

Electroenergy systems interference analysis

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Abstract – In this paper, a new method to allocate transmission losses for the distributive open circuit electric network is proposed. The methodology uses a method of superposition. Calculations are executed for a normal mode linear model, that fully equivalent to the initial nonlinear model for this moment of time and require a power flow solution.

I. INTRODUCTION

In the present tense the electric power losses account, planning and minimizing problems in the electric networks (EN) of the electroenergy systems (EPS) are actual. Especially if EPS is interconnected or incorporated and have different proprietors. Such target setting foresees financial (commercial) mutual settlements between the proprietors of EPS for the electric power transmission and mutual power flows between grids. That is why, research from effective analysis, prognostication and planning methods of EPS interference causes large interest at power supply companies.

Now the series of methods which allow to allocate transmission losses is used in engineering practice of different countries, both with the simply set information and with the probabilistic-statistical evaluation of losses (regressive analysis) [1-3]. They are universally recognized and physically justified. Miscalculation by general losses determination on every branch of network for the indicated methods, as a rule, is possible. However, the unique method of transmission losses distribution between the energy market participants now days does not exist.

Three families of transmission losses distribution procedures have been reported in technical literature:

1) Pro Rata Procedures that are based on assumption that losses allocated to generator/consumer are proportional to its corresponding level of energy generation/consumption. These methods, as a rule does not take into account the features of power flow and electric network structure [2];

2) Marginal Procedures that are based on, so-called incremental transmission loss (ITL) coefficients [2, 4].

3) Proportional Sharing Procedures, which are based on power flow solution and linearized transmission losses distribution from every participant of energy market [2,5,6].

In a number of works authors mark about impossibility of direct power losses distribution certain

after expression $3|I|^2 R$ between the constituents of current, that causes losses. Thus, there is not a physically meaningful measurement scheme or a theoretically based evaluation methodology to determine the losses caused by each particular transaction [4-7].

However, for the distributive open circuit EN is possible to use power losses calculation and distribution method on the basis of method of superposition with the partial currents usage. This method foresees the leadthrough of $n+1$ power flow solutions (for the amounts of energy market participants). These calculations can be executed fully automatically [1], that is fully accessible now days because of modern automation level of the electric power commercial account systems, vehicle and telemetry providing.

Unlike many other methods in this method assumption about power line (PL) voltage drop absence is not used [8]. The justified transition to the normal mode linear model of EN allows dismissing this assumption.

The developed method to allocate transmission losses for the distributive open circuit electric network is given in the next section. The results of developed method application on the electric network simplest scheme basis are presented in Section III. In Section IV the algorithm of the developed method usage is presented. In a final section conclusions and outlined scopes of method application are presented.

II. TRANSMISSION LOSSES ALLOCATION BY METHOD OF SUPERPOSITION

Considering the operation mode of EN in the arbitrary moment of time, at the known loads \dot{S}_i and voltages in buses \dot{U}_i it is possible to define load currents in buses of EN:

$$\dot{J}_i = \frac{\dot{S}_{Ci}}{\sqrt{3}\dot{U}_i}$$

with \dot{S}_{Ci} is calculating load (generation) power, which takes into account own load (generation) power \dot{S}_i , and also connected to bus i lines charge power.

Normal mode linear model, which obtained due to the presentation of EN buses loads and generations as the expected load currents, will be fully equivalent to the initial nonlinear model for this moment of time (Fig. 1).

We will consider the simplest electric circuit of electric network, which executes transit of power (Fig.1). EN busloads are set permanent to the module

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and phase by a current. Transversal constituent of equivalent circuit takes into account in the busloads calculations.

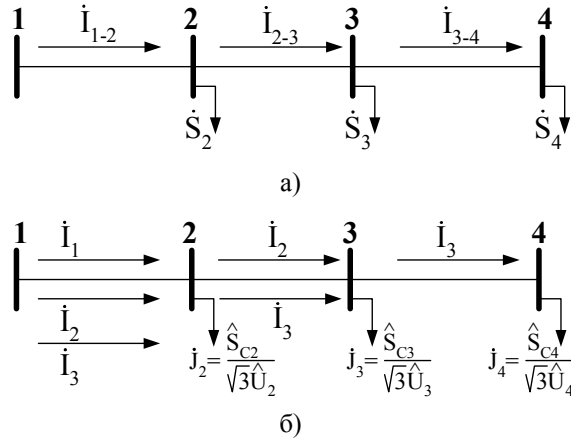


Fig.1. Circuit of the simplest case of power transit

According to the method of superposition through a line 1-2 will flow unidirectional partial currents that predefined by loads of energy market separate consumers. For this case partial currents equal to the proper load currents $\dot{I}_1 = \dot{J}_2$, $\dot{I}_2 = \dot{J}_3$, $\dot{I}_3 = \dot{J}_4$. Thus the power losses in this PL are equal:

$$\Delta \dot{S} = 3 \cdot |\dot{I}_{1-2}|^2 \cdot \dot{Z}_{1-2} = 3 \cdot |\dot{I}_1 + \dot{I}_2 + \dot{I}_3|^2 \cdot \dot{Z}_{1-2};$$

For the real plane the equation will assume as:

$$\Delta \dot{S}_\Sigma = 3 \cdot \left[(I'_1 + I'_2 + I'_3)^2 + (I''_1 + I''_2 + I''_3)^2 \right] \cdot \dot{Z}_{1-2};$$

with I', I'' are real and imaginary constituents of partial currents.

After some algebraic transformations this expression can be taken to the equation (1). Value of power losses in a line 1-2 depend on all partial currents which are obtain by the calculation of the partial modes:

$$\begin{aligned} \Delta \dot{S}_\Sigma = 3 \cdot & \left[I_1'^2 \left(1 + \frac{I_2' + I_3'}{I_1'} \right) + I_2'^2 \left(1 + \frac{I_1' + I_3'}{I_2'} \right) + \right. \\ & I_3'^2 \left(1 + \frac{I_2' + I_1'}{I_3'} \right) + I_1''^2 \left(1 + \frac{I_2'' + I_3''}{I_1''} \right) + \\ & \left. I_2''^2 \left(1 + \frac{I_1'' + I_3''}{I_2''} \right) + I_3''^2 \left(1 + \frac{I_2'' + I_1''}{I_3''} \right) \right] \cdot \dot{Z}_{1-2} \end{aligned} \quad (1)$$

or from every partial current separately:

$$\begin{aligned} \Delta \dot{S}_{(11)} &= 3 \left[I_1'^2 \left(1 + \frac{I_2' + I_3'}{I_1'} \right) + I_1''^2 \left(1 + \frac{I_2'' + I_3''}{I_1''} \right) \right] \dot{Z}_{1-2}; \\ \Delta \dot{S}_{(12)} &= 3 \left[I_2'^2 \left(1 + \frac{I_1' + I_3'}{I_2'} \right) + I_2''^2 \left(1 + \frac{I_1'' + I_3''}{I_2''} \right) \right] \dot{Z}_{1-2}; \\ \Delta \dot{S}_{(13)} &= 3 \left[I_3'^2 \left(1 + \frac{I_2' + I_1'}{I_3'} \right) + I_3''^2 \left(1 + \frac{I_2'' + I_1''}{I_3''} \right) \right] \dot{Z}_{1-2}. \end{aligned} \quad (2)$$

Naturally, that the last expressions can be generalized on the arbitrary amount of partial currents which flow in the elements of EN. Expression of power losses in the branch k of network from the currents of the mode i (i -th energy market participant

loads) will assume as follows:

$$\Delta \dot{S}_k(I_i) = 3 \left[I_i'^2 \left(1 + \sum_{j=1}^n \frac{I_j'}{I_i'} \right) + I_i''^2 \left(1 + \sum_{j=1}^n \frac{I_j''}{I_i''} \right) \right] \dot{Z}_k \quad (3)$$

where k is the number of network branch; n is amount of partial currents which flow on this branch; i, j is number of partial current.

From (3) evidently, that power losses in longitudinal part PL from partial current I_i depends not only on the value of his own constituents but also from the values of other partial currents that flow by this line. The size of this influencing can be described by the coefficients of interference:

$$\mu_k'(I_i) = \sum_{j=1}^n \frac{I_j'}{I_i'}; \quad \mu_k''(I_i) = \sum_{j=1}^n \frac{I_j''}{I_i''}. \quad (4)$$

The indicated coefficients can take on arbitrary values depending on a size and direction of partial currents that flow in k -th PL. The zero values indicate absence in this branch of partial currents except for I_i .

Taking into account expression (4) for power losses determination in the k -th branch of EN from a i -th current can be rewritten as follows:

$$\Delta \dot{S}_k(I_i) = 3 \left[I_i'^2 (1 + \mu_k'(I_i)) + I_i''^2 (1 + \mu_k''(I_i)) \right] \dot{Z}_k \quad (5)$$

Losses in electroenergy system j from loads of electroenergy system i concerne, as sum of losses on every branch of j -th EN from the currents of the partial mode i (load currents of i -th EN)

$$\Delta \dot{S}_j(\dot{I}_i)_\Sigma = \sum_{k \in M_j} \Delta \dot{S}_k(\dot{I}_i) \quad (6)$$

with M_j – subset of branches of the electroenergy system j .

The power losses distribution, according to the last expression, can be used for determination and distribution of power losses in distributive open circuit electric network of different energy supply companies.

The total losses in the incorporated electroenergy system concerns on a formula:

$$\Delta \dot{S} = \sum_{i=1}^n \sum_{j=1}^n \Delta \dot{S}_j(\dot{I}_i)_\Sigma \quad (7)$$

III. NUMERICAL RESULTS

As an example we will consider, already mentioned, electric network on Fig.1. It should be noted that this most simple network is used for illustration of the developed method and his analytical verification.

Assume, that network which is analyses includes at itself the networks of three power companies – “A”, “B”, “C”. The network “A” includes at itself buses 1, 2 and line 1-2. The networks “B” includes at itself bus 3 and line 2-3. The networks “C” includes at itself bus 4 and line 3-4. Denote consumer loads of each company, as indicated on Fig. 2, and specify them by the load currents. It admits, that: $\dot{J}_2 = 0,131 - j0,043$ kA; $\dot{J}_3 = 0,158 - j0,052$ kA; $\dot{J}_4 = 0,106 - j0,032$ kA. Specify the parameters of PL:

$$\dot{Z}_{1-2} = 0,27 + j0,391 \text{ Ohm}; \quad \dot{Z}_{2-3} = 0,54 + j0,782 \text{ Ohm};$$

$$\dot{Z}_{3-4} = 0,81 + j1,173 \text{ Ohm}.$$

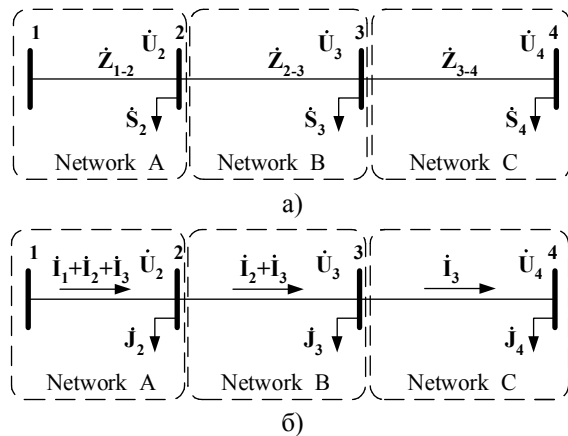


Fig.2. The networks "A", "B", "C"

After partial currents calculation and networks power losses definition we summarized numerical results in Table 1.

The electric networks power flow calculations are obtained by the power flow program "GrafScanner", that developed by Main Information-computer Center of the National power company UkrEnergo ("UkrEnergo NPC"). Used load currents values corresponding with their set in powers:

$$\dot{S}_2 = 25 + j8.22 \text{ (MWA)}; \quad \dot{S}_3 = 30 + j9.86 \text{ (MWA)};$$

$$\dot{S}_4 = 20 + j6 \text{ (MWA)}.$$

I TABLE
RESULTS OF CALCULATION

Loses, MWA	Network A	Network B	Network C
Normal mode losses by power flows program	0,14+0,202j	0,124+0,179j	0,03+0,043j
Losses caused in networks from network A loads	0,047+0,067j	0	0
Losses caused in networks from network B loads	0,056+0,081j	0,074+0,108j	0
Losses caused in networks from network C loads	0,037+0,054j	0,050+0,072j	0,030+0,043j
Total losses on electric networks	0,14+0,202j	0,124+0,18j	0,030+0,043j

IV. ALGORITHM OF POWER LOSSES DETERMINATION FROM ELECTRIC NETWORKS INTERFERENCE

In modern practice of operative calculations normal modes EPS power flows calculation is executed from the busloads of EPS denoted by equivalent power of consumption. Taking into account this fact and above premises the following developed method usage algorithm is proposed at presence of a few (n) subjects of energy market:

1. Normal modes power flow calculation and power losses definition with actual values of power loads of all n of power companies;

2. Load currents determination for all buses of electric network;

3. Delete the transversal constituent from passive part of electric network equivalent circuit (because

they are taken into account in the load currents of buses);

4. Calculation of n partial modes (for the amounts of power companies); for the i -th mode the load currents of company i and zeroing values of other companies busloads are set to the calculation;

5. Partial currents and losses determination in the branches of EPS using expression (5);

6. Determination of actual power losses for every power company after formulas (6, 7) from the own loads and loads of other energy market participants;

The resulted algorithm allows, on the basis of the developed method, to determine the power losses from interference of electric networks of one class of tension. Results obtained on the basis of the developed method and algorithm allows executing the high-quality estimation of losses optimization in distributive open circuit electric network.

V. CONCLUSIONS

1. It is presented and illustrated method that is based on physically justified power losses calculation from every load flow of distributive open circuit electric network.

2. A method is based on the electrical engineering basic concepts and universally recognized methods of normal mode calculation that provides the high measure of adequacy.

3. The algorithm of the offered method is developed. It allows executing the power losses calculation in distributive open circuit electric network and their distribution between the energy market participants.

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