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Simulation of Rural Distribution Electrical Networks of 10/0,4 kV

Abstract: The article deals with simulation of rural distribution networks of 10/0,4 kV. The main task of power saving in rural electrical energy industry is minimizing of electric system losses in rural distribution grids which amounts 50% of the whole farming sector electrical supply. One of the main factors governing the energy quality and transportation losses is voltages and currents unbalance caused by single phase appliance load domination. The calculation method of power and energy losses in electric grids with load unbalance based on symmetrical component method has gained the major prevalence.

Keywords: power distribution networks, unbalance voltages and currents, the simulation of electrical networks, power quality.

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Electrical power is a certificated commodity which possesses a number of unique qualities such as simultaneousness of production and consumption processes when distorting effect on power quality (PQ) may be produced by power consumer or caused by conducted electromagnetic interference distributed along the grid [1].

Electrical power is the only commodity the transportation of which is carried on by consumption of definite product part that causes inevitable transporting power losses. So the main task of power saving in rural electrical energy industry is minimizing of electric system losses in rural distribution grids which amounts 50% of the whole farming sector electrical supply [2].

One of the main factors governing the energy quality and transportation losses is voltages and currents unbalance caused by single phase appliance load domination.

The calculation method of power and energy losses in electric grids with load unbalance based on symmetrical component method has gained the major prevalence.

The grid of 0,4 kV with evenly distributed single-phase consumers of different wattage (Figure 1) may be viewed upon as a grid with several distributed balanced three-phase loads generated by "star" connected three groups of one-phase loads of different wattage the neutral point of which is connected to neutral conductor [3].

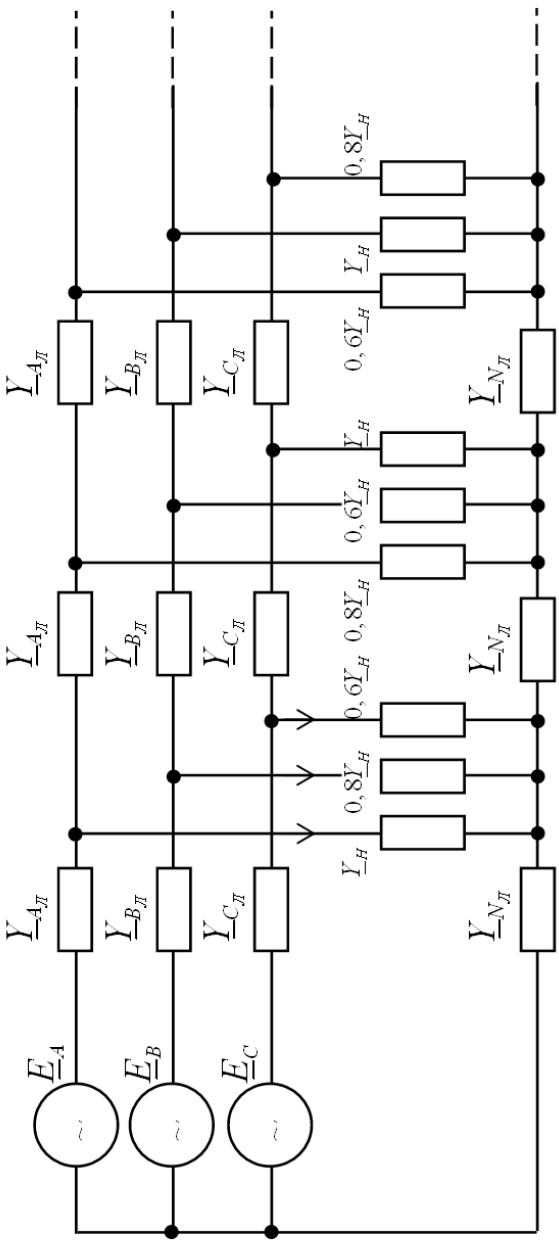

Figure 1. The grid with evenly distributed single-phase consumers of different wattage

One can easily replace any unbalanced three-phase load with equivalent balanced three-phase load and with two one-phase consumers of different wattage connected to Y-voltage. Equivalent condition of such replacement is symmetry of voltages and currents on consumers' terminals. And for equivalent circuits of unbalanced three-phase consumers it includes the equality of pulsed power sets [4]. For general case of unbalanced system of three-phase voltage of unbalanced consumer terminal phase currents may be expressed as [5]:

$$\underline{I}_A = \underline{U}_A \underline{Y}_{HA}, \quad \underline{I}_B = \underline{U}_B \underline{Y}_{HB}, \quad \underline{I}_C = \underline{U}_C \underline{Y}_{HC}$$

where $\underline{U}_A, \underline{U}_B, \underline{U}_C$ – phase voltages;

$\underline{Y}_{HA}, \underline{Y}_{HB}, \underline{Y}_{HC}$ – conductivity of phase conductors.

Power losses are characterized by power losses coefficient which is equivalent to the ratio of unbalanced load losses Pн to the power losses caused by direct sequence currents P_1:

$$K_p = \frac{\Delta P_i}{\Delta P_1} = 1 + K_{2i}^2 + K_{0i}^2 \frac{R_0}{R_1}$$

Where $K_{2i} = \frac{I_2}{I_1}$ – is the coefficient of inverted sequence of currents;

$K_{0i} = \frac{I_0}{I_1}$ – is the coefficient of zero sequence of currents;

R_0, R_1 – are resistive loads of zero and direct sequence grid sections;

I_1, I_2, I_0 – are currents of direct, inverted and zero sequence for the same grid section.

Specific values of phase losses on a grid section are defined as:

$$\left.\begin{aligned} \underline{\delta}_A &= \frac{\underline{\Delta U}_A}{\underline{\Delta U}_1} = 1 + \underline{K}_{2i} + \underline{K}_{0i}\underline{K}_Z; \\ \underline{\delta}_B &= \frac{\underline{\Delta U}_B}{\underline{\Delta U}_1} = \underline{a}^2 + \underline{a}\underline{K}_{2i} + \underline{K}_{0i}\underline{K}_Z; \\ \underline{\delta}_C &= \frac{\underline{\Delta U}_C}{\underline{\Delta U}_1} = \underline{a} + \underline{a}^2\underline{K}_{2i} + \underline{K}_{0i}\underline{K}_Z, \end{aligned}\right\}$$

where $\underline{\Delta U}_A, \underline{\Delta U}_B, \underline{\Delta U}_C$ – are sets of phase voltage losses on a grid segment;

$\underline{\Delta U}_1$ – a set of phase voltage loss on a direct sequence grid section;

$\underline{K}_{2i}$, $\underline{K}_{0i}$ – complex coefficients of inverted and zero current sequences:

$$\underline{K}_{2i} = \frac{\underline{I}_2}{\underline{I}_1}\ ;\ \underline{K}_{0i} = \frac{\underline{I}_0}{\underline{I}_1}\ ;$$

$\underline{I}_1, \underline{I}_2, \underline{I}_0$ – sets of direct, inverted and zero current sequences;

$\underline{a} = e^{j\frac{2\pi}{3}}$ – complex factor of vector rotation on 120^0.

Balanced component method has some restrictions for unbalanced electrical grids due to definite sophistication of substitution schemes when the number of unbalances in the grid tends to aggravate. Balanced component method application is rather problematic with some specific transformers, such as phase-shifting transformers, used in controlled self-compensating ETL with advanced transmission capacity [6].

Application of math software package enables to specify the task and obtain adequate calculation accuracy. Nowadays there exist a number of programs for electric grid simulation. All of them have these or that advantages. The major advantage of SimPowerSystems is the possibility of combining simulation and structural modelling methods in modelling of sophisticated electrical engineering system. For instance the power block of semiconductor converter can be carried out with the help of SimPowerSystems simulation units and control block – with the help of standard Simulink blocks showing only the working algorithm but not its electrical schematic. [7]

Actual performance of electrical engineering system correlates with probability of load connection [8, 9]. That is why one can mention that simulation of electrical engineering systems with the help of MatLAB software enables simultaneous application of numerical computation methods and prediction elements based on neural network logics for calculation of electrical circuits.

Simulink has a versatile block component library for compiling of functional flowchart of simulated electrical engineering systems. Simulink enables to create flowcharts of electrical engineering systems, i.e. S-model. It makes possible to solve sophisticated algebraic and differential equations sets describing the given function chart (S-model). This makes performance control of virtual electrical engineering system more comfortable and visual.

Resulting "virtual chart" will make possible to carry out all the research steps characteristic of experimental or test model investigation, i.e:

– planning of model experiments;

– implementation of experiment plan;

– analyzing and interpreting of simulation results.

Definite simulation advantages are:

– automatic monitoring of all chart elements connections and correlations;

– obtaining of simulation results in the form analogous to that of real schemes investigation (oscillogramms, temporary process etc.) which leads to simplifying of modelling results analysis and their relation to commercial electrical engineering devices;

– possibility of performance investigation of separate units of an electrical machine or scheme, e.g. one can monitor the value of electromagnetic moment of the engine etc.;

– possibility of scheme performance investigation in conditions which are difficult to accomplish on test installations, e.g. high temperatures and emergency modes;

– possibility of studying electrical engineering devices and schemes in action, e.g. electrical engine reaction on accidental load changes which is difficult to accomplish on commercial installations;

– possibility of scheme performance investigation under conditions of confounding factors or hindrances [10].

An example of electrical distribution grid of 10/0,4 kV simulation is given on Figure 2, where is presented schematic circuit diagram created with the help of SimPowerSystems package in in math software MatLAB 7.0.

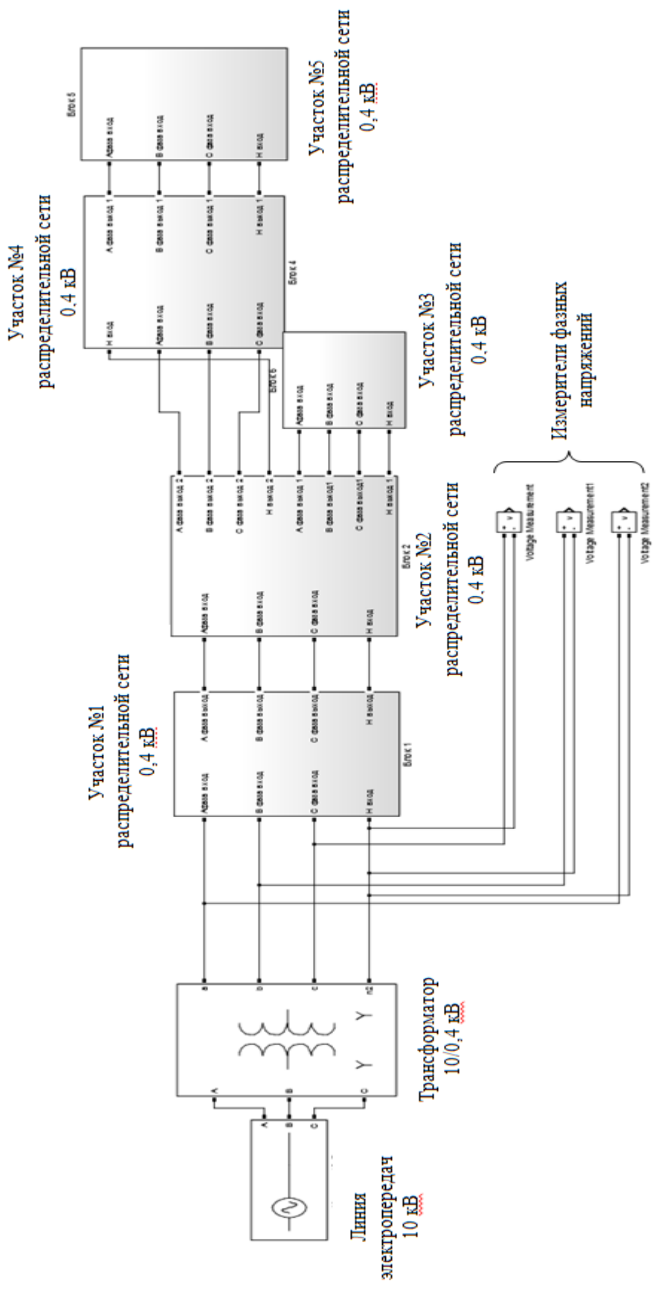

Figure 2. Simulation of the electrical distribution grid of 10/0,4 kV.

The main characteristic feature of this scheme is modularity of creating. Each module comprises substitution elements of power lines and loads. The example of such module looks as follows - Figure 3.

Application of such module mechanism of the electrical distribution grid enables to investigate any grid of any complexity. The accuracy of the obtained results depends on correct creation of substitution scheme.

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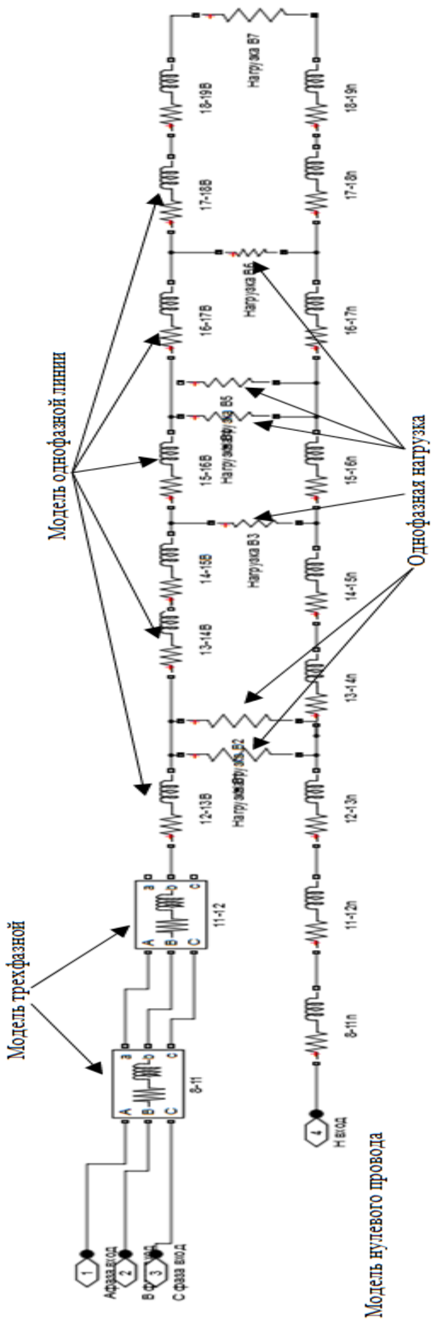

Figure 3. Simulation (module) of the electrical distribution grid of 10/0,4 kV with one phase load

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