O. I. Grachova, Dr. Sc. (Eng.), Professor; A. V. Shagidullin

IMPACT OF CONTACT JOINTS RESISTANCES ACCOUNT OF LOW VOLTAGE SWITCHING DEVICES

The paper studies the problem of the impact of basic circuit and mode parameters of the equipment and shop-floor grids on the value of the equivalent resistance of low voltage grids of the industrial enterprises. The conditions, under which non-accounting of contact joints resistances of switching devices does result in the substantial error in the process of determination of the equivalent resistance in 0.4 kV grid, are considered.

Key words: *low voltage grids, switching devices, automatic circuit breaker, magnetic starter, equivalent resistance.*

Energy system comprises several thousand transmission lines, rated for less than 1000 V. Such grids are the most important elements in the system of the industrial energy supply. As a result of their branching and length, low voltage grids are characterized by considerable losses of electric energy [1], that is why, the increase of the reliability of losses calculation is important due to constant growth of electric energy cost [2,3].

For more accurate determination of energy losses the application of the specialized models, [4], the parameters of which can be easily formed separately for each specific shop-floor grid is expedient. In the process of composition of such models all the lines of the radial shop-floor grid are replaced by one equivalent line.

As it is known, the equivalent resistance of the shop-floor grid is a determining parameter for electric energy losses calculation [5] and consumption of electric energy [6]. Electric energy losses, stipulated by the square of the efficient current and equivalent resistance of the circuit is one of the most important indices, characterizing the efficiency of grids operation [7]. Determination of the losses value with minimal possible error is necessary for the solution of the problems, emerging in the process of planning of electric energy losses and operation of shop-floor grids [8]. During the planning of energy supply and assessment of losses, the equivalent resistance of the whole circuit is used as the basic characteristic of the circuit with the different set of the quantity and types of the devices, installed in the line [3].

For the assessment of the degree of impact of basic factors, determining the equivalent resistance of the shop-floor grid, the parameters of energy supply circuit of the mechanical shop section with the majority of radial lines will be studies (Fig. 1).

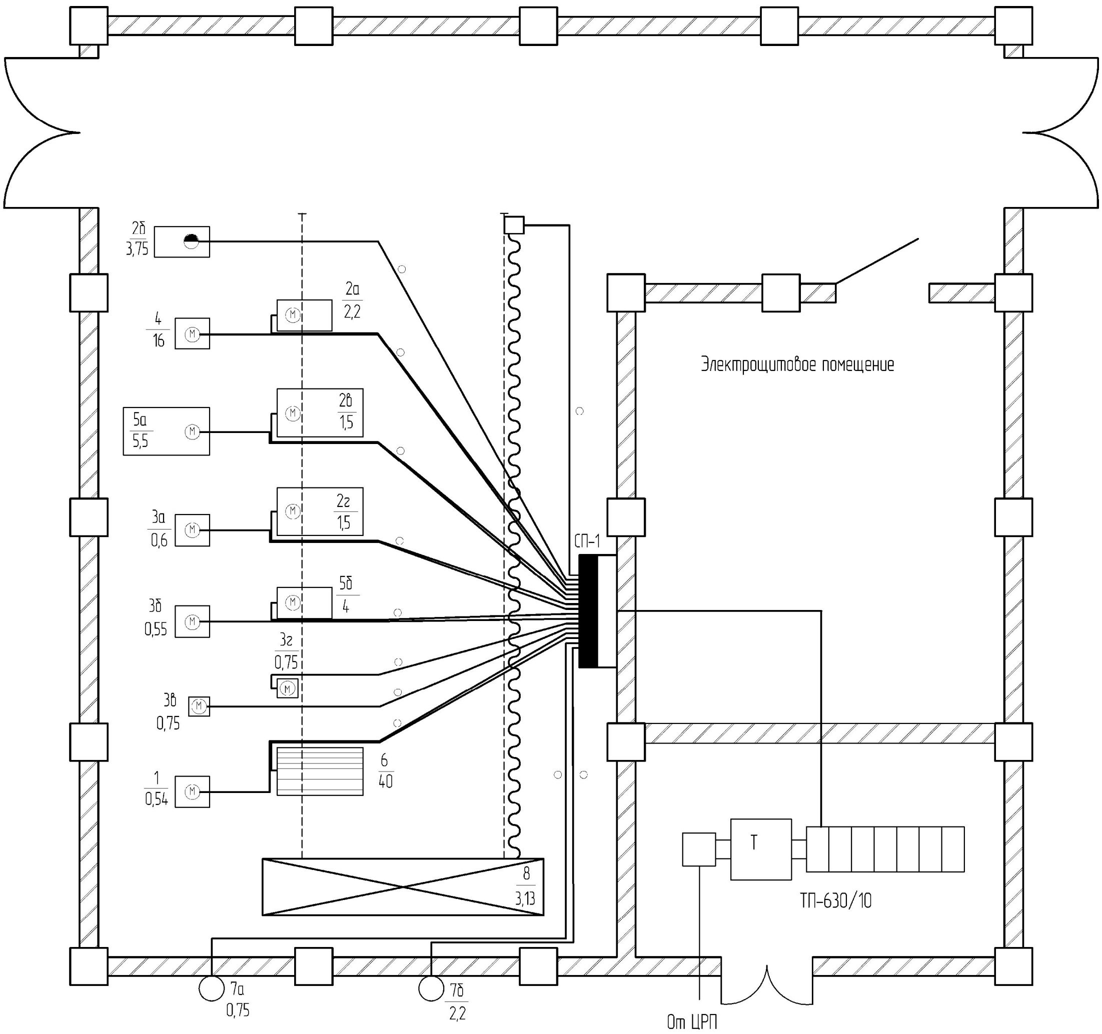

Fig. 1. Radial scheme of electric energy supply of mechanical shop section , where
1 – bench-type drilling unit; 2b – universal milling machine; 2c – universal milling machine; 3a – lather machine; 3b – lather machine; 3c – lather machine; 3d – lather machine; 5a – compressor; 5b – compressor; 6 – bench-type drilling machine; 2a – universal milling machine; 2b – universal milling machine; 4 – bench-type drilling machine; 7a – fan; 7b – fan; 8 – electric top-running crane beam; L1-L16 – cable lines from the switchboard to the consumer; SB-1 –switchboard; T – transformer; TS – transformer substation; CDP– central distribution point

Equivalent resistance of the radial grid is determined by the expression [9]:

$$R_{eq} = \frac{\dfrac{\sum\limits_{i=1}^{n} r_{i,20} \cdot l_i}{n}\left[1 + \alpha\left(\Theta_{i,cond} - 20^{\circ}\right)\right] + \dfrac{\sum\limits_{i=1}^{m} r_{i,un}}{n}}{n}, \tag{1}$$

where $r_{i,un}$ – is the resistance of the contact joints of the low voltage switching devices, installed in the line of low-voltage switching devices; l_i – is the length of the line, m; $r_{i,20}$ – is the specific resistance of 1 m of the conductor at the temperature of 20° C, mOhm/m; α – is the temperature coefficient of the line conductor material resistance increase, for copper it equals 0.0044 $1/{}^{\circ}C$, for aluminium – 0.0042 $1/{}^{\circ}C$; n – is the number of electric loads; m – is the number of the units in the circuit.

The heating temperature of current conducting wire is determined by the expression [10]:

$$\Theta_{wire} = k_l^2 \cdot \left(T_{adm} - \Theta_{amb}\right) + \Theta_{amb}, \tag{2}$$

where k_l^2 – is root mean square coefficient of line loading; T_{adm} – is admissible temperature of cable conductor, determined by the reference data; Θ_{wire} – is the temperature of the wire strand, that changes, depending on the ambient temperature and line loading, $^{\circ}C$; Θ_{amb} – is the ambient temperature.

For determination of the reference equivalent resistance, losses of power in each line of the radial grid section are found element-wise [11] ΔP_i

$$R_{\text{eq}} = \frac{\sum_{i=1}^{n} \Delta P_i}{3 I_{\text{tot}}^2} = \frac{\sum_{i=1}^{n} I_{i,\text{c}}^2 \left\{ r_{i,20} \cdot l_i \left[1 + \alpha \left(\Theta_{i,wire} - 20^{\circ} \right) \right] + \sum_{i=1}^{N} r_{i,\text{un}} \right\}}{I_{\text{tot}}^2}, \tag{3}$$

where $I_{i,c}$ – is the calculated current of the i^{th} section of the grid, A; I_{tot} – is total current of the n^{th} number of the consumers, A; N – is the number of units in the line.

Fig. 2 shows the dynamics of the value change of the equivalent resistance of shop-floor grid section, shown in the Fig. 1, on condition of taking or not taking into account such parameters as:

– heating of the conductors by loading current Θ_{wire};

– resistance of the switching devices $r_{i,\text{un}}$;

– k_1^2 – is root mean square coefficient of line loading.

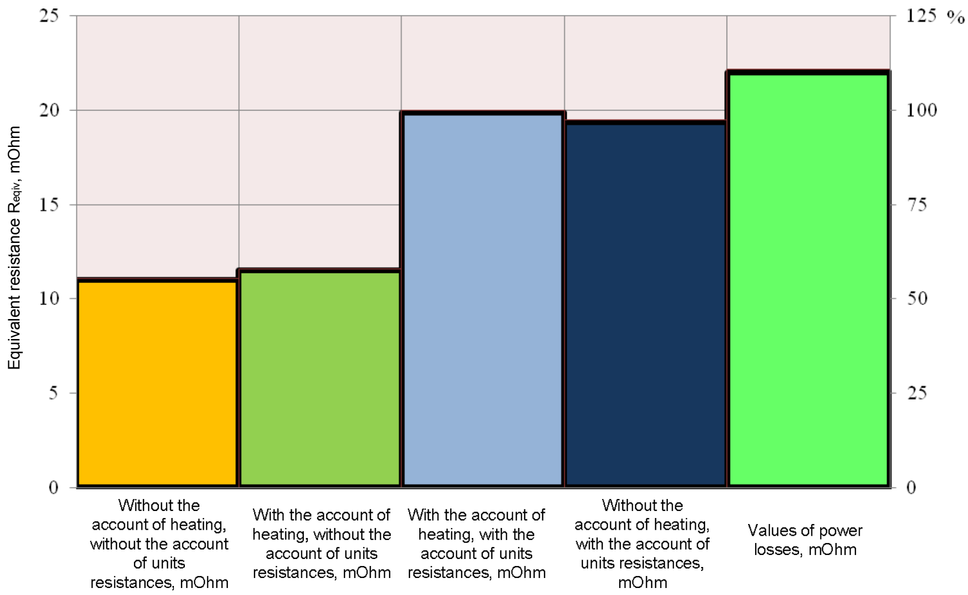

Fig. 2. Value of the equivalent resistance of shop-floor section of the grid with the account of the impact of main parameters of the equipment

Equivalent resistance of the radial grid without the account of the resistance of switching devices is determined by the expression [12]:

$$R_{\text{eq}} = \frac{\frac{\sum_{i=1}^{n} r_{i,20} \cdot l_i}{n} \left[1 + \alpha \left(\Theta_{i,wire} - 20^{\circ} \right) \right]}{n}. \tag{4}$$

By the results of the research, carried out, the ratio in the equivalent resistance of radial grid to the resistance of contact joints of low voltage units and the resistance of the lines, depending on the number of consumers, connected to the distribution device (Fig. 3) is determined.

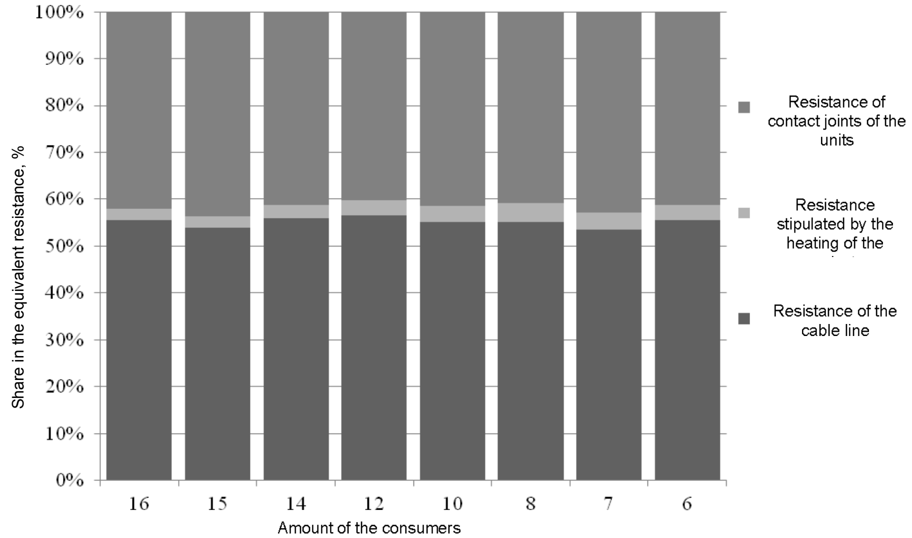

Fig. 3. Ratio in the equivalent resistance of the radial grid the resistance of the contact joints of low voltage units and the resistance of the lines, with the account of conductors heating

As the studies showed [12,13] in the process of calculation of equivalent resistance in shop-floor lines it is necessary to take into consideration the impact of conductors heating, caused by the passage of loading current and ambient temperature [14,15]; resistances of the contact systems of switching devices and their number; because the shop-floor lines contain numerous nodes, serially connected with contact joints and the resistance of the devices is comparable with the resistance of the line; also it is necessary to take into account mean-square loading coefficient of the grid lines k_1^2, that enables to decrease the error of the equivalent resistance calculation and improve the calculation accuracy of electric energy losses in low voltage shop-floor grids.

Dependences of the equivalent resistance of the radial grid on the number of consumers connected to one power point (switch gear), and dependence on the number of power points connected in parallel with the equal number of electric energy consumers are shown in Fig. 4.

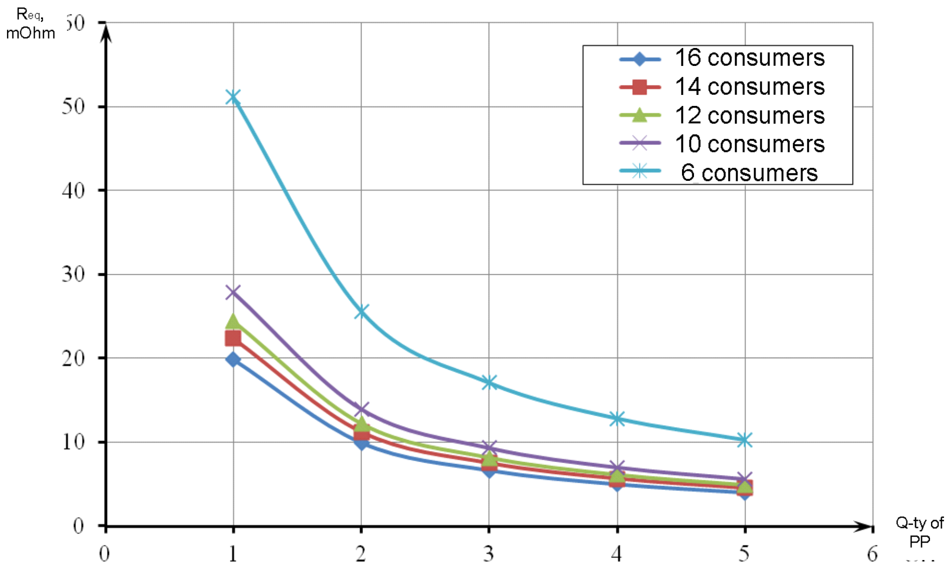

Fig. 4. Dependence of the equivalent resistance of the grid on the number of power points connected in parallel

By the results of the research, the conditions of the account/non-account of switching devices resistance for various schemes of radial shop-floor grids with the following changing parameters are analyzed and determined:

– quantity of the electric energy consumers 6 – 10;

– length of the line 5 – 200 m;

– cross-section of the line 2.5 – 240 mm^2;

– quantity of switching devices in the line: 1 automatic circuit breaker; 1 automatic circuit breaker and 1 magnetic starter; 2 automatic circuit breakers and 1 magnetic starter.

The results of the account/nonaccount of switching devices resistance are given in Fig. 5, 6, where AB – is the quantity of automatic circuit breakers, MS – magnetic starters, installed in the line.

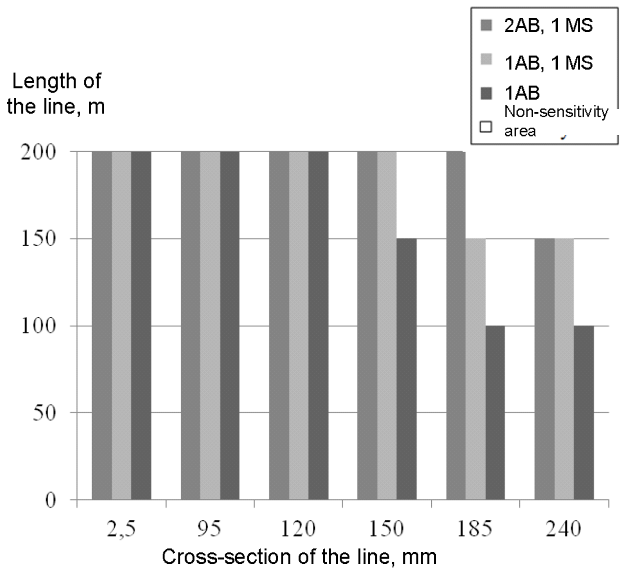

Fig. 5. Area of the account of switching devices resistance in the equivalent resistance of shop-floor grid with 6 radial lines

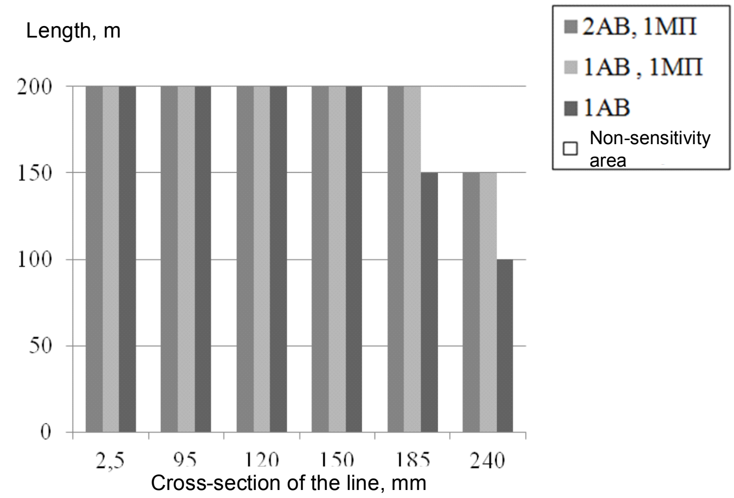

Fig. 6. Area of switching devices resistance account in the equivalent resistance of shop-floor grid with 10 radial lines

Thus, determination of the equivalent resistance by the expression (4) for the variants of equipment circuits that are not in the area of contacts resistance account, will lead to the difference of less than 5% as compared with the account of switching devices resistances in the equivalent resistance. The given nomographs simplify the algorithm of low voltage grids equivalent resistance determination for different circuits.

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Grachova Olena – Dr. Sc., (Eng.), Professor, Federal state-sponsored educational establishment of higher education «Kazan State Power Engineering University», e-mail: grachieva.i@bk.ru.

Shagidullin Andriy– Senior Lecturer, Federal state-sponsored educational establishment of higher education «Kazan State Power Engineering University», e-mail: shagidullinav@gmail.com.

Federal state-sponsored educational establishment of higher education «Kazan State Power Engineering University».