primary (R) phase, another parallel three-phase filter is set up to eliminate the maximum harmonic component of the current on the 10 kV side of the transformer.

Also, in this part of the paper, the waveform and the corresponding harmonic content (of the primary phase current) are shown [19]. In this case, the THDI (10 kV side) is calculated.

With the help of the MATLAB/PSB computer program, a simulation was performed.

The observation time was Tstop = 0.1s..

With this filter we completely reduce the second and third harmonic components [20]. The second filter is installed in parallel with the first one that we installed earlier. The capacity of the second filter is 2.25 times smaller than the first because of the frequency of the second amount, 150 Hz.

The parameters of both filters are:

First: R=0.1 Ohm, L=0.156 H, C=20e-06 F
Second: R=0.1 Ohm, L=0.156 H, C=8,94e-06 F

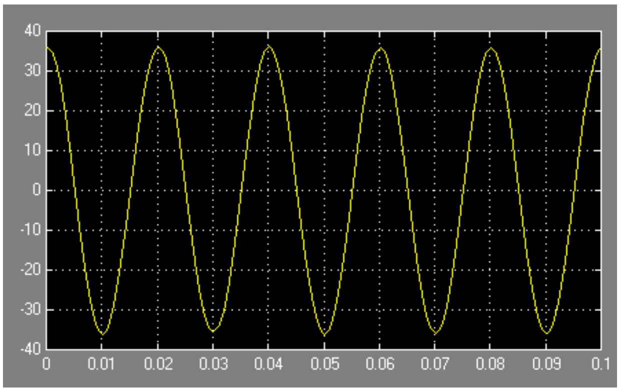

Fig. 14 The wave of primary phase (R) on the 10 kV side (two filters)

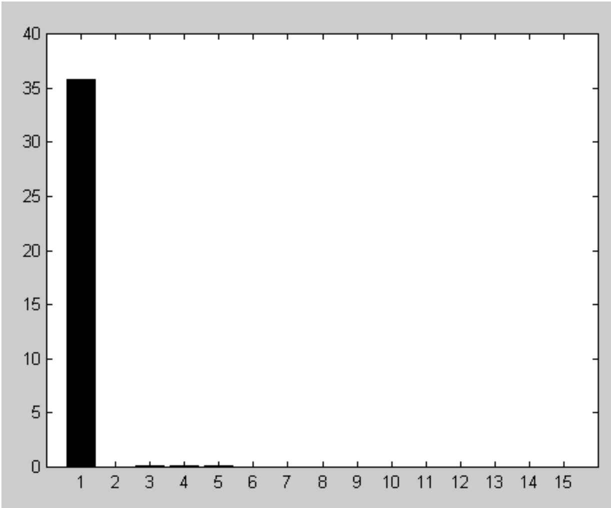

Fig. 15 Spectral current of primary phase (R) current on 10 kV side (2 filters installed)

The value of THDI for primary phase (R) current is:

$$THDI_{\%} = \sqrt{\sum_{n=2}^{10} \frac{I_n^2}{I_1^2}} \cdot 100\%$$

$$THDI = 0.0023\ \%$$

Comparison of THDI in either case:

From the analysis we can see that THDI is the smallest when both filters are turned on for the elimination of the 2 and 3 current harmonics, but then the current of the primary (R) phase has the highest value, i.e. 36A

The THDI current of the primary (R) phase is distinguished on the 10 kV voltage because it is higher THDI in the case of installing one in relation to the two filters (in parallel).

In the following period, the authors will perform practical measurements of the above dimensions and compare the simulation in MATLAB and concrete measured values in the particular given power grid.Metrel MI 2192 (Power Quality Analyzer), a portable multifunctional instrument for measuring and analyzing parameters of three-phase systems, will be used for measurement purposes.

The instrument has been produced in accordance with the following European standards:

- Safety (EN 61010-1)
- Electromagnetic compatibility (EN 50081-1 and EN 61000-6-1)
- Measurements in accordance with European stand-by (EN 50160)

This device is enabled in the specific case:

- Real-time monitoring, recording and parameter analysis in a three-phase system.
- Large selection of measuring functions: voltage, current, power (W, Var and VA), power factor, energy, oscilloscope, harmonics analysis, statistical analysis, anomalies.
- In shooting mode, the measured sizes will be stored in memory for later an-alignment
- Special shooting mode for wavelength recording, with various trigger options.

- Special recording modes for monitoring the quality of the observed system: periodic, waveform, transient, fast-logging, EN 50160
- Calculation of the minimum, mean and maximum values of the measured sizes, with various predefined report forms
- Oscilloscopic display of waveforms, in real time and when analyzing recorded data
- Analysis of harmonic distortion to 63 harmonics during operation and later on recorded data
- Monitoring and analysis of energy opportunities
- RS232 connector for connecting to a computer
- Windows software for analyzing recorded data and instrument management

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