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SECURING ALLOWABLE VOLTAGE LOSSES AND STANDARD VOLTAGE CHARACTERISTICS

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The mathematical model for studying the possibility of securing standard voltage characteristics is analyzed and the model with taking into account requirements of new normative documents about voltage losses and voltage variations in a distributive network is perfected. Voltage variations near especially remote consumers are taken into account too. The block diagram of algorithm for studying the possibility of securing allowable voltage losses and standard voltage characteristics is developed.

Problem Statement. When designing the distribution network of the power supply system, calculations to determine the possibility of securing of standard voltage characteristics near the consumer should take into account the design features of the transmission lines (TL), the possibilities of technical means of voltage regulation and certain restrictions imposed by the regulatory documents. Improvement of the mathematical model for studying the possibility of securing of standard voltage characteristics is a topical issue in the conditions of the emergence of new normative documents.

Analysis of Recent Researches and Publications. In the standard [1] there are recommendations about maximum allowable voltage losses in power supply networks with voltage 0,38 kV and 6 (10) kV, which must be taken into account in the calculations with using the mathematical model of voltage variations of consumer power supply. According to this, the famous mathematical model of voltage losses [2] needs to improvement. In addition, it is necessary to take into account new recommendations of ДСТУ EN 50160-2014 [3] about voltage variations near the consumer.

Article Purpose is the analysis and perfection of the mathematical model for studying the possibility of securing standard voltage characteristics with taking into account requirements of new normative documents about voltage losses and voltage variations in a distributive network of power supply.

Main Research M aterials. The algorithm of calculation that is given in [2] allows determining voltage losses and voltage variations near the consumer in the time of the maximal and minimal load modes of operation. Thus it is possible to research influence on these parameters of load, resistance of wires, lengths of lines, power factors etc.

Limitation for this mathematical model is requirements of the ГОСТ13109-97 for long-term voltage variations near the consumer (long-term normal voltage variations must be within the limits of from +5 % up to -5 % near the consumer). In the near future the ГОСТ13109-97 becomes void and ДСТУ EN50160:2014 [3] will remains valid only. But voltage variations in public distribution systems can be within the limits of from -10 % up to +10 % based on this standard.

Recommendations [1] should be taken into account too, in particular, such as real voltage losses in the networks with voltage up to 1000 V and in the networks with voltage 6(10) kV, including losses in transformers with voltage 6(10)/0,4 kV should not exceed 6 %, as a rule, with taking into account the possible loadings heterogeneity of transformer substation (TS).

Thus, during designing a distributive network of power supply with voltage 6(10) kV the mathematical description of calculation algorithm for studying the possibility of securing allowable voltage losses and standard voltage characteristics are

$$\delta U = f(\Delta U_{35}, \Delta U_{10}, \Delta U_{0,38}) \Rightarrow \delta U_{\min}, \qquad (1)$$

$$\Delta U_{35} = f(S_{35}, r_{35}, x_{35}, L_{35}, Cos\varphi_{35}, U_{35(100)}, U_{35(25)}, \Delta U_{DSt(100)}, \Delta U_{DSt(25)}, \qquad (2)$$

$$\Delta U_{10} = f(r_{i10}, x_{i10}, L_{i10}, Cos\varphi_{i10}, E_{DS(100)}, E_{DS(25)}, S_{i10}, \Delta U_{TSt(100)}, \Delta U_{TSt(25)} \le 6\%, \qquad (3)$$

$$\Delta U_{0,38} = f(r_{0,38}, x_{0,38}, L_{0,38}, Cos\varphi_{0,38}, E_{TS(100)}, E_{TS(25)}, S_{0,38} \le 6\%, \qquad (4)$$

$$-10\% \le \delta U \le +10\%, \qquad (5)$$

where δU – voltage variations, %;

$\Delta U_{35}, \Delta U_{10}, \Delta U_{0,38}$ – voltage losses in a distributive network (with voltage 35, 10 and 0,38 kV respectively), %;

S_{35} – load of the projected system, kV·A;

r_{35}, x_{35} – specific resistances and reactance of the wires TL with voltage 35 kV, Om/km;

L_{35} – length of TL with voltage 35 kV, km;

$Cos\varphi_{35}$ – Power factors in a distributive networks with voltage 35 kV, r. u.;

$U_{35(100)}, U_{35(25)}$ – 100 %-load voltage and 25%-load voltage on the bus-bars with voltage 35 kV (the maximal and minimal load, 37 and 35 kV is adopted respectively), kV;

$\Delta U_{DSt(100)}, \Delta U_{DSt(25)}$ – voltage losses in transformers of the district substations (DS) in the time of 100 % and 25% load (4% and 1 % is adopted respectively), %;

$S_{35}, r_{35}, x_{35}, L_{35}, Cos\varphi_{35}, U_{35(100)}, U_{35(25)}, \Delta U_{DSt(100)}, \Delta U_{DSt(25)}$ – set values during designing a distributive network of power supply with voltage 6(10) kV, ΔU35 is set value too respectively;

r_{i10}, x_{i10} – specific resistances and reactance of the wires TL with voltage 6(10) kV, Om/km;

L_{i10} – length of TL with voltage 6(10) kV, km;

$Cos\varphi_{i10}$ – Power factors in a distributive networks with voltage 6(10) kV, r.u.;

$E_{DS(100)}, E_{DS(25)}$ – variable voltage on the DS with device of load voltage regulation (in the time of 100 % and 25% load respectively), %;

S_{i10} – load of TL with voltage 6(10) kV, кВ·А;

$r_{i10}, x_{i10}, L_{i10}, Cos\varphi_{i10}, E_{DS(100)}, E_{DS(25)}, S_{i10}$ – variables values, changing it, in everyone i-th iterations solve a problem of reduction of losses in networks 6(10) kV during designing a distributive network of power supply;

$\Delta U_{TSt(100)}, \Delta U_{TSt(25)}$ – voltage losses in transformers with voltage 6(10)/0,4 kV of the TS in the time of 100 % and 25% load (4% and 1 % is adopted respectively), %;

$r_{0,38}, x_{0,38}$ – specific resistances and reactance of the wires TL with voltage 0,38 kV, Om/km;

$L_{0,38}$ – length of TL with voltage 0,38 kV, km;

$Cos\varphi_{0,38}$ – Power factors in the distributive networks with voltage 0,38 kV, r.u.;

$S_{0,38}$ – load of TL with voltage 0,38 kV, кВ·А;

$r_{0,38}, x_{0,38}, L_{0,38}, Cos\varphi_{0,38}, S_{0,38}$ – parameters of a distributive network with voltage 0,38 kV are not taken into account during designing a distributive network of power supply with voltage 6(10) kV and taken into account condition (6)

$$\Delta U_{0,38} = f(E_{TS(100)}, E_{TS(25)}) \le 6\%, \qquad (6)$$

where $E_{TS(100)}, E_{TS(25)}$ – variable voltage on the TS with device of voltage regulation without load (it unchanged in the time of 100 % and 25% load), %.

The calculation results with use of offered mathematical model presented in table 1. For example the voltage variations calculated for the closest and remote TS 10/0,4 kV and near the consumer with taking into account requirements of normative documents about allowable voltage losses.

The presented mathematical model allows not only to model voltage variations near the consumer at a design stage, but also to determine "especially remote consumers" during operation.

The voltage variations can be within the limits of from -15 % up to +10 % based on standard [3] for especially removed consumers. Respectively, the condition (5) is replaced by the condition (7) in the offered mathematical model

$$-15\% \le \delta U \le +10\%. \qquad (7)$$

Definition "especially remote consumer" can differ in the different countries (based on standard [3]). The presented mathematical model allows taking into account design parameters of the TL, technical opportunities of voltage regulation and other features of distributive network of power supply.

The simplified condition for definition of especially remote consumer according to distance from the TS is offered in [5]. The offered mathematical model allows counting also results of technical actions for influence on voltage variations near the consumer of the specified category (change of a configuration of a network, replacement of a wire by a wire with greater wire cross-section etc.).

Table 1 – Example of calculation results

Load, %		100	25
Voltage losses in the TL with voltage 35 kV, %		1,69	0,42
S_{35}, kV·A	2500		
L_{35}, km	16		
r_{35}, Om/km	0,420		
x_{35}, Om/km	0,382		
$U_{35(100)}$, kV	37		
$U_{35(25)}$, kV	35		
$Cos\varphi_{35}$, r.u.	0,97		
Voltage variations on the bus-bars with voltage 35 kV, %		+5,71	0
Voltage variations on the bus-bars with voltage 10 kV of DS 35/10 kV		+7,52	+1,08
$E_{DS(100)}$, %	7,5 [4]		
$E_{DS(25)}$, %	2,5 [4]		
$\Delta U_{DSt(100)}$, %	4		
$\Delta U_{DSt(25)}$, %	1		
Voltage variations on the bus-bars with voltage 0,4 kV of the closest TS 10/0,4 kV, %		**+2,60**	**-0,15**
$\Delta U_{TSt(100)}$, %	0,92		
$\Delta U_{TSt(25)}$, %	0,23		
$E_{TS(100)}$, %	0		
$E_{TS(25)}$, %	0		
Voltage variations on the bus-bars with voltage 0,4 kV of the remote TS 10/0,4 kV, %		+2,71	+0,67
$\Delta U_{TSt(100)}$, %	3,51		
$\Delta U_{TSt(25)}$, %	0,878		
$E_{TS(100)}$, %	2,7 [1]		
$E_{TS(25)}$, %	2,7 [1]		
Allowable voltage losses in the TL with voltage 0,38 kV, %		6,00	1,50
Voltage variations near the consumer, %		**-3,29**	**+2,17**

The block diagram of algorithm for studying the possibility of securing allowable voltage losses and standard voltage characteristics is developed.

The calculation algorithm of voltage losses in a distributive network of power supply is in the first part of the block diagram (from p. 1 up to p. 16 – look figure 1), the check and updating of variable data is in another part of the block diagram. It is in figure 1:

$\delta U_1, \delta U_2$ – voltage variations based on the standard [3] (-10% та +10% respectively);

$\delta U_{c(100)i}, \delta U_{c(25)i}$ – voltage variations near the consumer in the time of 100% and 25% load respectively;

$\delta U_{0,4(100)i}, \delta U_{0,4(25)i}$ – voltage variations on the bus-bars with voltage 0,4 kV of the closest TS 10/0,4 kV in the time of 100% and 25% load respectively;

$\delta U2_{0,4(100)i}, \delta U2_{0,4(25)i}$ – voltage variations on the bus-bars with voltage 0,4 kV of the remote TS 10/0,4 kV in the time of 100% and 25% load respectively.

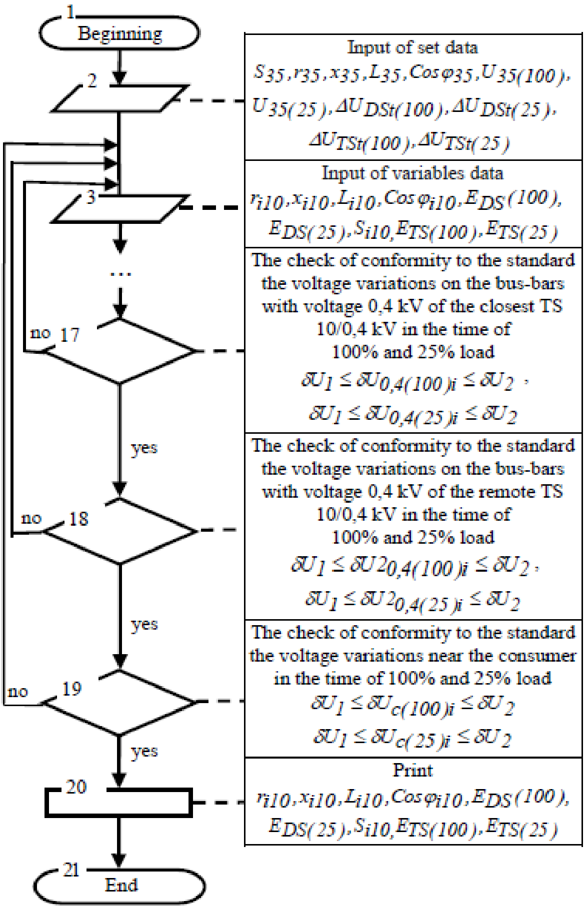

Figure 1 – The block diagram of algorithm for studying the possibility of securing allowable voltage losses and standard voltage characteristics

The block diagram has been developed is realized in the calculation computer program by means of Microsoft Excel, that students used in educational process of Scientific Educational Institute of Power and Computer Technologies of KNTUA.

Conclusions. The presented mathematical model for studying the possibility of securing allowable voltage losses and standard voltage characteristics can be useful not only at the design stage, but also during operation of a distributive network of power supply with voltage 6(10) kV.

References

1. Методика вимірювання якості електричної енергії в системах електропостачання загального призначення: СОУ-Н ЕЕ40.1-37471933-55:2011 [Чинна з 31.10.2011]. – К.: Міненерговугілля, 2012. – 98 с.

2. Трунова І. М. Енергетичний аудит підприємств-електропостачальників з врахуванням якості електроенергії / І. М. Трунова // Вісник ХНТУСГ. Проблеми енергозабезпечення та енергозбереження в АПК України. – 2009. – Вип. 87. - С. 20-23.

3. Характеристики напруги електропостачання в електричних мережах загальної призначеності: ДСТУ EN 50160:2014 (EN 50160:2010, IDT). [Чинний з 1.10.2014]. – К.: Держстандарт України, 2014. – 27 с.

4. Офіційний сайт ВАТ "Электрозавод". [Електронний ресурс]. Режим доступу до сайту: http://www.elektrozavod.ru/production/2_3. Дата звернення до сайту 27.11.2017 р.

5. Трунова І. М. Аналіз врахування якості електроенергії у стандартах якості послуг / І. М. Трунова // Енергетика та комп’ютерно-інтегровані технології в АПК. – 2016. – Вип. 2 (5). – С. 38-40.

Анотація

ЗАБЕЗПЕЧЕННЯ ДОПУСТИМИХ ВТРАТ ТА СТАНДАРТНИХ ХАРАКТЕРИСТИК НАПРУГИ

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Проведений аналіз та вдосконалення математичної моделі для дослідження можливості забезпечення стандартних характеристик напруги з врахуванням вимог нових нормативних документів щодо втрат напруги в розподільної мережі електропостачання та відхилень напруги у споживача. Враховані характеристики напруги у особливо віддалених споживачів. Розроблена блок-схема алгоритму дослідження можливості забезпечення допустимих втрат та стандартних характеристик напруги.

Аннотация

ОБЕСПЕЧЕНИЕ ДОПУСТИМЫХ ПОТЕРЬ И СТАНДАРТНЫХ ХАРАКТЕРИСТИК НАПРЯЖЕНИЯ

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Проведен анализ и усовершенствована математическая модель для исследования возможности обеспечения стандартных характеристик напряжения с учетом требований новых нормативных документов по потерям напряжения в распределительной сети электроснабжения и отклонениям напряжения у потребителя. Учтены характеристики напряжения у особо отдаленных потребителей. Разработана блок-схема алгоритма для исследования возможности обеспечения допустимых потерь и стандартных характеристик напряжения.