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CHOSEN RESULTS OF VOLTAGE ASYMMETRY SIMULATION INVESTIGATIONS AT RURAL CONSUMERS SUPPLIED BY LOW VOLTAGE POWER LINE

***Piotr Kolber*[1], *Janusz Piechocki*[2]**

[1] Department of Machine Maintenance
University of Technology and Life Sciences in Bydgoszcz
[2] Department of Electric and Power Engineering
University of Warmia and Mazury in Olsztyn

K e y w o r d s: load asymmetry, simulation program, voltage asymmetry.

A b s t r a c t

A simulation program facilitating to determine values of the chosen parameters characterizing electric energy quality (δU – voltage deviation, α_{U2} – voltage asymmetry coefficient) supplied to the rural consumers has been built on the basis of the elaborated model of a low voltage power line (LV). The simulation program representing a computerised realization of the model has been written in Turbo Pascal language. This paper presents chosen investigation results regarding, among other things, influence of the cable cross-sections on the voltage asymmetry in a low voltage power line.

WYBRANE WYNIKI BADAŃ SYMULACYJNYCH ASYMETRII NAPIĘCIOWEJ U ODBIORCÓW WIEJSKICH ZASILANYCH Z LINII NISKIEGO NAPIĘCIA

***Piotr Kolber*[1], *Janusz Piechocki*[2]**

[1] Katedra Eksploatacji Maszyn
Uniwersytet Technologiczno-Przyrodniczy w Bydgoszczy
[2] Katedra Elektrotechniki i Energetyki
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: asymetria obciążeń, program symulacyjny, niesymetria napięć.

A b s t r a k t

Na podstawie opracowanego modelu linii niskiego napięcia (nN), zbudowano program symulacyjny umożliwiający wyznaczanie wartości wybranych parametrów charakteryzujących jakość energii elektrycznej (δU – odchylenie napięcia, α_{U2} – współczynnik asymetrii napięciowej) dostarczanej odbiorcom wiejskim. Program symulacyjny, będący komputerową realizacją modelu, napisano w języku Turbo Pascal. W artykule przedstawiono wybrane wyniki badań dotyczące m.in. wpływu przekrojów przewodów na asymetrię napięciową w linii niskiego napięcia.

Introduction

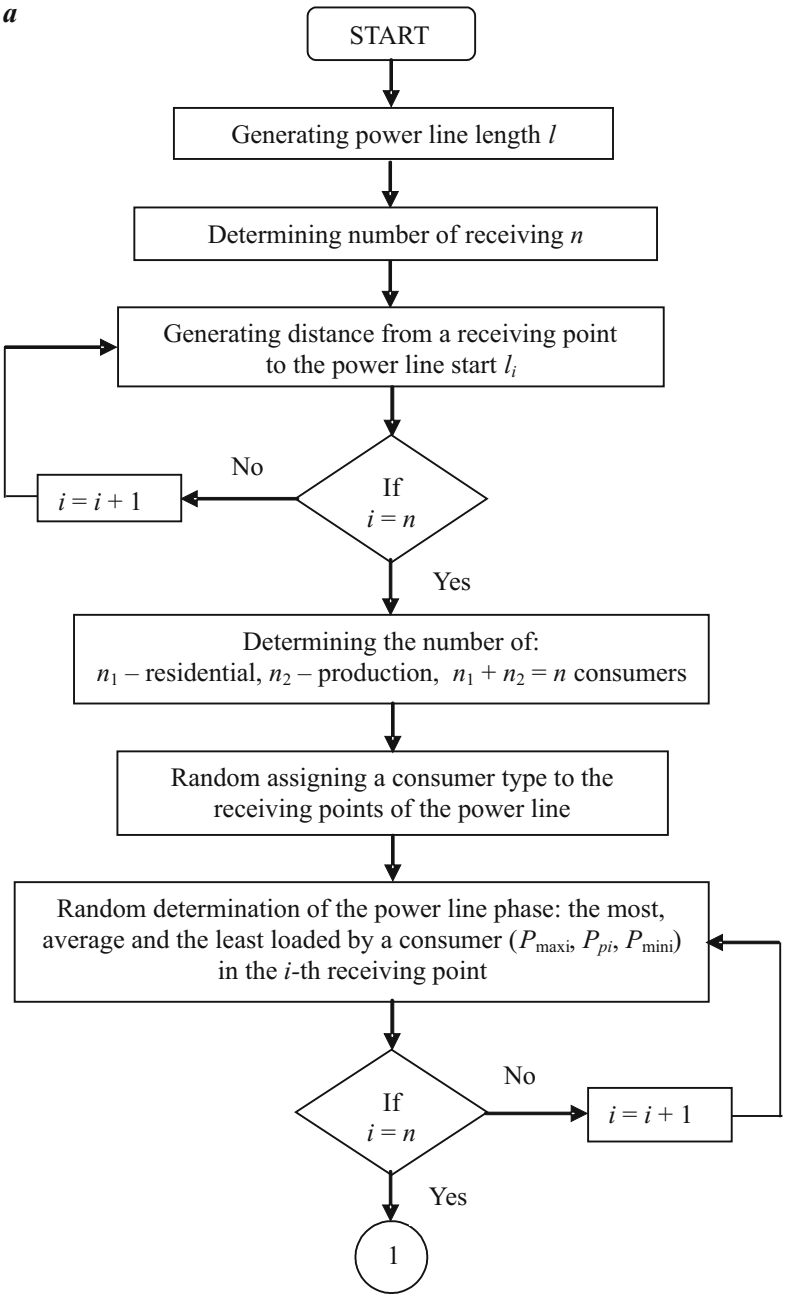
It may be stated that the values of the voltage drops, and subsequently levels and asymmetry of voltages in a LV power line are affected by the parameters of the power line being a transmission element that means its length, arrangement of the cables, cross-sections of the cables, distribution of the receiving points and the very consumers by the value of the consumed power and the asymmetry of phase loads. Because of a great number of the factors being crucial for the level and voltage asymmetry in a power line and due to the difficulties related to realization of complex investigations regarding the consumers' loads, as well as their expensiveness, a simulation model to determine values of the chosen quality parameters of electric energy has been elaborated. It facilitates to determine the values of voltage drops and deviations as well as of voltage asymmetry with various methods of distribution of the consumers along the power line, various values of the power consumed by the consumers and various levels of phase load asymmetry.

A simulation program, presented as a flowchart in Figure 1 has been elaborated on the basis of the model built to determine chosen parameters characterizing electric energy quality supplied to the consumers fed by a three-phase, four-cable low voltage power line (KOLBER 2006).

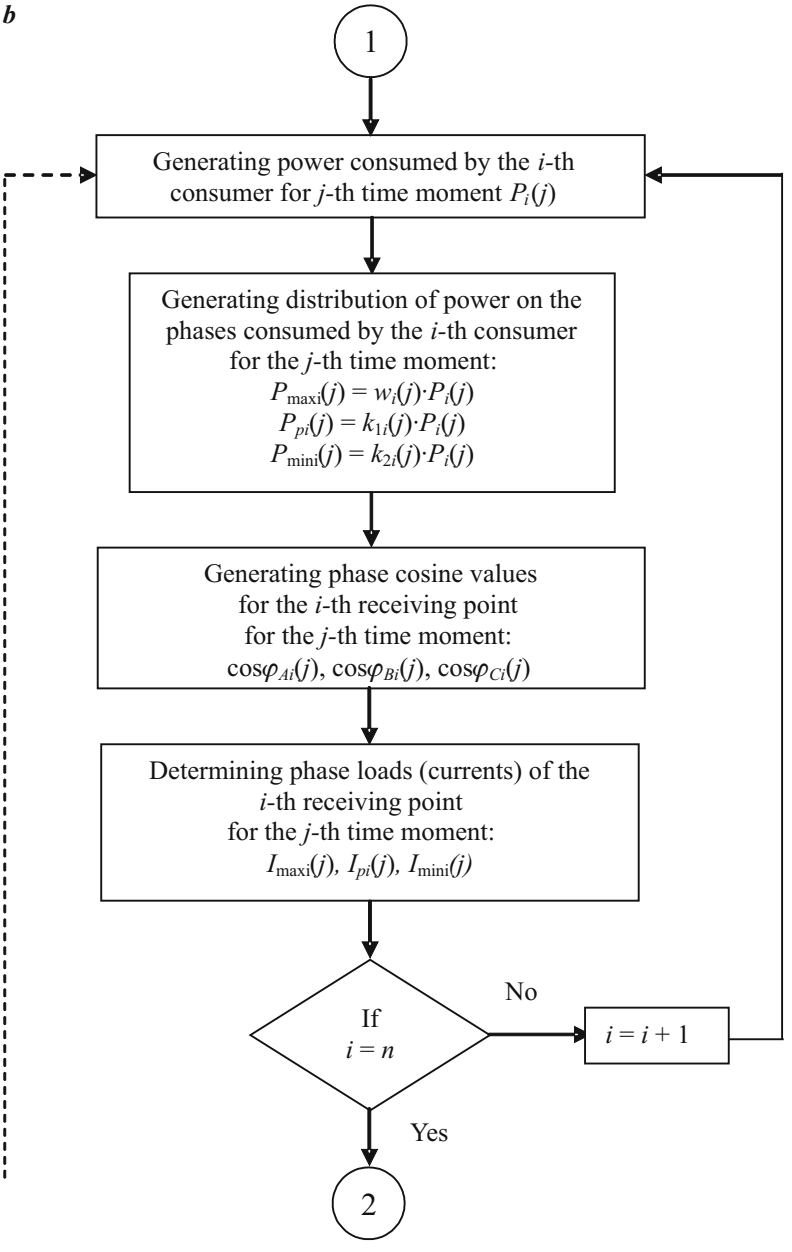
Simulation program to determine values of chosen parameters characterizing electric energy quality

The simulation program, presented below on the flowcharts, may be used to determine the values of the voltage drops and deviations as well as voltage asymmetry coefficients. This paper presents analysis of excess percentage of the admissible value of the voltage asymmetry coefficient α_{U2}, taken from a week time, for various variants of cable cross-sections applied and various variants regarding the type of the consumers connected to. The algorithms to generate random numbers used to perform the simulation were taken from the work (ZIELIŃSKI 1979), while the probability distributions were taken from the work (HELLWIG 1993).

The standardised requirements (Polish Standard PE 50160 1998) regarding the voltage asymmetry coefficient refer to its admissible value (α_{U2dop}=2%) and admissible excess percentage of this value over a week time, which for this parameter is equal to 5%.


a
START
Generating power line length l
Determining number of receiving n
Generating distance from a receiving point to the power line start l_i
If i = n
No
i = i + 1
Yes
Determining the number of: n_1 – residential, n_2 – production, $n_1 + n_2 = n$ consumers
Random assigning a consumer type to the receiving points of the power line
Random determination of the power line phase: the most, average and the least loaded by a consumer (P_{maxi}, P_{pi}, P_{mini}) in the i-th receiving point
If i = n
No
i = i + 1
Yes
1

b


1
Generating power consumed by the i-th consumer for j-th time moment $P_i(j)$
Generating distribution of power on the phases consumed by the i-th consumer for the j-th time moment:
$P_{maxi}(j) = w_i(j) \cdot P_i(j)$
$P_{pi}(j) = k_{1i}(j) \cdot P_i(j)$
$P_{mini}(j) = k_{2i}(j) \cdot P_i(j)$
Generating phase cosine values for the i-th receiving point for the j-th time moment:
$\cos\varphi_{Ai}(j)$, $\cos\varphi_{Bi}(j)$, $\cos\varphi_{Ci}(j)$
Determining phase loads (currents) of the i-th receiving point for the j-th time moment:
$I_{maxi}(j)$, $I_{pi}(j)$, $I_{mini}(j)$
If $i = n$
No
$i = i + 1$
Yes
2

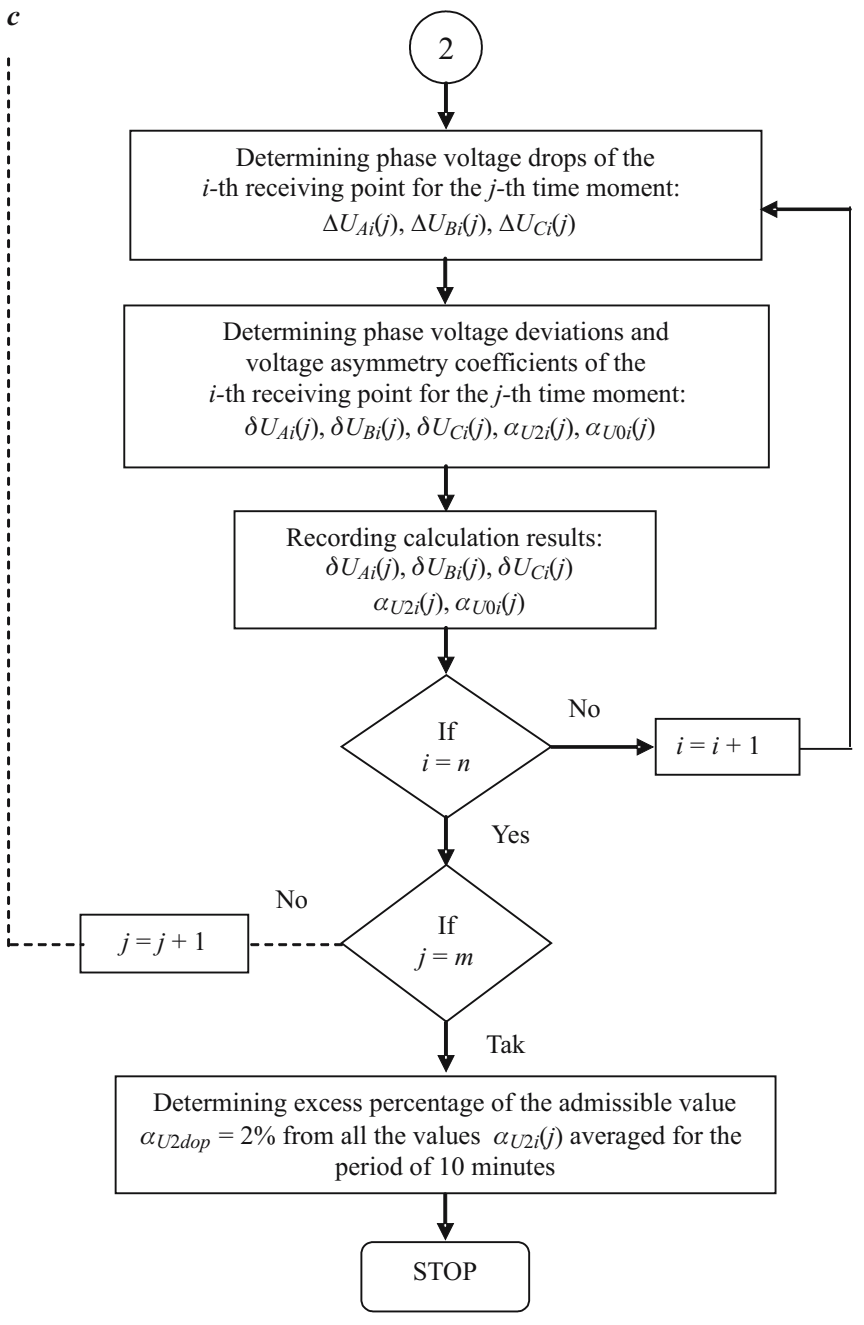


Fig. 1. Flowchart of the simulation program to determine values of the parameters characterizing electric energy quality

Chosen results of the simulation investigations

As a result of the simulation carried out a power line of length l = 1048 m supplying 15 consumers distributed at the following distances from the power line start has been generated:
l_1 = 82 m, l_2 = 92 m, l_3 = 105 m, l_4 = 284 m, l_5 = 296 m, l_6 = 301 m, l_7 = 312 m, l_8 = 368 m, l_9 = 495 m, l_{10} = 589 m, l_{11} = 663 m, l_{12} = 750 m, l_{13} = 795 m, l_{14} = 841 m, l_{15} = 1048 m.

The calculations were performed for the following variants regarding the type of the consumers connected to:

a) 0 residential consumers, 15 production consumers,
b) 5 residential consumers, 10 production consumers,
c) 10 residential consumers, 5 production consumers.

They referred also to the variants of the applied cross-sections of the cables used in a low voltage power line:

a) phase cables cross-section s= 35 mm^2;
   neutral cable cross-section s_n= 35 mm^2,
b) phase cables cross-section s= 35 mm^2;
   neutral cable cross-section s_n= 50 mm^2,
c) phase cables cross-section s= 50 mm^2;
   neutral cable cross-section s_n= 50 mm^2,
d) phase cables cross-section s= 50 mm^2;
   neutral cable cross-section s_n= 70 mm^2,
e) phase cables cross-section s= 70 mm^2;
   neutral cable cross-section s_n= 70 mm^2.

The obtained values of the asymmetry coefficient α_{U2} for the performed simulations are presented in the Figures: 2, 3, 4, 5, 6 and in the Table 1.

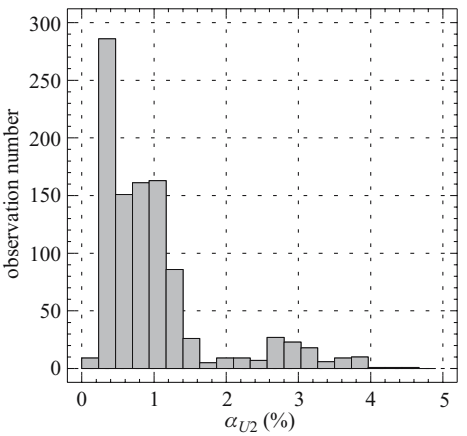
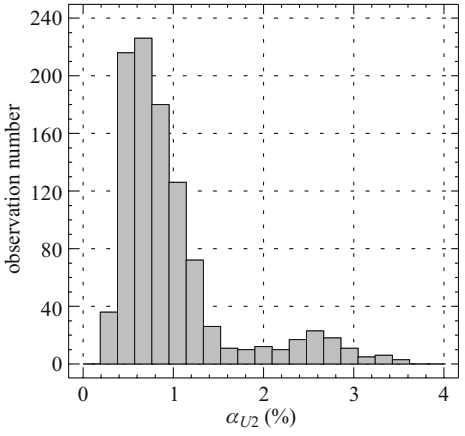


Fig. 2. Histogram of the voltage asymmetry coefficient values obtained as a simulation result for the following parameters:
– phase cables cross-section – 35 mm^2,
– neutral cable cross-section – 35 mm^2,
– number of residential consumers – 0



Rys. 3. Histogram of the voltage asymmetry coefficient values obtained as a simulation result for the following parameters:
– phase cables cross-section – 35 mm^2,
– neutral cable cross-section – 35 mm^2,
– number of residential consumers – 5

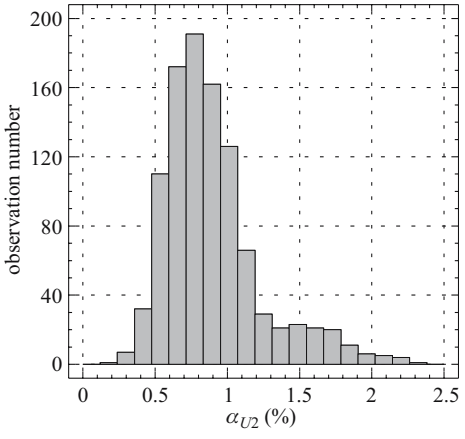


Fig. 4. Histogram of the voltage asymmetry coefficient values obtained as a simulation result for the following parameters:
– phase cables cross-section – 35 mm^2,
– neutral cable cross-section – 35 mm^2,
– number of residential consumers – 10

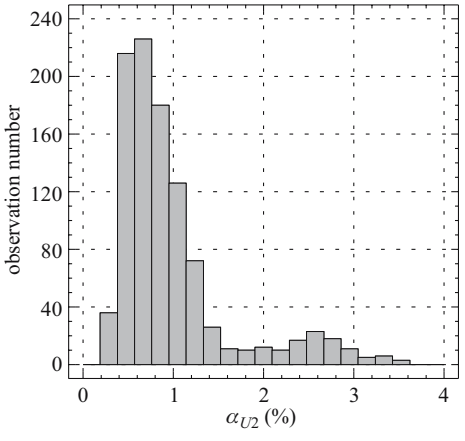


Fig. 5. Histogram of the voltage asymmetry coefficient values obtained as a simulation result for the following parameters:
– phase cables cross-section – 35 mm^2,
– neutral cable cross-section – 50 mm^2,
– number of residential consumers – 5

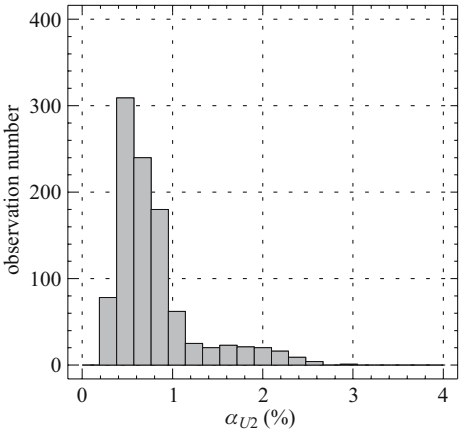


Fig. 6. Histogram of the voltage asymmetry coefficient values obtained as a simulation result for the following parameters:
– phase cable cross-section – 50 mm^2,
– neutral cable cross-section – 50 mm^2,
– number of residential consumers – 5

Table 1

Chosen results of the simulation investigations

Cable cross-sections:		Excess percentage value of the admissible value of the coefficient α_{U2}		
phase	neutral			
70	70	2.09	0.49	0.00
50	70	9.72	2.97	0.00
50	50	10.32	3.97	0.20
35	50	11.71	9.82	0.99
35	35	12.10	10.02	1.09
Number of residential consumers		0	5	10

Summary

On the basis of the results obtained from the simulation investigations it may be stated that the risk to exceed admissible values of the electric energy parameters caused by the load asymmetry is the greater, the greater is consumption of the power in a power line. According to the terms specified by the standard PE 50160 no excess of admissible values of the coefficient α_{U2} was observed for the prevailing number of the residential consumers (10 compared to the total number of the consumers – 15). It is caused by lower consumption of power by this type of consumers. The highest excess percentage of the parameter admissible value, in this case, was 1.09% of the weekly results

compared to the admissible 5%. In case of greater number of the production consumers (5 residential consumers) the greatest excess percentage of the parameter admissible value was 10.02%. While for the line supplying exclusively production consumers it was 12.1%.

By analysing methods to ease load asymmetry effects by increasing the cable cross-section it may be stated that increasing only cross-section of a neutral cable slightly improves the voltage asymmetry coefficient value α_{U2}. A radical improvement of the analysed parameter value was achieved by increasing cross-sections of the phase cables and the neutral one.

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