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The influence of nonlinear background on the quality of electricity

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- This paper discusses the load in the power distribution network, three-phase of the power supply where the transformer coupling via YgYg powered nonlinear load for a set of personal computers (PC). The load is balanced at each stage. The aim is partly to show through the analysis of higher harmonic loads personalinih computer, coupling transformer Yg Yg.
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The tool will be used software tool MATLAB.

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Inroduction:

The interest in analyzing the quality of electricity has recently 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
- With the development of modern measuring devices, today the quality of electricity can only be measured and memorized

The two main categories of problems in the analysis of quality of electricity are:

a) Disorders:
    Transits
    Decay and increase voltage
    Power supply interruptions

b) Stationary variations:
    Voltage regulation
    Harmonic distortion
    Voltage flickers

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Model of solving problems of higher harmonics

The paper is taken as an example in Fig. 1, where a three-phase part of the electrical network is presented, whereby the YgYg transformer connects the non-linear circuits of a set of personal computers (PCs) through the transformer. The load is balanced at each stage.

MATLAB software package is used for realization of the program.

MATLAB/Simulink/Power System Blockset (PSB) is a software package for modeling, simulation and analysis of electrical energy systems within the known tool MATLAB.

The package supports linear and nonlinear systems modeled in continuous time or discrete time moments, or in both ways. PSB contains a comprehensive blockbibliotype of sources, linear and non-linear elements, connectors and accompanying block subsystems.

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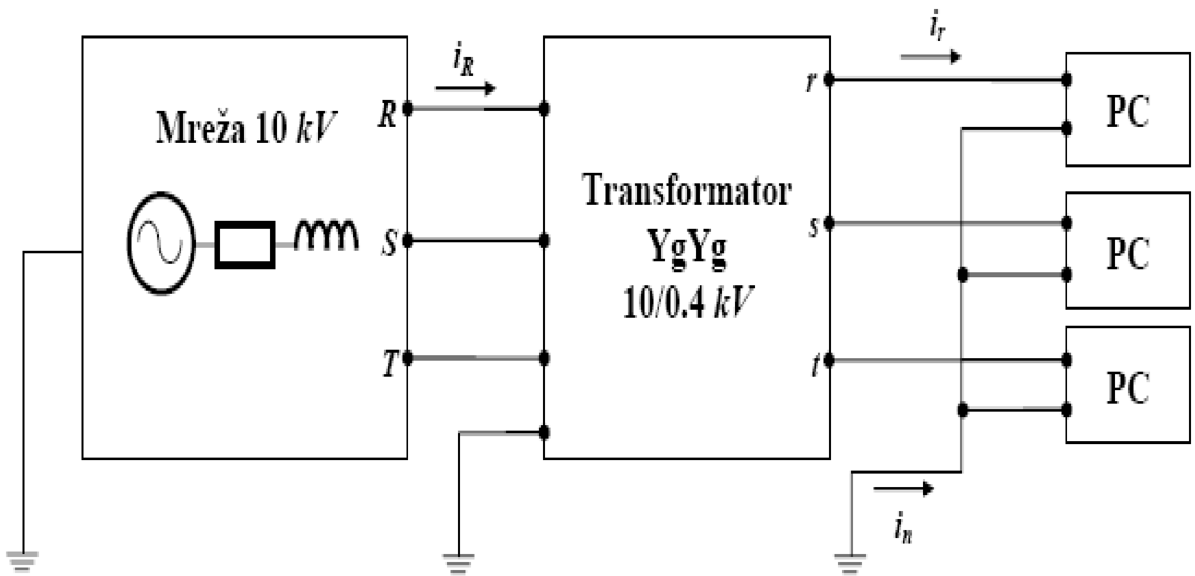
- **Figure 1**. The analyzed part of the network



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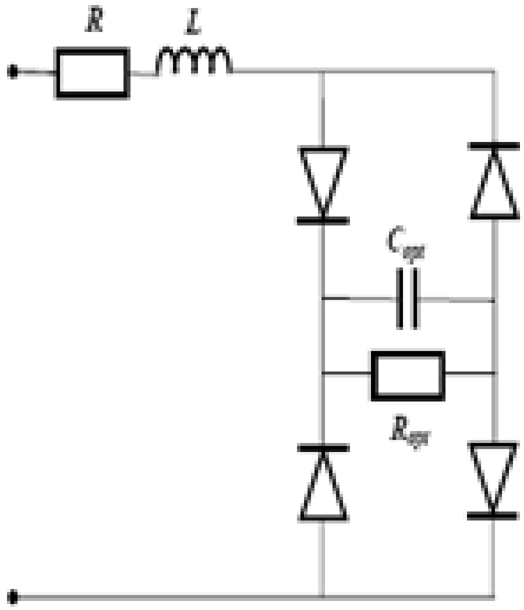
In Figure 2, the equivalent nonlinear load model for each phase is reset.

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



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- **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

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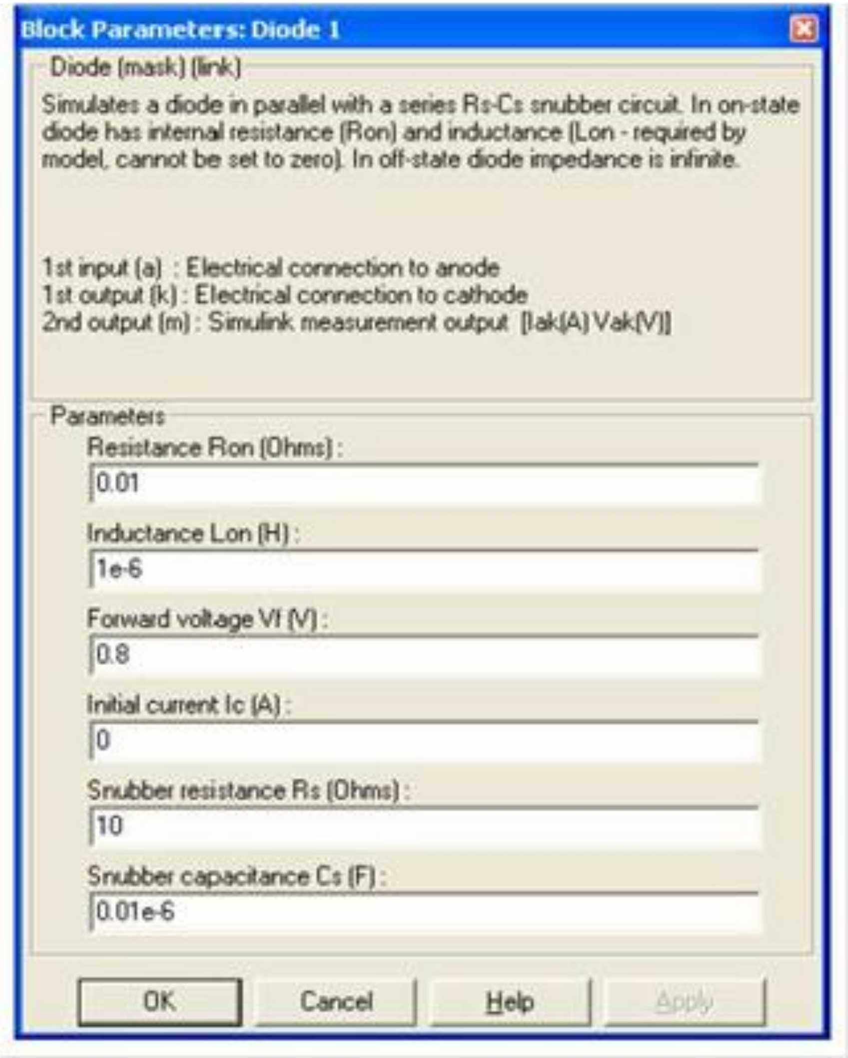
- **Internal diodes parameters::**



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The work is:

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. A concrete example is given.

2. For the part of the electrical network from Figure 1, a waveform of phase R at 10 kV voltage level will be determined, the current of the neutral conductor phase at 0.4 kV voltage level, as shown in Figure 1.

   The harmonic content will be determined up to 15. accordion and the effective value of all these currents. (phases R and r).

- % THD for current R and r will be calculated.

3. The three-phase filter set to eliminate the maximum harmonic component current phase R at the 10 kV side of the transformer will be dimensioned. The waveform and the corresponding harmonic content of phase R phase will be determined. In this case, the THD% will be calculated for the phase R phase.

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4. Additional measures will be proposed to reduce the THD% of current phase R. It will be realized another parallel filter for elimination of the second by size of the harmonic component of phase R phase. Comparison of THD% for the phase R phase will be made in cases under 3 and 4 .

5. For the total duration of the simulation, the time taken Tstop = 0.1 sec.

6. The mentioned simulations will be realized with the MATLAB / PSB type program package. The corresponding simulation models will be displayed.

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The causes of the formation of higher harmonics

More harmonics in the network are caused by the generation of non-linear consumers in the electric power network, which inject the more harmonic components of the current into the system, which through the impedance of the system result in distortion of the supply voltage, which affects the reduced reliability and shortening of the life of electrical equipment. Praxis are interesting to the higher ranks of the order from 0 to 100 ..

The causes of higher harmonics 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 furnace furnaces
  - Inverters
  - discharge lamps
  - saturated electrical machines

Components of the power system 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:

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Components of the power system 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 - causes an increase in losses
- the influence on the protection elements, which leads to unwanted protection of the protective devices (protection) or fuse overheating
- Impact on the accuracy of indications of standard measuringinstruments
- additional losses in electrical machines (eg overheating,heating of cables, and the like)
- interference with tt signals (higher harmonics from power lines are transmitted by electromagnetic interference to tt cables, thus creating noise and disturbances In telecommunications
- influence on transformers,

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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 compatible with three,
- transformers in connection Yd 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 order
- Second order
- Third row

b) active filters

- active filters have the ability generating and managing non-linear currents

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Resonant frequency change system

When there are condensing batteries in the system or with consumers, compensation resonance can occur to compensate for the reactive energy. 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

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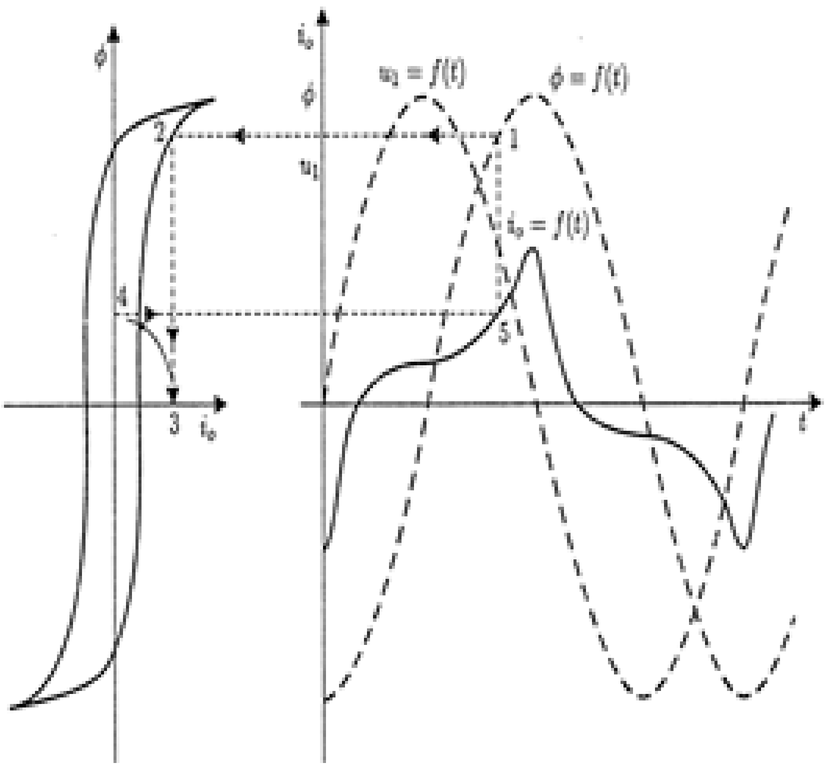
The role of the transformer in the Dyg compound

When we look at the magnetization component 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%



- **Figure 1.1** - Hysteresis transformer curve

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Figure 1.1. 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 decrease the positive values . In the second third of the semiperduct, the positive values are summed up with positive values , and in this way a sharpening form occurs . With zero water, each single-phase transformer pulls along the basic accordion and more harmonics.

The magnetization current of the first harmonic is:

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

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

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

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.

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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.

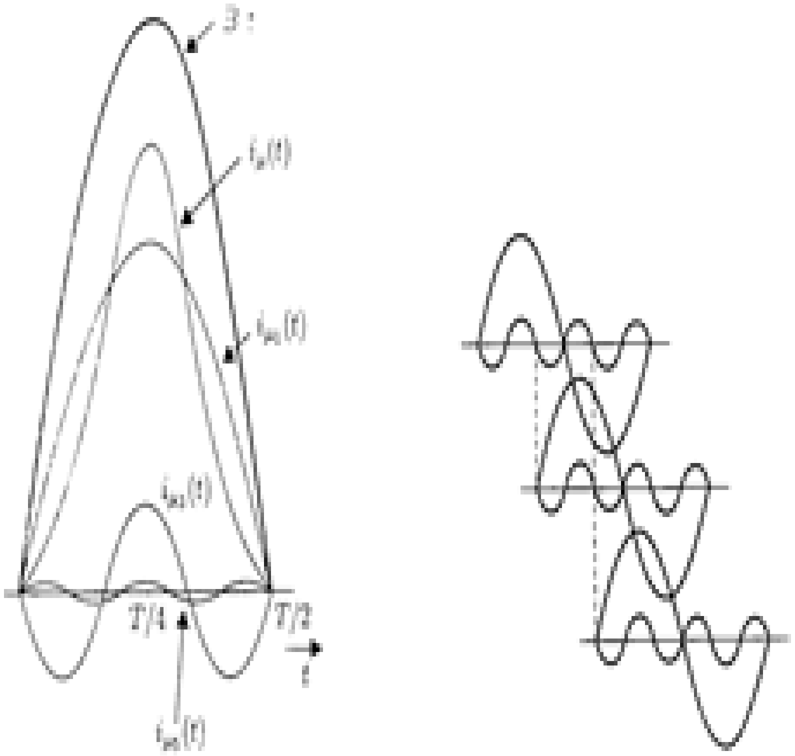

Figure 1.2 - First, third and fifth harmonics

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Use of MATLAB / PSB in the solution problems

A simulation was performed for the part of the electrical network from Figure 1 with the help of the MATLAB/PSB computer program. The observation time was Tstop = 0.1s and the harmonic currents were counted up to the fifth period. In Figure 2.1. the wave form of phase R 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.

A simulation was performed for the part of the electrical network from Figure 1 with the help of the MATLAB / PSB computer program. The observation time was Tstop = 0.1s and the harmonic currents were counted up to the fifth period.

In Figure 2.1. the wave form of phase R 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.

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 it is insufficiently shaped.

The flow of the insoluble current causes a decrease in the perpendicular to the impedance of the net, which leads to the distortion of the basic sinusoid voltage, while on the consumer side, the waveform of the voltage consists of parts of the sinusoid, that is, in addition to the one-way component, there are also alternating components-higher (steam) harmonics.

Most personal computers use mono-outs in the power supply section and have the role of generating stable single-voltage voltages with simple designs and reliability.

For these reasons, most commonly 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.

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- 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 filling of condensation in periods when the mains voltage is higher than one-way, there is a distortion of the current, that is, the voltage at the condenser. The paper deals with the detail and 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.
- 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 personal computers (PCs) and is balanced at each stage. The 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 In-n harmonic.

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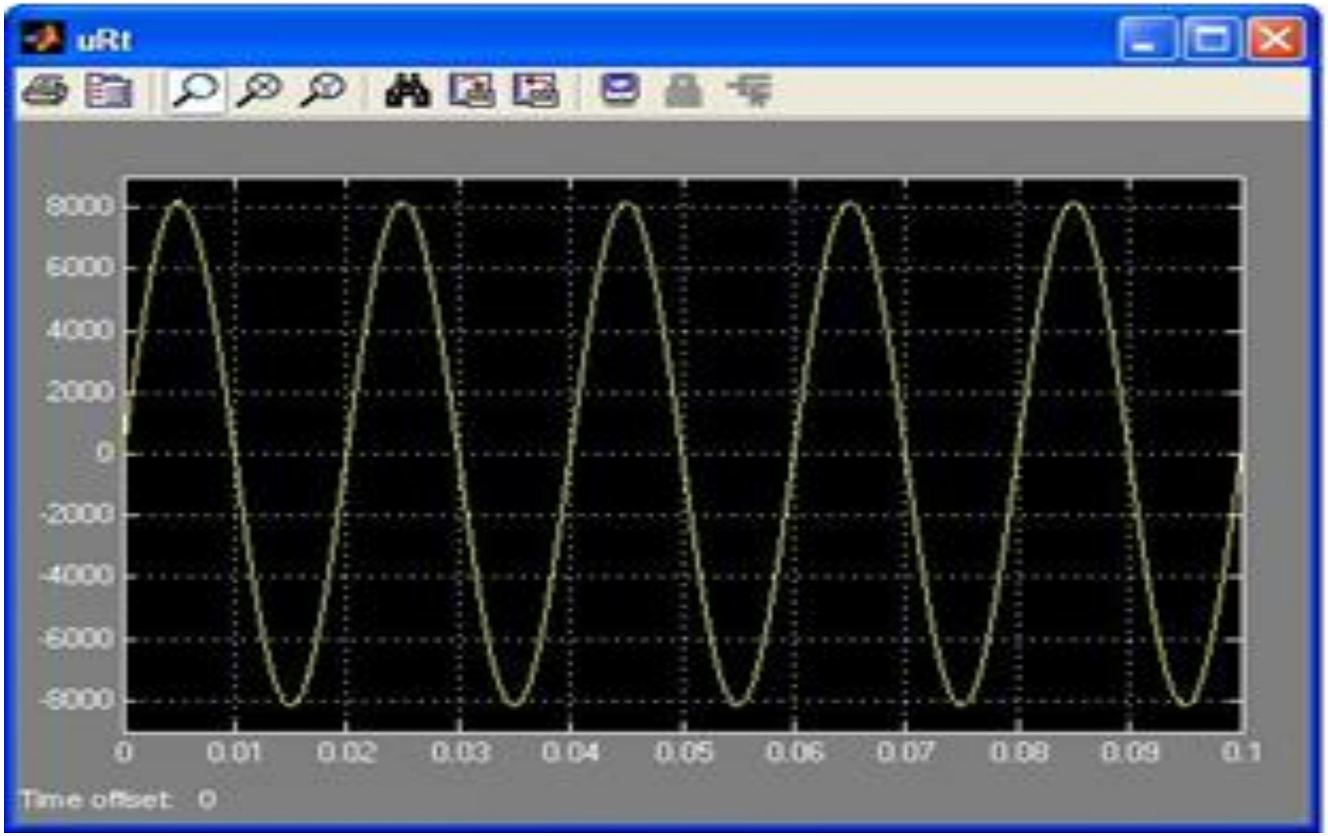
The wave forms of the phase R and r phases are given in the figures as follows:



- Figure 2.1. Wave phase voltage waveform on the 10 kV sidei

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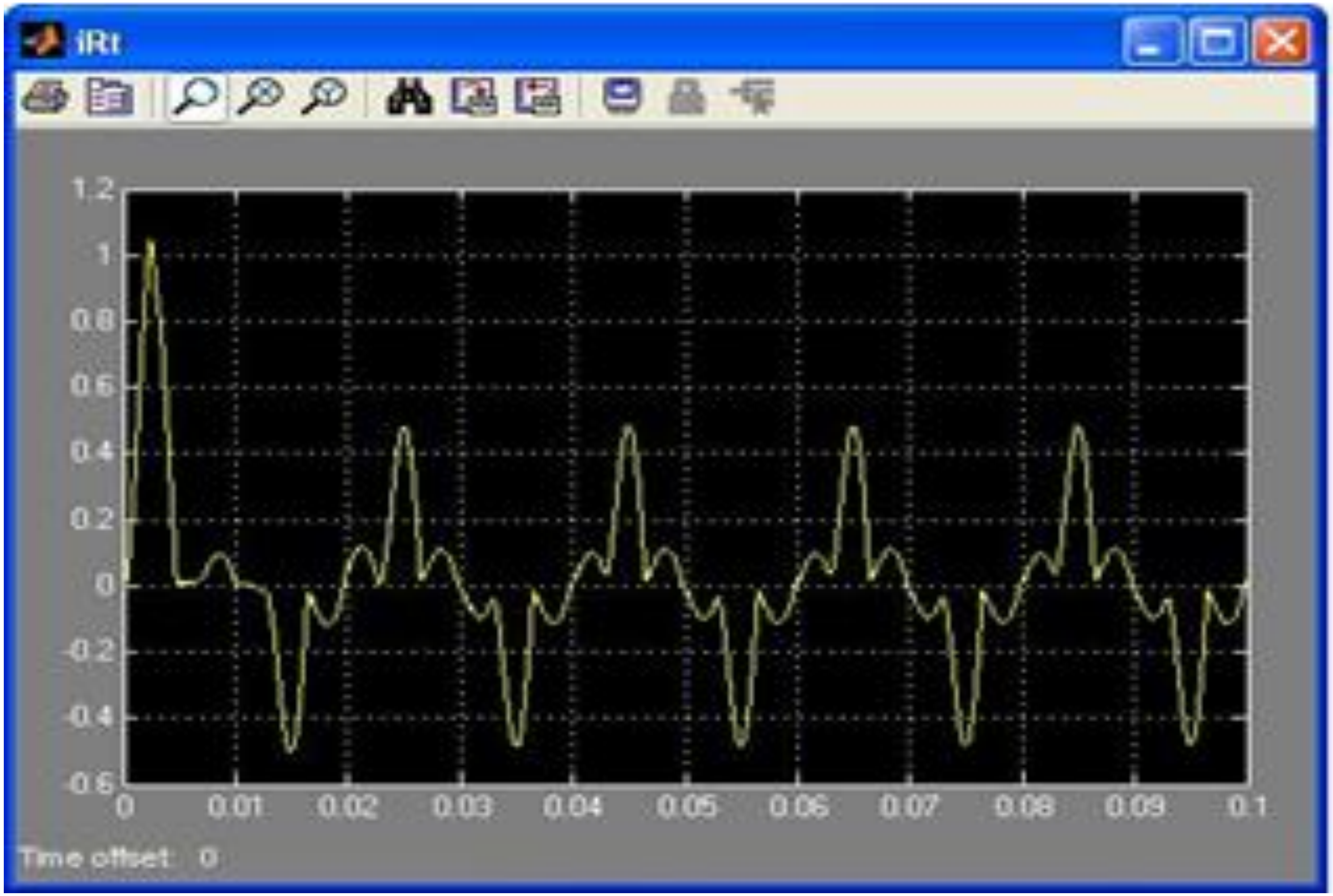

Figure 2.2. The wave form of the iRt phase on the 10 kV sidei

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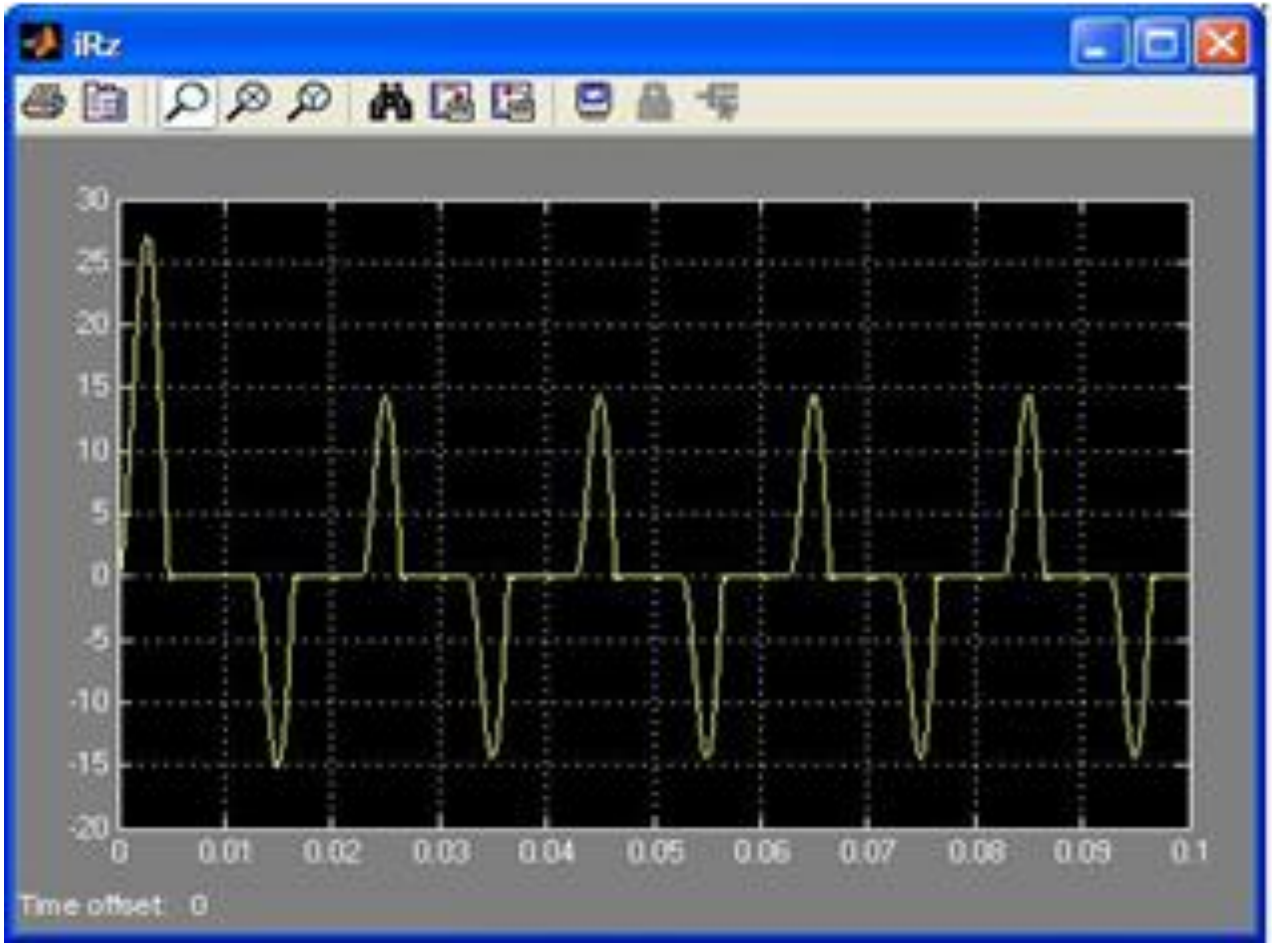

- Figure 2.3. Wave phase current iRz at 0.4 kV – side

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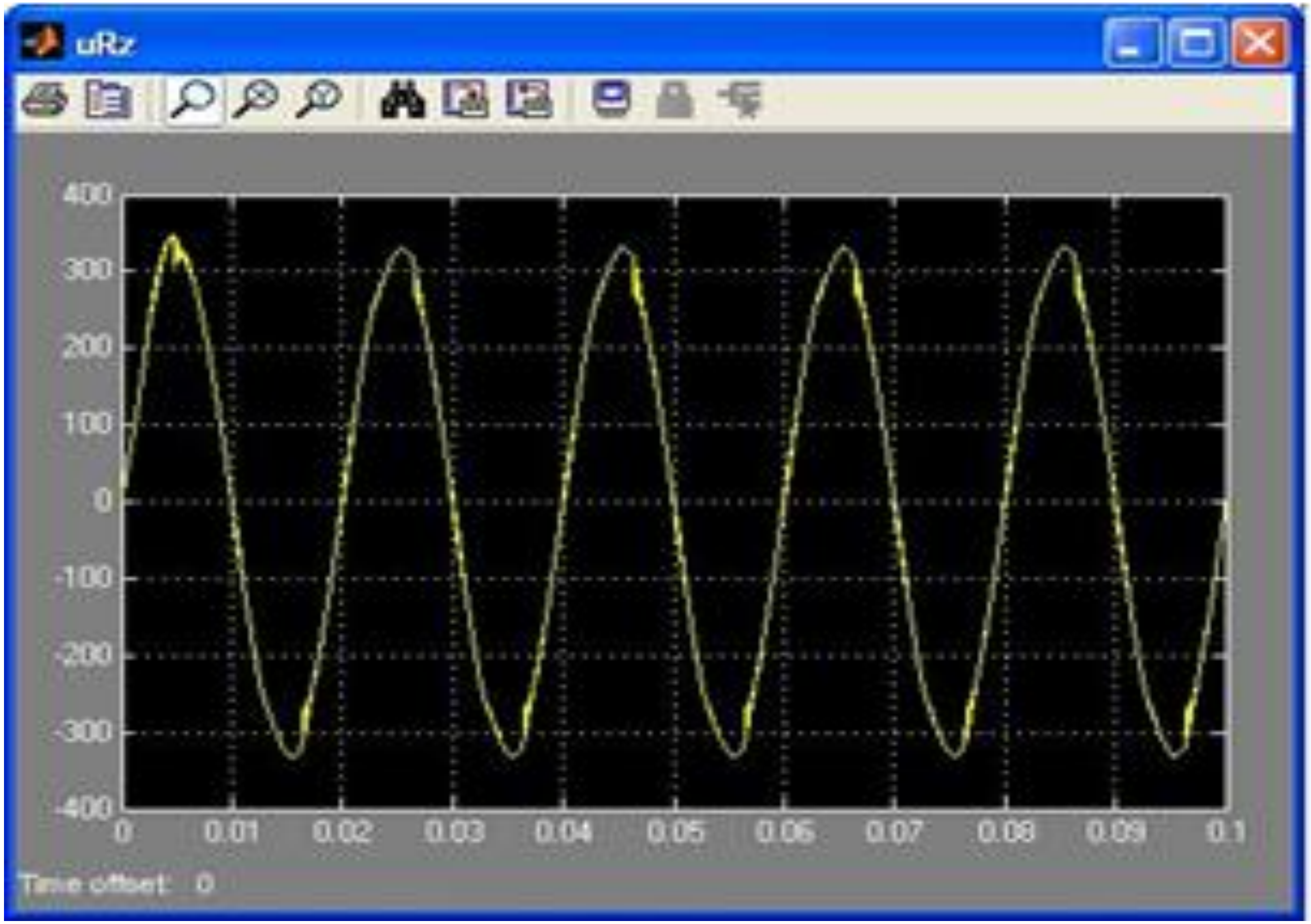

- Figure 2.4 - Wave waveform of phase uRz at 0.4 kV voltage level

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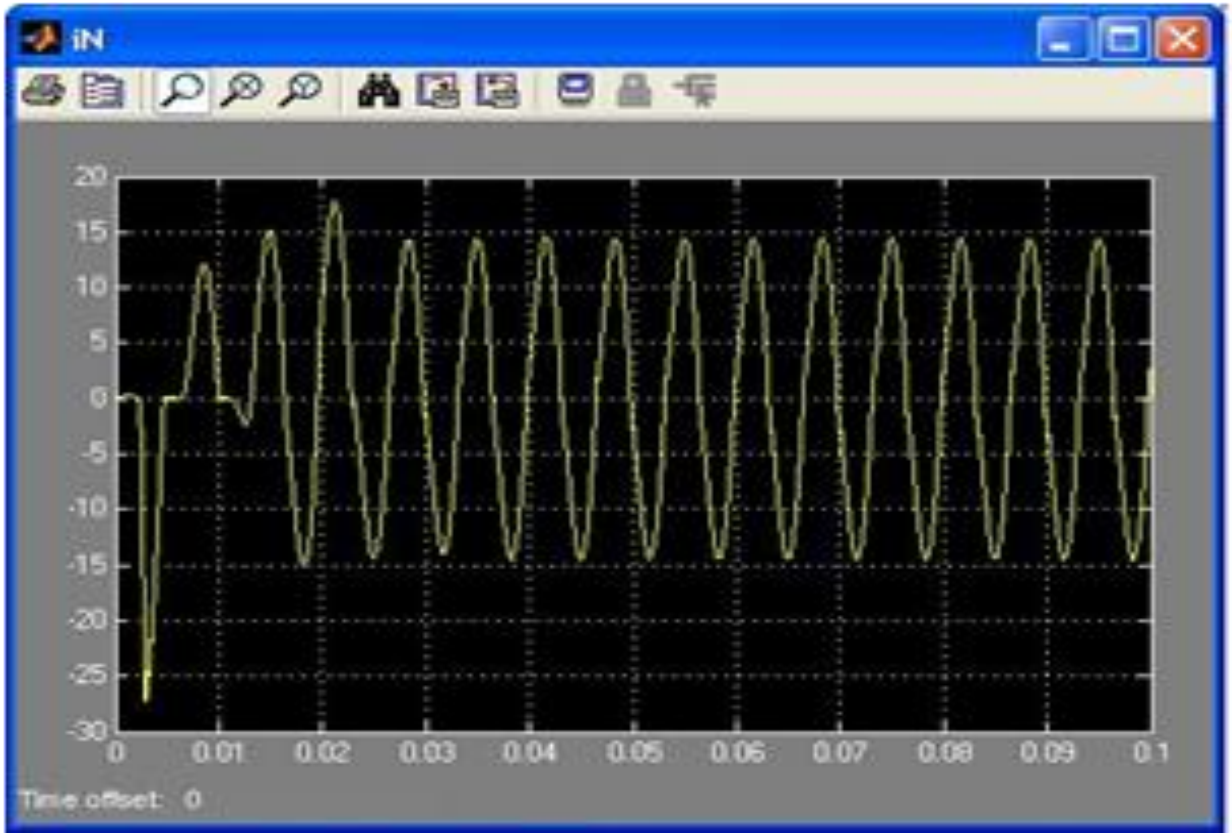

Figure 2.5. The current shape of the iN-neutral con ductor at 0.4 kV voltage

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Figure 2.6. Harmonic current content iRt on 10 kV side without filter / not installed//

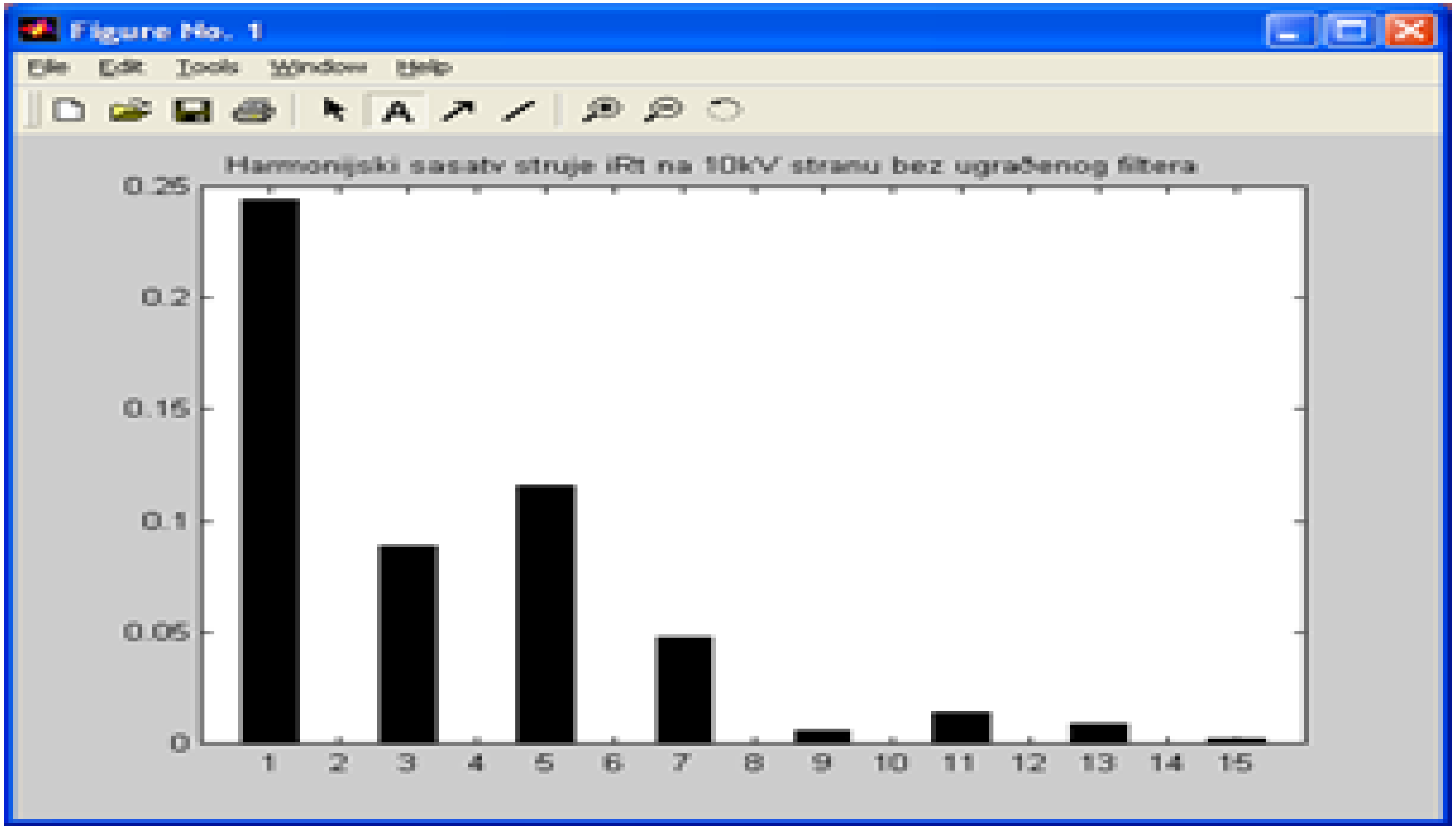

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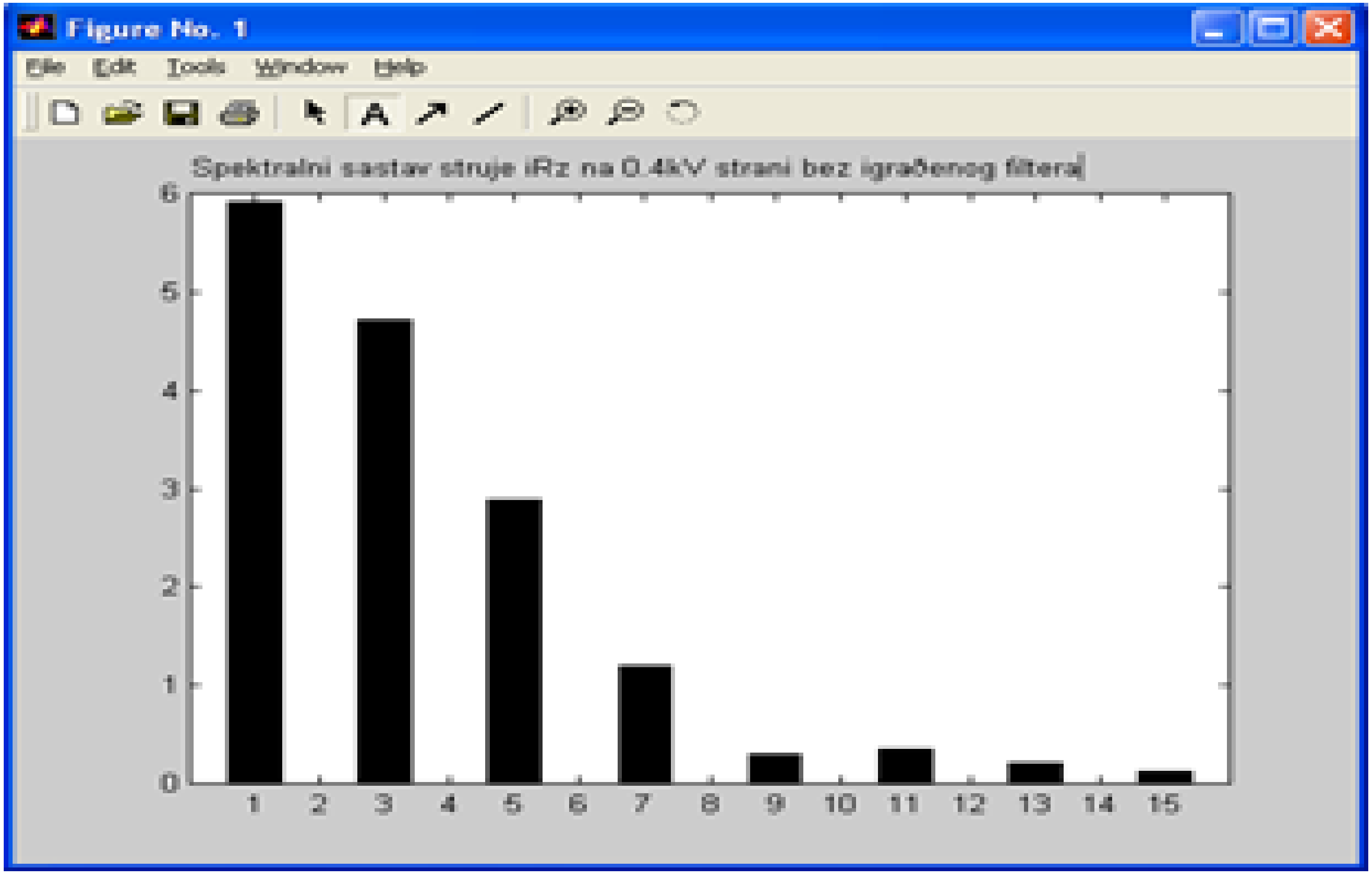
Figure 2.7. Harmonic current content iRz at 0.4kV without filter /not installed//



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

For phase current R (on the 10-kV side) THDI%= 268%.
For the current phase r (at 0.4-kV side) is THDI%= 279%.

<u>Results and solutions to the problem</u>

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 10/0.4kV transformer to the 3x10 kV classical electricity distribution network. The load we have is a non-linear set of personal computers (PCs) and 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 phase R current on the 10 kV side of the transformer.

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

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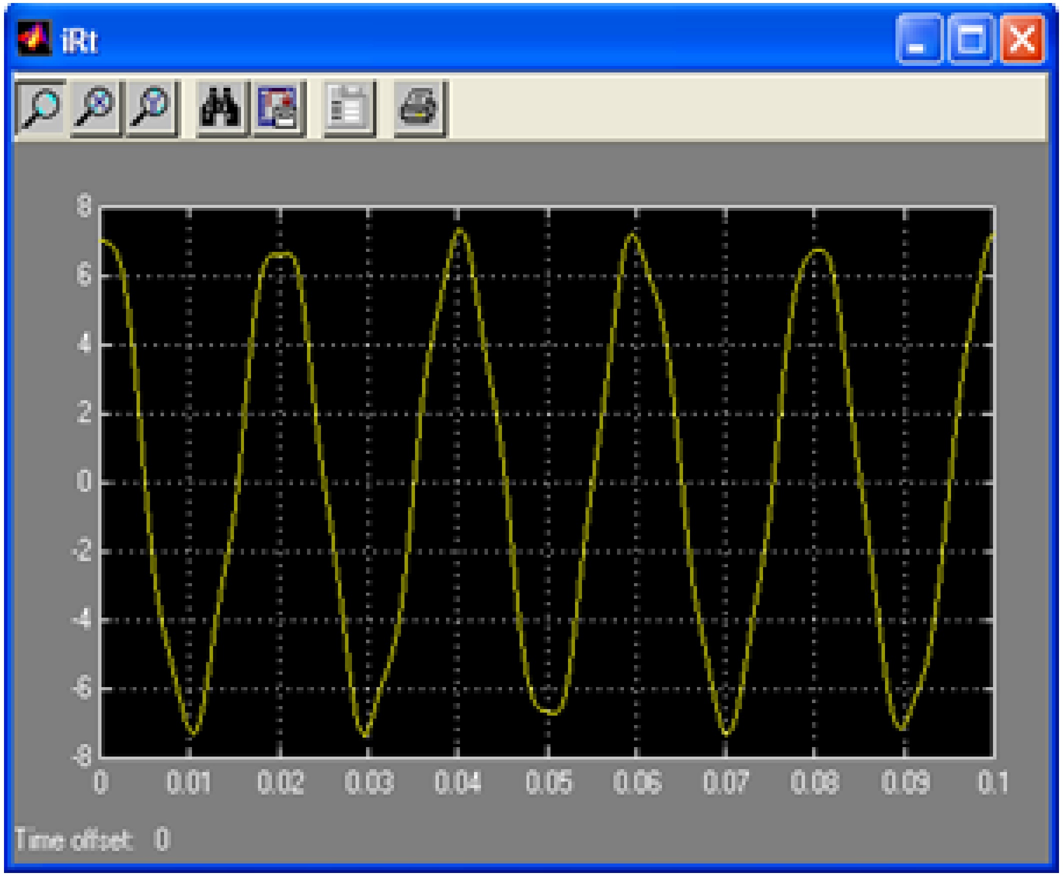
With the help of the MATLAB / PSB computer program, a simulation was performed. The observation time was Tstop = 0.1s.

Figure 2.8. Phase R phase current waveform on a 10-kV side (built-in filter)



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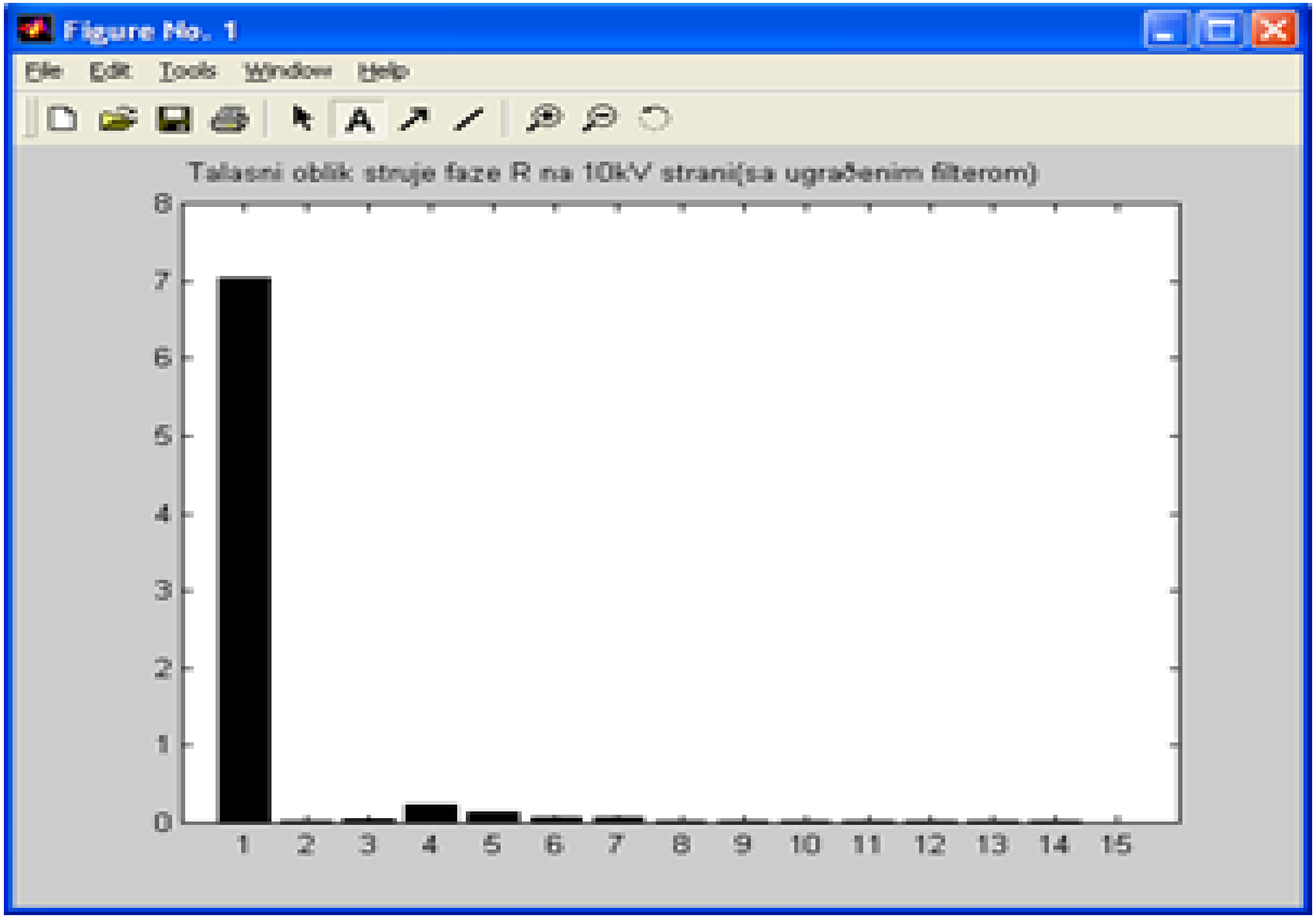
- **Figure 2.9.** Frequency spectrum of phase R current on 10 kV side (with built-in filter)



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The value of THDI% for phase R current is:

THDI % = 0.239 %

The pictures show the oscillogram of the phase wave R waveform 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 and odd harmonics, so that the total THDI % of the phase current R is about .239 %, which is quite satisfactory, given the regulations in this field and the transforamtors' in practice often does not meet.

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Cnclusion

In order to further reduce the THDI% of the current phase R, another parallel three-phase filter is set up to eliminate the maximum harmonic component of the R phase 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 phase R phase are shown. In this case, the THDI % for the current phase R (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. The second filter is installed in parallel with the first one that we installed earlier. The capacity of the second filter is that its capacity 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 Ohma, L=0.156 H, C=20e-06 F
- Second: R=0.1 Ohma, L=0.156 H, C=8,94e-06 F

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- **Figure 2.10**. The phase wave R wave on the 10 kV side (two filters)

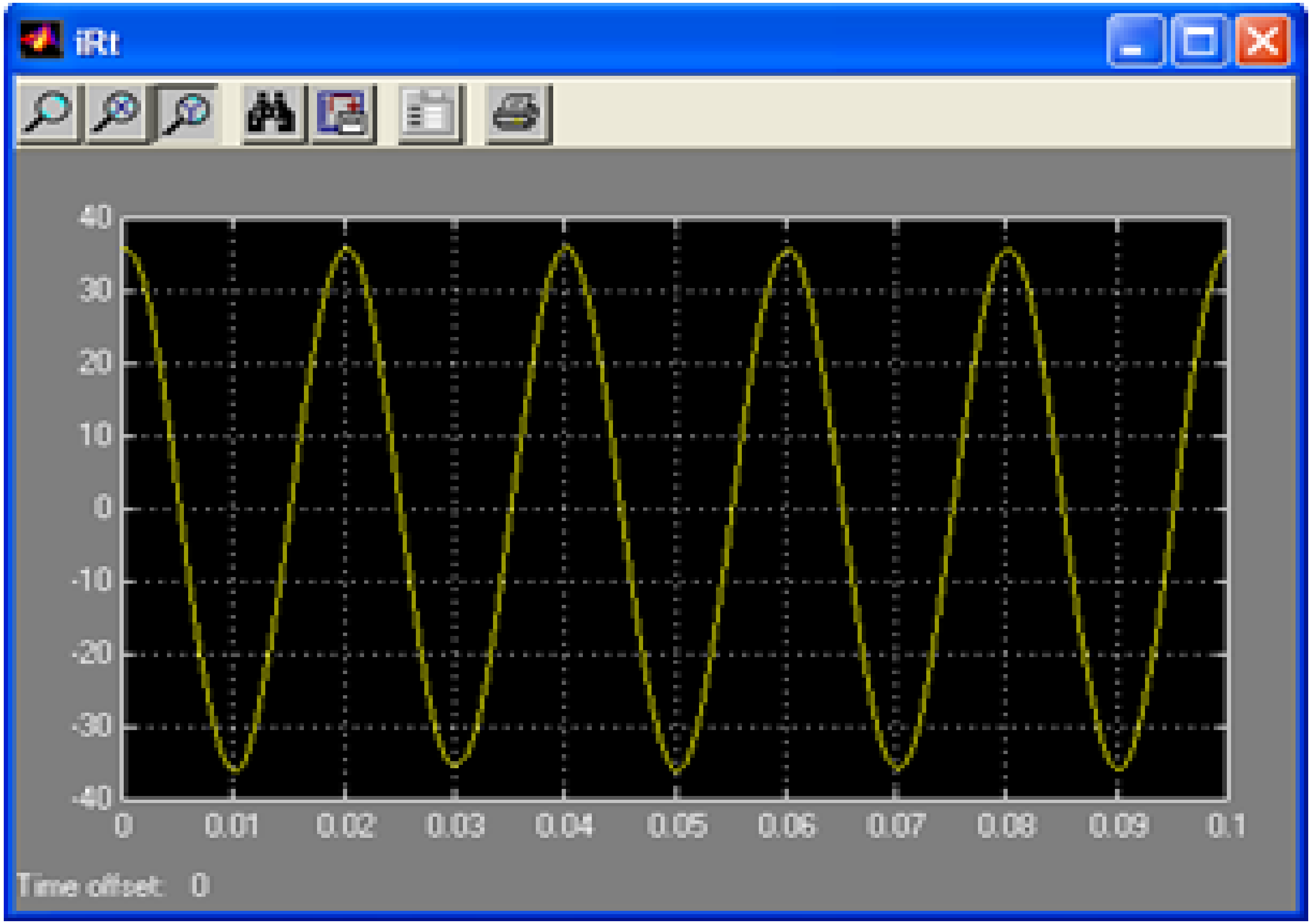

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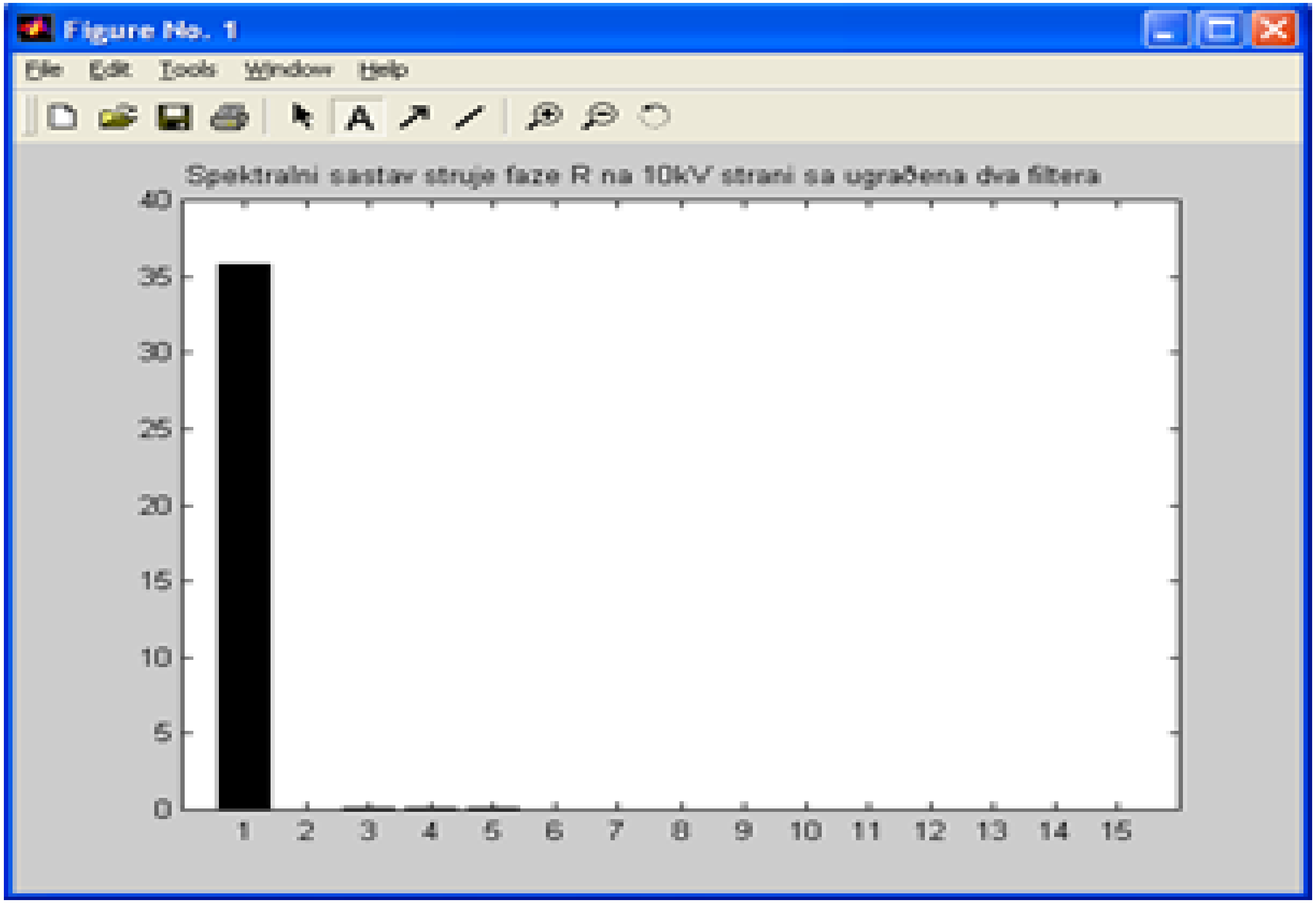
Figure 2.11. Spectral current phase R current on 10 kV side (2 filters installed)



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The value of THDI% for phase R current is:

THDI % = 0.0023 %

Comparison of THDI in either case:
From the analysis we can see that THDI% is the smallest when both filters are eliminated for the elimination of the 2 and 3 current harmonics, but then the current in the R phase has the highest value, ie 36A
The THDI current of the phase R 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).

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Autors

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