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P.D. Lezhnyuk, Dr. Sc. (Eng.), Prof.; O. B. Burykin, Ph.D., V.O. Lesko

POWER LOSSES SENSITIVITY TO ELECTRICAL POWER SYSTEMS TRANSITS CHANGES

The paper presents the method of an estimation of electrical power system (EPS) mode parameters sensitivity to changes in the nodes load. Possibility of sensitivity to changes in the nodes load of other systems estimation allows to estimate sensitivity of losses in transit overflows in separate EPS elements. The method is based on using the calculation and estimation algorithms as well as calculative programs of electric networks with transformer communications interference.

Keywords: *electrical power system, power transit, the sensitivity analysis, power losses distribution.*

Introduction

Assuming that the electrical power system (EPS) is opened for all energy market participants, there appears a research problem of transit power flows (TPF) contribution to the electrical power additional losses and their reduction in networks EPS. Nowadays there are many transits power loss (TPL) definition methods [1-4]. They are intended to determine losses of the electric power for the certain period of time. In view of various reasons the value of transit overflows within this time can essentially change considering the ways of transit flow and a place of an adjunction with other systems (fig. 1) that influences accuracy of determination TPL. The absence of methods of operative calculation TPL does not allow to correct in due time the parameters of the regulating devices intended to optimization of transit overflows.

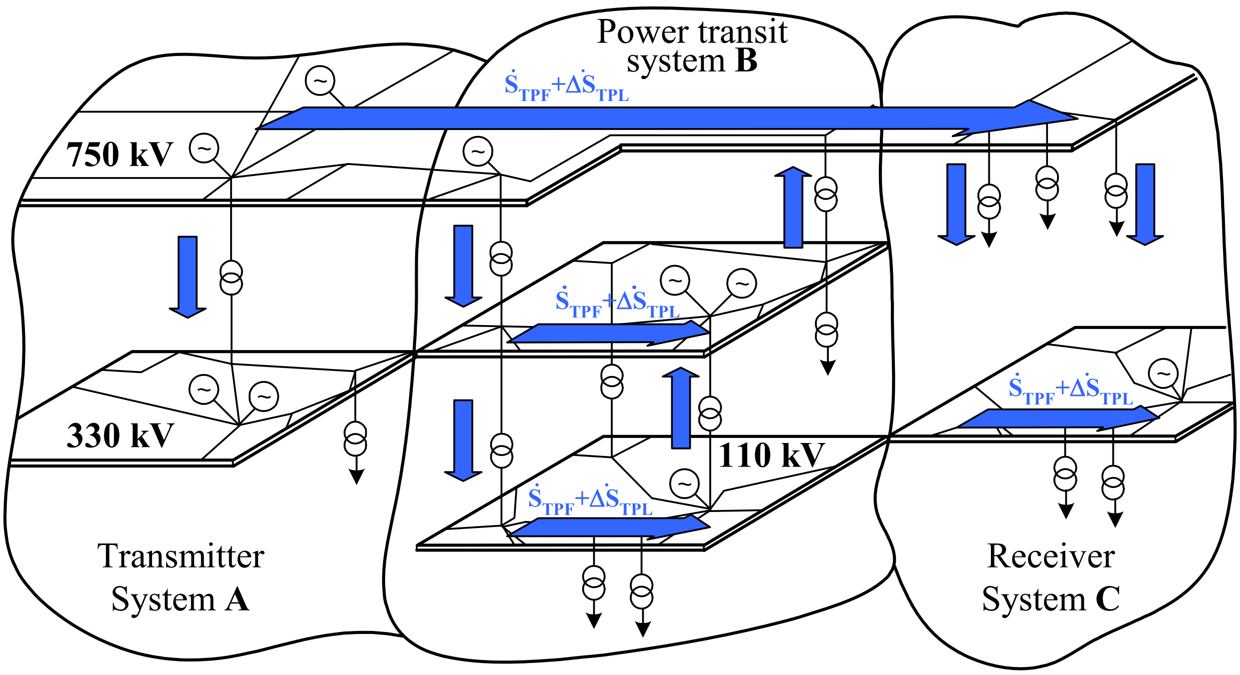

Fig. 1. An example of possible ways of electric power transit flow

Corresponding methods are necessary for operative monitoring TPL and optimum control of transit overflows. One of the tasks of these methods is to determine the elements EPS which are the most sensitive to transit overflows and in which TPL changes most of all during the disturbance, both external, and internal. The account of sensitivity of optimum decisions to the change of value of transit overflows will allow to carry out actions for reduction of losses of active power by more effective and economically expedient ways, having revealed the most sensitive elements in EPS.

Besides, the change of parameters of these elements will enable a great reduction of the heterogeneity of the system, thus, approaching it to a homogeneous condition reducing the additional losses of power.

The given paper develops a method of an estimation of sensitivity of parameters of mode EPS to a change of loading in nodes of scheme EPS, including nodes of an adjunction with other systems (the latter allows to estimate sensitivity TPL in separate elements EPS). The method is based on the usage of algorithms and programs of calculation and on the estimation of interference of electric networks EPS with transformer communications [6].

Definition of matrix of power losses sensitivity coefficients

In [6] is shown, that power losses in branches of schema EPS taking into account transformation factors are implicitly defined in such a way:

$$\Delta\dot{\mathbf{S}}_{nod} = \dot{\mathbf{T}}\dot{\mathbf{S}}, \tag{1}$$

where – $\dot{\mathbf{T}}$ a matrix of factors of distribution of losses of power in branches of electric networks depending on capacities in nodes taking into account factors of transformation of transformers of communication; $\dot{\mathbf{S}}_{nod}$ – a vector of loadings in scheme nodes.

Accordingly (1) power losses in the i-th branch of EPS are calculated by the formula:

$$\Delta\dot{S}_{nodi} = \dot{\mathbf{T}}_i\dot{\mathbf{S}},$$

where

$$\dot{\mathbf{T}}_i = (\dot{\mathbf{U}}_t\mathbf{M}_{\Sigma i})\widehat{\mathbf{C}}_i\dot{\mathbf{U}}_d^{-1}, \tag{2}$$

Line of a matrix $\dot{\mathbf{T}}$ which answers the i-th branch; $\dot{\mathbf{U}}_t$ – the transposed vector of pressure in nodes; $\mathbf{M}_{\Sigma i}$ – the i-th line of a matrix of connections of branches in nodes including and balancing; – $\widehat{\mathbf{C}}_i$ the i-th a vector-line of a matrix of distribution of currents in nodes on scheme branches; $\dot{\mathbf{U}}_d$ – a diagonal matrix of voltage in nodes including and balancing.

Let's assume, that the factors of distribution of losses of power in $\dot{\mathbf{T}}$ branches do not depend on power of transit overflows and are constant. Then, during a change of loading in nodes, power losses in the i-th the branches which values are calculated according to the expression will change:

$$\delta\Delta\dot{S}_{nodi} = \dot{\mathbf{T}}_i\ \delta\dot{\mathbf{S}}, \tag{3}$$

where – $\delta\dot{\mathbf{S}} = \dot{\mathbf{S}}^k - \dot{\mathbf{S}}^{k+1}$ - a change of power of loading of nodes EPS during transition from the k -th to the k + 1-st mode.

If a change of power of loading occurs only in the j -th knot than the increase of losses of power in the i-th branches from change of power of loading of the j- th knot will be defined as:

$$\delta\Delta\dot{S}_{ij} = \dot{t}_{ij}\ \delta\dot{S}_j. \tag{4}$$

From the expression (4) follows, that

$$\dot{t}_{ij} = \frac{\delta\Delta\dot{S}_{ij}}{\delta\dot{S}_j}. \tag{5}$$

The factor meets the requirements, $\dot{t}_{ij}$ resulted in [7], and is factor of sensitivity of losses of power in i-th branch to change of power of loading of j- th knot. Thus, the matrix establishes $\dot{\mathbf{T}}$ connection between the increases power losses in branches EPS and changes of power of loading in nodes and is the sensitivity matrix which each factor consists of kind elements $\dot{t}_{ij}$.

In practice in EPS there are problems when only active or jet capacities change in nodes. If in a transit overflow the active power changes ($\delta Q_j = 0, \quad \delta P_j \neq 0$), it follows from (5), that

$$\dot{t}_{ij} = \frac{\delta \Delta P_{ij}}{\delta P_j} + j\frac{\delta \Delta Q_{ij}}{\delta P_j}. \tag{6}$$

In the other case, during compensation of a jet overflow in the knot, there changes the jet power (the source of jet power switches on or off, $\delta Q_j \neq 0, \quad \delta P_j = 0$), then according to expression (5) we will receive, that

$$\dot{t}_{ij} = \frac{\delta \Delta Q_{ij}}{\delta Q_j} - j\frac{\delta \Delta P_{ij}}{\delta Q_j}. \tag{7}$$

As the criterion of an optimality of normal mode of EPS in the given work are losses of active power, the first component of expression (6) and the second component of expression (7) are of special interest. According to the specified factors the matrixes of sensitivity $\mathbf{T}_{iP}$ and $\mathbf{T}_{iQ}$ losses of active power in branches to the changes of active and jet capacities of loading in nodes accordingly are formed. Then losses of active power in the i-th branches during the changes of power of loading in nodes are defined by the expression:

$$\delta \Delta P_{iP} = \mathbf{T}_{iP}\, \delta \mathbf{P}, \quad \delta \Delta P_{iQ} = \mathbf{T}_{iQ}\, \delta \mathbf{Q}, \tag{8}$$

where $\delta \mathbf{P}$ and $\delta \mathbf{Q}$ - change of active and jet capacities of loading in nodes EPS, accordingly.

Coefficients of branches power losses sensitivity to the voltage in nodes

As is seen from (2), the values of factors of a matrix of sensitivity generally $\dot{\mathbf{T}}$ depend on voltage in nodes $\dot{\mathbf{U}}_t$ which, in turn, also depend on capacities of loading and generation in nodes. In this case during the change of power in nodes, the losses in the i-th branch will change and, unlike (3), will be equal to:

$$\delta \Delta \dot{S}_i = \dot{\mathbf{T}}_i^k \dot{\mathbf{S}}^k - \dot{\mathbf{T}}_i^{k+1} \dot{\mathbf{S}}^{k+1}.$$

Taking into account that, $\dot{\mathbf{S}}^{k+1} = \dot{\mathbf{S}}^k - \delta \dot{\mathbf{S}}$ and, $\delta \dot{\mathbf{T}}_i = \dot{\mathbf{T}}_i^k - \dot{\mathbf{T}}_i^{k+1}$ the last expression will be:

$$\delta \Delta \dot{\mathrm{S}}_{\mathrm{i}} = (\delta \dot{\mathbf{T}}_i + \dot{\mathbf{T}}_i^{k+1}) \cdot \dot{\mathbf{S}}^{\mathrm{k}} - \dot{\mathbf{T}}_i^{k+1} \cdot (\dot{\mathbf{S}}^{\mathrm{k}} - \delta \dot{\mathbf{S}}) =$$

$$= \delta \dot{\mathbf{T}}_i \cdot \dot{\mathbf{S}}^{\mathrm{k}} + \dot{\mathbf{T}}_i^{k+1} \cdot \dot{\mathbf{S}}^{\mathrm{k}} - \dot{\mathbf{T}}_i^{k+1} \cdot \dot{\mathbf{S}}^{\mathrm{k}} + \dot{\mathbf{T}}_i^{k+1} \cdot \delta \dot{\mathbf{S}},$$

or

$$\delta \Delta \dot{S}_i = \delta \dot{\mathbf{T}}_i \dot{\mathbf{S}}^k + \dot{\mathbf{T}}_i^{k+1} \delta \dot{\mathbf{S}}. \tag{9}$$

If changes occurred only in one knot – the j –th one, according to (9), the increase in losses of power in the i-th branches from change of power in the j- th knot $\delta \Delta \dot{S}_j$ is defined as follows:

$$\delta \Delta \dot{S}_{ij} = \delta \dot{t}_{ij} \dot{S}_j^k + \dot{t}_{ij}^{k+1} \delta \dot{S}_j. \tag{10}$$

From last expression the factor of sensitivity of losses of power in the i-th branches to change of power in the j- th knot during the transition from the k- th to the k + 1 st mode taking into account the change of voltage in nodes, is determined as:

$$\dot{t}_{ij}^{k+1} = \frac{\delta \Delta \dot{S}_{ij}}{\delta \dot{S}_j} - \frac{\delta \dot{t}_{ij}}{\delta \dot{S}_j} \dot{S}_j^k. \tag{11}$$

Comparing (5) and (11) we see that in the general case the sensitivity of losses of power in the i-th branches to the change of power of the j -th knot is caused also by factor of sensitivity $\frac{\delta \dot{t}_{ij}}{\delta \dot{S}_j}$ and values of capacities of loadings of nodes in initial mode $\dot{S}_j^k$.

The expression for definition of factors of sensitivity $\delta \dot{t}_{ij}$ is determined as the difference of factors of a matrix $\dot{\mathbf{T}}$ for the k- th and the k+1 -th mode, each of which is determined from (2):

$$\delta \dot{\mathbf{T}}_i = \dot{\mathbf{T}}_i^k - \dot{\mathbf{T}}_i^{k+1} = (\dot{\mathbf{U}}_t^k \mathbf{M}_{\Sigma i})\widehat{\mathbf{C}}_i (\dot{\mathbf{U}}_d^{-1})^k - (\dot{\mathbf{U}}_t^{k+1} \mathbf{M}_{\Sigma i})\widehat{\mathbf{C}}_i (\dot{\mathbf{U}}_d^{-1})^{k+1} =$$

$$= \widehat{\mathbf{C}}_i (\delta \dot{\mathbf{U}}_{id}^k - \delta \dot{\mathbf{U}}_{id}^{k+1}),$$

where – $\delta \dot{\mathbf{U}}_{id}$ the diagonal matrix, which element of each is defined from the relation

$$\frac{\Delta \dot{U}_i}{\dot{U}_j}, \quad j = \overline{1, m},$$

where – $\Delta \dot{U}_i = \dot{\mathbf{U}}_t \mathbf{M}_{\Sigma i}$ voltage drop in the i-th scheme branches.

Value of factors of a matrix $\dot{\mathbf{T}}$ allows to determine which branches response to the voltage change in nodes which, in turn, also depends on capacities of loading and generating in nodes.

The algorithm of determination of coefficients of sensitiveness power losses

Structurally-logical scheme of power losses sensitivity coefficients determination, from disturbance caused the load changes in the nodes of EPS, and transit power flows shown on a fig. 2.

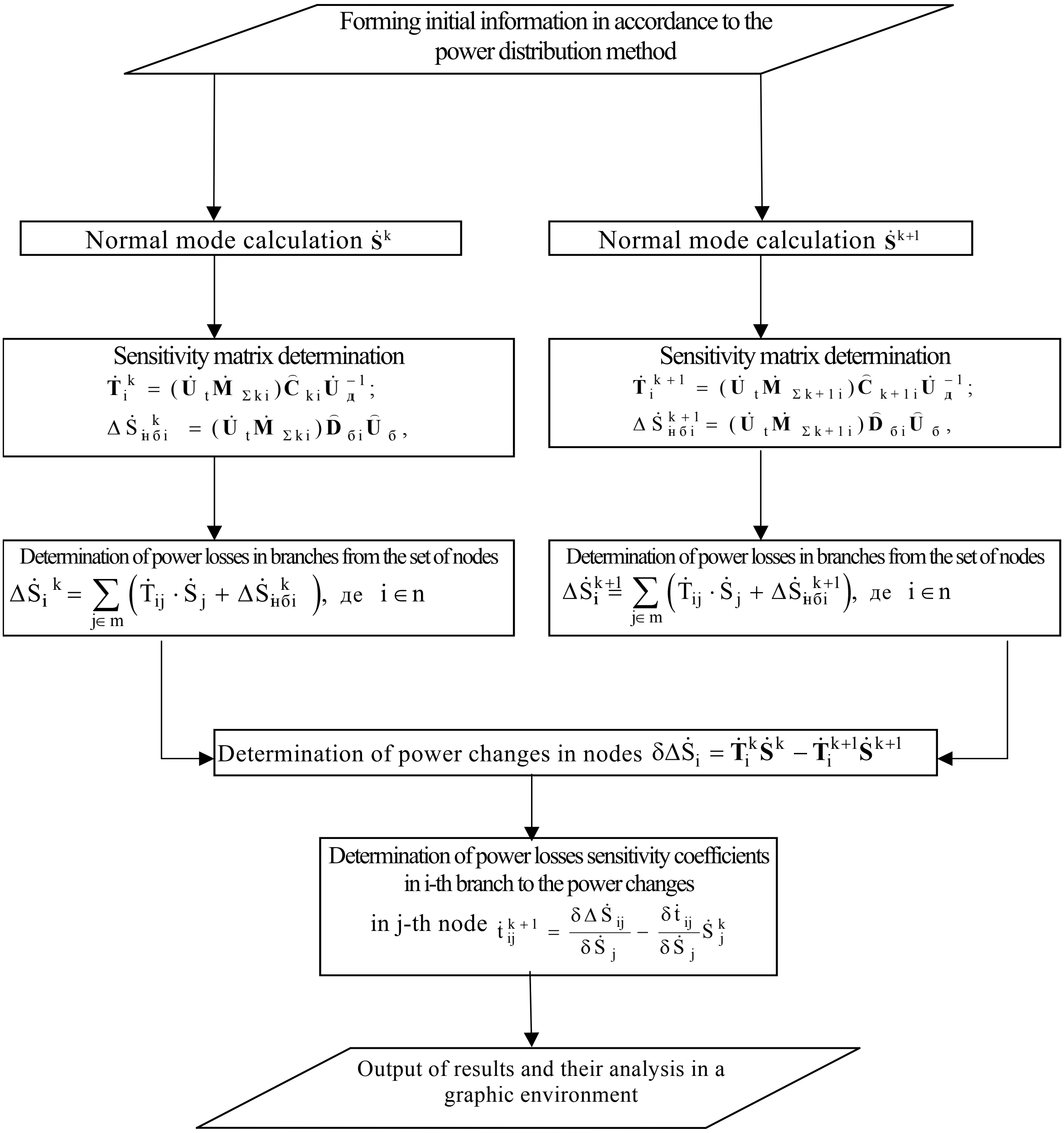

Fig. 2. The algorithm of determination of coefficients of sensitiveness power losses

Conclusions

1. For an operative monitoring of losses from transit overflows and their optimization is possible to use the factors of sensitivity of power losses to disturbance in system, in particular to a change of loading or generating in nodes. The matrix of factors of sensitivity is formed by means of results of calculation of the typically established mode and is, if necessary, specified by the account of change of voltage in nodes of scheme EPS.

2. The developed method of an estimation of sensitivity of parameters of mode EPS to a change of loading in scheme nodes, allows to estimate sensitivity of losses of power in its separate elements during external and internal indignations, such as a change of loading or generating of separate nodes of the scheme. Application of a method concerning nodes of an adjunction with other systems allows to estimate the sensitivity of losses in separate elements EPS to transit overflows.

REFERENCES

1. Таласов А.Г. Потери на транзит электроэнергии и их распределение между участниками энергообмена // Электрические станции. – 2002. – №1. – С. 20–25.

2. Стогний Б., Павловский В. Определение транзитных потерь мощности в фрагментированных электрических сетях областных энергоснабжающих компаний // Энергетическая политика Украины. – 2004. – №5. – С. 26–31.

3. Потребич А.А. Определение норматива потерь электроэнергии облэнерго с учётом ёё транзитных перетоков // Энергетика и электрификация. – 2000. – №10. – С. 20–23.

4. Лежнюк П.Д., Кулик В.В., Бурикін О.Б. Втрати потужності в електроенергетичних системах від транзитних перетікань // Енергетика та електрифікація. – 2006. – №3. – С. 26–33.

5. J. Conejo, J. M. Arroyo, N. Alguacil, and A.L. Guijarro, "Transmission loss allocation: a comparison of different practical algorithms," Power Systems, IEEE Trans. Power Syst., vol. 17, pp. 571–576, Aug. 2002.

6. Лежнюк П.Д., Кулик В.В., Бурикін О.Б. Оцінка взаємовпливу електричних мереж енергосистем з трансформаторними зв'язками // Технічна електродинаміка. Тематичний випуск: проблеми сучасної електротехніки. ч. 7. – 2006. – С. 27–30.

7. Розенвассер Е.Н., Юсупов Р.М. Чувствительность систем управления. – М.: Наука, 1981. – 464 с.

Lezhnyuk Petro Demjanoyich – Head of the Department of Electric Power Stations and Systems;

Burykin Olexandr Borysovych – a PhD (Eng), the senior lecturer with the Department of Electric Power Stations and Systems;

Lesko Vladyslav Oleksandrovych – the assistant with the chair of Electric Power Stations and Systems.

Vinnytsia National Technical University