ABOUT THE SOFTWARE OF ELECTRIC NETWORKS MODES CALCULATION PROBLEMS

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Calculation of the established modes of electric networks takes the basic place in practice of work of operatively-dispatching services of power supply systems at all territorial and time levels of management and planning. At the Azerbaijan Scientific – Research and Designed-Prospecting Institute of Energetic (ASRDPIE) the software is developed for calculation, the analysis and optimization of modes and losses of capacity and energy in electric networks of power supply systems. In the given report the basic characteristics of methods applied in the developed software-computing complexes (SCC) for calculation the established modes of electric networks (CEMEN) are resulted.

In 1972 the computer centre «Azenergo» has started to function, and in 1977 the operatively-information complex of the Automated system of dispatching management where according to technological process of manufacture and electric power distribution electric equipment conditions, capacity streams on network elements were reflected, levels of voltage in nodes etc. In «Azerenerji» has been installed now the modern Automated system of the dispatching management which functions consist in gathering, to transfer and processing of the information on technological process to the operating centre and transfer of operating influences to the process equipment is created.

It is necessary to notice, that the number of knots and branches of the big power supply systems reach some thousand owing to what for calculation of the established modes of electric systems it is necessary to solve nonlinear system of the algebraic equations of a corresponding order numerical methods.

The most widespread form of record of the equations of the established mode is the equations of balance of currents in nodes in rectangular coordinates [1]

$$\Delta I_i = \frac{\overset{*}{S}_i}{\overset{*}{U}_i} + \dot{U}_i \cdot \sum_{\substack{i=1 \\ j\neq i}}^{k} \dot{Y}_{ij} - \sum_{\substack{i=1 \\ j\neq i}}^{k} \dot{U}_j \cdot \dot{Y}_{ij} = 0, \qquad i = 1,\ldots,n \tag{1}$$

where i is nodal number, U_i is nodal voltage, S_i is nodal capacity, Y_{ij} is mutual conductivity of a branch connecting nodes i and j.

The equations of established voltage (EEV) in the form of nodal capacities balance in polar coordinates look like:

$$\Delta P_i = g_{ii}U_i^2 - U_i \sum_{\substack{j=1 \\ j\neq i}}^{n} U_i \left(g_{ij}\cos\delta_{ij} + b_{ij}\sin\delta_{ij} \right) + P_i, \tag{2}$$

$$\Delta Q_i = -b_{ii}U_i^2 - U_i \sum_{\substack{j=1 \\ j\neq i}}^{n} U_j \left(g_{ij}\sin\delta_{ij} - b_{ij}\cos\delta_{ij} \right) + Q_i, \tag{3}$$

where P_i and Q_i are the nodal active and reactive powers; ΔP_i and ΔQ_i are active and reactive power nonbalances of node i; g_{ii} and b_{ii} are nodal active and reactive conductivity; δ_i is a corner of shift of voltage of i th node concerning voltage of basic node; g_{ij} and b_{ij} are active and jet conductivity of a branch, $\delta_{\iota\varphi} = \delta_\iota - \delta_j$.

LFE in the form of balance of capacities of nodes in rectangular coordinates are represented as:

$$W_{pi} = P_{Gi} - P_{Hi} - U_i^2 g_{ii} + U_i^{'} \sum_{j \in S_i} (U_i^{'} g_{ij} + U_j^{''} b_{ij}) + U_i^{''} \sum_{j \in S_i} (U_j^{''} g_{ij} - U_j^{'} b_{ij}), \quad i = 1,...,n \qquad (4)$$

$$W_{Qi} = Q_{Gi} - Q_{Hi} - U_i^2 b_{ii} - U_i^{'} \sum_{j \in S_i} (U_i^{''} g_{ij} - U_j^{'} b_{ij}) + U_i^{''} \sum_{j \in S_i} (U_j^{'} g_{ij} + U_j^{''} b_{ij}), \quad i = 1,...,n \qquad (5)$$

For the decision of the nonlinear equations of the established modes of a high order method Gauss-Zeydel method Gauss-Zeydel with secondary correction, Newton's method, Newton's method with the division, Newton's accelerated method with division, Newton's method with the parameter, the second serial methods are used.

The decision of the equations (2), Newton's (3) method in a matrix kind is represented as follows

$$\begin{vmatrix} \Delta P \\ \Delta Q \end{vmatrix} = \begin{vmatrix} H & N \\ M & L \end{vmatrix} \cdot \begin{vmatrix} \Delta\delta \\ \Delta U \end{vmatrix} \qquad (6)$$

Where □U and □□ - amendments to voltage and node; H, N, M, L – Jacobian's sub matrixes which is represents the private derivatives of the first order no balance of active and reactive power on U and □□.

Newton's method with division. Newton's method with division consists in neglect sub matrixes N and M in (6), leading to two matrix equations corresponding to problems P - □ and Q - U and their separate decision

$$|\Delta P| = |A| \cdot |\Delta\delta| \qquad (7)$$

$$|\Delta Q| = |C| \cdot \left|\frac{\Delta U}{U}\right| \qquad (8)$$

where *A* and *C* is Jacobian matrixes.

The decision of the equations in each cycle of iteration can be spent at first rather $\Delta\delta$ (7) and then rather ΔU (8) taking into account the specified values, $\Delta\delta$ to the same areas of a computer memory. In that case Newton's method with division demands four times less memories and volume of calculations on iteration less from the basic variant of a method of Newton. Elements of Jacobian matrixes A and C in each step of iteration are specified.

Newton's accelerated method with division. The further development of a method of Newton with division is the assumption of a constancy of matrixes *A* and *C* [2-4]. For real power supply systems parities $g_{ij*}\sin\delta_{\iota\varphi} \le b_{ij}$, $\cos\delta_{\iota\varphi} \approx 1$ and $Q_i \le b_{ii} * U^2_i$ are usually fair. In that case (7) and (8) it is possible to present the equations in a kind

$$|\Delta P| = |UB'U| \cdot |\Delta\delta| \;, \qquad (9)$$

$$|\Delta Q| = |UB''U| \cdot |\Delta U / U| \;, \qquad (10)$$

where *B*' and *B*'' poorly filled nodal reactive conductivity matrixes.

Efficiency of a high-speed method is reached by application of special modeling receptions.

Newton's method with parameter. The widest application for CEMEN was found by methods in which basis Newton's method lies. At the analysis of modes, scarce on active and reactive powers with low levels of voltage in the presence of weak communications or at sharp heterogeneity of elements of an equivalent circuit, Newton's method often does not provide convergence of the decision. This results from the fact that in some point of computing process Jacobian matrix becomes singular or system of the linear algebraic equations badly caused and amendments to variables are calculated with the big errors. For maintenance of convergence of a method of Newton at CEMEN in such conditions it is required to improve at first initial approach of vector X, and then to pass to Newton's method. As the methods improving initial approach for a method of Newton, methods with less severe constraints of convergence, such as gradient, Gauss-Zeydel, a method of the centers - the ellipses, Newton's combining method were used. The method of secondary correction for these purposes possesses the best properties.

The second serial methods are based in decomposition abreast Taylor of the equations of balance of capacities in rectangular system of coordinates in a point of initial voltage $U_i=U_o+j0$, the equations (4) and (5) can be written down in a kind:

$$P_i = P_i^0 + \sum_{j=1}^{n}\left(\frac{\partial}{\partial U_j^{'}}\Delta U_j^{'} + \frac{\partial}{\partial U_j^{''}}\Delta U_j^{''}\right)\cdot P_i + \Delta\Delta P_i \tag{11}$$

$$Q_i = Q_i^0 + \sum_{j=1}^{n}\left(\frac{\partial}{\partial U_j^{'}}\Delta U_j^{'} + \frac{\partial}{\partial U_j^{''}}\Delta U_j^{''}\right)\cdot Q_i + \Delta\Delta Q_i \tag{12}$$

Here U_i', U_j', U_i'', U_j'' are the real and imaginary components of complex voltage of nodes *i* and *j*; P_i^0, Q_i^o are active and reactive powering point U_o+j0; $\Delta U_j' + j\Delta U_j''$ is complex value of the amendment of voltage of node j; $\Delta\Delta P_i$, $\Delta\Delta Q_i$ are members of the second order are equal to zero. In a matrix kind of the equation (11, 12) are represented in a kind:

$$\begin{bmatrix}\Delta P_i \\ \Delta Q_i\end{bmatrix} = U_{БУ}\cdot\begin{bmatrix}B & G \\ -G & B\end{bmatrix}\begin{bmatrix}\Delta U_j^{'} \\ \Delta U_j^{''}\end{bmatrix} + \begin{bmatrix}L_1 & L_2 \\ L_3 & L_4\end{bmatrix}\cdot\begin{bmatrix}\Delta U_j^{'} \\ \Delta U_j^{''}\end{bmatrix} \tag{13}$$

Effective algorithms and programs of calculation of the established modes of electric networks including devices of longitudinal indemnification, small and sharply differing resistance, taking into account the features, inherent UHV AL, such as, the big lengths, capacitor conductivity on the earth, corners between voltage on the line ends, affinity of a limit on the static stability, providing high reliability of convergence, economic use of an operative computer memory with application are developed: Zeydel method with secondary correction; a combination of Zeydel method for the basic network and Newton's method for separate sub circuits; a high-speed method with division; the second serial methods, and also a method of stochastic approximation at the is likelihood-set initial information.

Programs are developed on "Fortran", used on COMPUTER EU separately, and also in complexes of calculation of losses of energy in radial and the power lines, some of these programs are registered in the State Funds of Algorithms and Programs and Specialized Branch Funds of Algorithms and Programs. The offered methods and algo - rhythms in the form of complexes of programs are introduced and Distant electricity transmissions "are used in"Azerenerji", in scientific research institute "Energosetproject".

Under programs were solved problems with 1000 nodes to corresponding 2000 nonlinear equations EEV for calculation of the established modes.

Programs CEMEN are used as independently, and in structure SCC [2-3] optimizations of modes on active power, optimization of modes of electric networks on voltage, reactive power and factors of transformation, calculation, the analysis, rationing of losses of energy and planning of actions for decrease in losses of energy in electric networks of power supply systems.

The database for modeling of normal modes, the established modes of electric networks, electric power losses, equivalence conversion, optimization of modes [5-7] with programming system use - DELPHI and the programming language - BORLAND PASCAL is developed.

Now works on creation of adaptive algorithms and programs of increase of reliability and convergence CEMEN are conducted.

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