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CONTROL OF BALANCING DEVICES IN CASE OF MULTIPLE ASYMMETRY OF LOADS IN DISTRIBUTIVE ELECTRIC NETWORK

The paper analyzes the criteria and algorithms for control of compensative balancing device in case of multiple asymmetry in distributive network.

Key words: *balancing devices, distributive network, asymmetric load, load.*

Introduction

Compensative balancing devices (BD), providing simultaneously compensation of reactive loads and reduction of negative sequence voltage in the nodes of consumers connection are most efficient for balancing of loads in distributive networks of utility companies. Balancing devices (BD) can rather easily be controlled.

In the process of BD control, criteria, based on moduli minimization, are used: negative sequence voltage $\dot{U}_2$ [1] or negative sequence current $\dot{I}_2$ [1, 2]. Along with this criterion, loads balancing is also realized by means of usage of moduli minimum of pulsating power $\underline{N} = 3\left(\dot{U}_1\dot{I}_2 + \dot{U}_2\dot{I}_1\right)$ [3, 4]; pulsating power of negative sequence of the load $\underline{N}_2 = 3\dot{U}_1\dot{I}_2$, conventional power of negative sequence $\underline{S_2'} = 3\dot{U}_1 \overset{*}{I}_2$, conventional conduction of negative sequence $\underline{Y}_2 = \dot{I}_2/\dot{U}_1$, difference of pulsating powers $\Delta\underline{N} = 3\left(\dot{U}_1\dot{I}_2 - \dot{U}_2\dot{I}_1\right)$ [5, 6].

In case of multiple asymmetry of loads in distributive networks of the utilities, minimum of the sum of real values square of negative voltages in all the nodes of the network and minimum losses of active power in the network, caused by negative sequence currents can be used as the criterion of loads balancing [7]. At the same time, while multiple asymmetry, the substantiation of information parameter and control algorithms of BD is missing.

The aim of the research

The aim of the given research is to substantiate the information parameter and algorithm of BD control.

Substantiation of the results

Let us consider main supply network with two asymmetric loads, connected to nodes A and B, at their minor electric distance, for instance, in case $\left|\underline{Z}_B\right| \le \left|\underline{Z}_0\right|$ (Fig. 1).

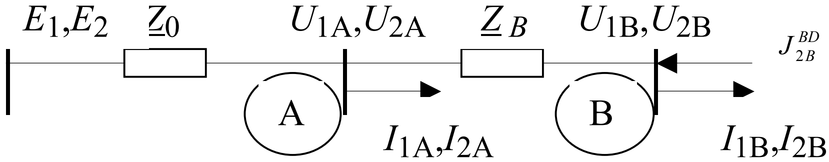


Fig. 1. Diagram of main supply network with two asymmetric loads

Vector of powers of BD phases in case of multiple asymmetry, for instance, if pulsing power $\underline{N}_2$, is formed as [8]:

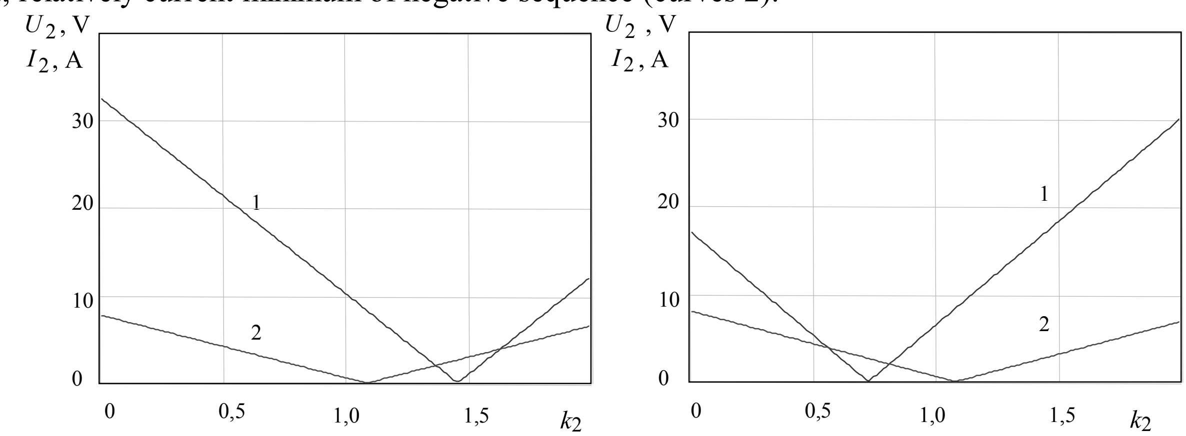
$$Q_{BC} = \frac{1}{3}\left[\left(Q_l - Q_{in}\right) + 2k_2 \operatorname{Im}\underline{N}_2\right];$$

$$Q_{CA} = \frac{1}{3}\left[\left(Q_l - Q_{in}\right) - k_2 \operatorname{Im} \underline{N}_2 - \sqrt{3} k_2 \operatorname{Re} \underline{N}_2\right]; \qquad (1)$$

$$Q_{AB} = \frac{1}{3}\left[\left(Q_l - Q_{in}\right) - k_2 \operatorname{Im} \underline{N}_2 + \sqrt{3} k_2 \operatorname{Re} \underline{N}_2\right].$$

where $Q_{input} = P_e \, tg \, \varphi_{input}$ – is the set value of input reactive power after balancing, $tg \, \varphi_{input}$ –is the set value of reactive power factor; P_e, Q_e – is active and reactive power of the load; k_2 –is the coefficient, characterizing the degree of loads balancing.

Characteristic feature of multiple asymmetry is non-coincidence of voltage minima and negative sequence current in the process of regulation (Fig. 2). As it is seen in the Figure, during regulation of k_2 using conditions (1), minimum of voltage (curves 1) at the same character of asymmetry in contiguous nodes of the networks is shifted to the right, and in reverse character – is shifted to the left, relatively current minimum of negative sequence (curves 2).



a) b)

Fig. 2. Dependences of voltage and negative sequence current on loads asymmetry:
a) at identical character of loads asymmetry;
б) at opposite character of loads asymmetry

Let us consider simplified equivalent circuit for negative sequence currents (Fig. 3).

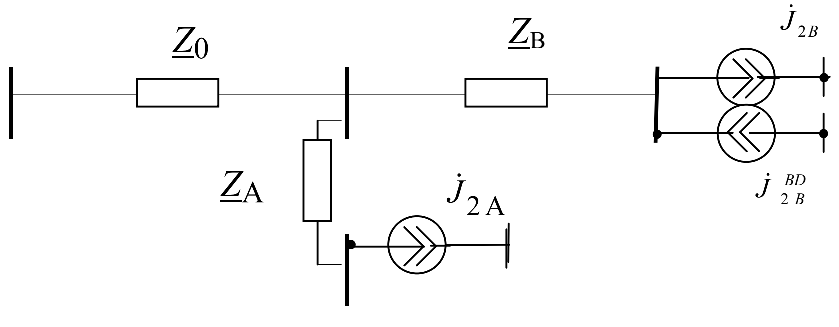


Fig. 3. Simplified equivalent circuit for negative sequence currents of the network with two sources of asymmetry

The condition of minimum voltage of negative sequence in node B, if BD is installed in this node by twofold loads asymmetry can be obtained from the expression

$$\dot{U}_{2B} = \left(\underline{Z}_0 + \underline{Z}_B\right)\left(\dot{J}_{2B} - \dot{J}_{2B}^{BD}\right) + \underline{Z}_0 \dot{J}_{2A} \rightarrow min, \qquad (2)$$

taking into account the possibility of obtaining zero value of negative sequence voltage we obtain

$$\dot{J}_{2B}^{BD} = \dot{J}_{2B} + \dot{J}_{2A} \frac{1}{1 + \underline{Z}_B / \underline{Z}_0}. \qquad (3)$$

From this expression it is seen that minimum voltage of negative sequence in the process of BD regulation will be biased relatively minimum of negative sequence current $\dot{J}_{2B}^{BD} = \dot{J}_{2B}$. The value of the bias depends on negative sequence current in contiguous node and ratio of the resistances of BD connection section and main section of the network.

The question arises: what criterion should the preference be given? The main aim of compensation BD is loads balancing.

Simultaneously, according to GOST 13109-97 (State Standard) requirements, main parameter being regulated in electric networks, is asymmetry factor by negative sequence of the voltage. For comparison of criteria, we make use of the criterion of minimum losses of active power, stipulated by the currents of negative sequence.

The condition of minimum losses of active power, stipulated by the currents of negative sequence, if BD are installed in node B by twofold asymmetry of loads, can be obtained from the expression

$$\Delta P_2 = R_0 \left| \dot{J}_{2A} + \dot{J}_{2B} - \dot{J}_{2B}^{BD} \right|^2 + R_B \left| \dot{J}_{2B} - \dot{J}_{2B}^{BD} \right|^2 \to min, \quad (4)$$

where

$$\dot{J}_{2B}^{BD} = \dot{J}_{2B} + \dot{J}_{2A} \frac{1}{1 + R_B / R_0}. \quad (5)$$

From the comparison of the obtained conditions (3) and (5) it follows, that for uniform networks, the ratio of reactive and active resistances of transmission lines and transformers is the same, the bias of optimal solutions, obtained by the criteria of minimum voltage of negative sequence in node B and minimum losses of power will be missing.

We will investigated the influence of loads asymmetry of various character in contiguous nodes on residual asymmetry of voltage in case of load balancing in one of the nodes. Fig 4 shows the dependences of negative sequence voltages in contiguous nodes at identical phase, shift of negative sequence currents in both nodes (Fig 4a) and at phase shift 2π/3 (Fig. 4b).

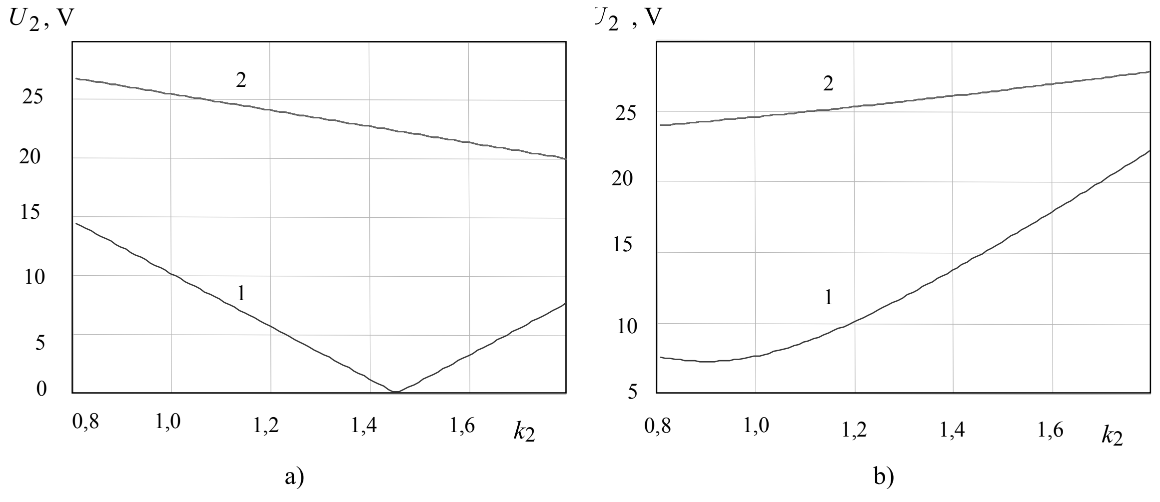


Fig. 4.Dependences of negative sequence voltages in contiguous nodes:
a) at identical character of loads asymmetry;
b) at different character of loads asymmetry

It follows from Fig. 4b, that at any character of loads asymmetry, residual values of negative sequence voltage in the node of BD location at the moment of condition (1) realization will be comparatively small.

On the basis of this conclusion we suggest: at identical character of loads asymmetry increase k_2 coefficient to k_2=1,2 value, at different character of asymmetry - accept k_2=1, and at opposite character of asymmetry – reduce the value to k_2=0,8.

The choice of information parameter regulation value k_2 it is expedient to realize by negative sequence voltage in the node of BD regulation at k_2=1. From (2) it follows, that at the moment of current $\dot{J}_{2B}$, compensation the voltage of negative sequence in the node B is determined by the current of negative sequence in the node A :

$$\dot{U}_{2B} = \underline{Z}_0 \dot{J}_{2A} . \quad (6)$$

To evaluate the expediency of k_2 increasing or decreasing it is recommended to use the increment of negative sequence voltage. If at the increase of k_2 negative sequence voltage decrease (identical asymmetry of loads in contiguous nodes) then k_2 is to be increased, if negative sequence voltage increase (opposite asymmetry of loads in contiguous nodes), then k_2 should be decreased, and if negative sequence voltage is unchanged (different asymmetry of loads in contiguous nodes), - k_2 should remaine unchanged (k_2=1).

Conclusions

It is shown that at multiple asymmetry of loads it is expedient to carry out the control of compensation BD by currents, powers or conductivities of negative sequence of one of the loads, adjusting the degree of loads balancing depending on mutual character of asymmetry in contiguous nodes of network. For evaluation of the expediency of increasing or decreasing k_2 it is recommended to use the increment of negative sequence voltage in BD regulation node.

REFERENCES

1. Аввакумов В. Г. Технико-экономическая оценка качества электроэнергии в промышленности / В. Г. Аввакумов, Г. Л. Багиев, Д. М. Воскобойников. – Л.: Изд-во ЛГУ, 1977. – 132 с.

2. Аввакумов В. Г. Методы нескалярной оптимизации и их приложения / В. Г. Аввакумов. – К.: Вища школа, 1990. – 188 с.

3. Шидловский А. К. Повышение качества энергии в электрических сетях / А. К. Шидловский, В. Г. Кузнецов. – К.: Наукова думка, 1985. – 268 с.

4. Кузнецов В. Г. Снижение несимметрии и несинусоидальности напряжений в электрических сетях / В. Г. Кузнецов, А. С. Григорьев, В. Б. Данилюк. – К.: Наукова думка, 1992. – 240 с.

5. Бурбело М. Й. Квазізрівноважені частотно-варіаційні вимірювальні системи / М. Й. Бурбело: Монографія. – Вінниця: УНІВЕРСУМ-Вінниця, 2004. – 225 с.

6. Бурбело М. Й. Квазізрівноважена вимірювальна система для компенсаційних установок симетрування трифазних навантажень / М. Й. Бурбело, О. В. Бабенко // Энергетика и электрификация. – 2003. – № 9 – 10. – С. 52 – 54.

7. Бурбело М. Й. Аналіз цільових функцій симетрування навантажень за багатократної несиметрії / М. Й. Бурбело, М. В. Кузьменко // Вісник Вінницького політехнічного інституту. – 2010. – № 6. – С. 43 – 47.

8. Бурбело М. Й. Симетрування навантажень вузлів електричних мереж з використанням двофазних симетрувальних установок / М. Й. Бурбело, М. В. Кузьменко, О. О. Бірюков, О. М. Кінзерська // Вісник Вінницького політехнічного інституту. – 2008. – № 5 . – С. 35 – 38.

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