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OPERATION OF THE “MODE” SOFTWARE PACKAGE IN REAL-TIME MODE

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ABSTRACT *The software for analyzing the operating modes of electric power systems and networks is presented. The theory of calculations, a general description of the software package (SP) and recommendations for its operation are considered. The theoretical foundation is nodal equations and modifications of the Newton method. The SP uses nonlinear equations of nodal voltages, where current sources are represented by a nonlinear function. The mathematical apparatus uses the power balance equation and is presented in matrix form. The iterative process ends with convergence control, which is implemented using the imbalance vector. The principles and sequence of working with the SP are presented in detail. The window when starting the program is considered. An example of data entry for schemes with eight and three nodes is given. The window for setting branch parameters is presented. The quick view mode is considered. An example of the content of the ‘DAN’ file is considered. The selection of calculation options, correction of initial data and setting the number of iterations are presented. An example of the window for outputting results and exiting the program is considered. The output of results is carried out by network branches. The program provides a quick view of the calculation results. SP hardware: IBM-compatible computer with a 650 MHz processor, 512 MB of RAM and 10 MB of free disk space. The program is compatible with Windows operating systems. The SP operates in real time. The developer of the calculation program is the Department of Electrical Power Transmission of NTU "KhPI". The initial versions of the program were written in BASIC, and the latest ones in Python 3.5. The SP is used by employees in the educational process and in scientific research.*
Keywords*: software package; electrical network mode; nodal equations; Newton's method; quality of electrical energy.*

РОБОТА ПРОГРАМНОГО КОМПЛЕКСУ «РЕЖИМ» У РЕЖИМІ РЕАЛЬНОГО ЧАСУ

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АНОТАЦІЯ *Представлено програмне забезпечення для аналізу режимів роботи електроенергетичних систем та мереж. Розглянута теорія розрахунків, загальний опис програмного комплексу (ПК) та рекомендації щодо його роботи. Теоретичним фундаментом є вузлові рівняння та модифікації методу Ньютона. В ПК застосовані нелінійні рівняння вузлових напруг, де джерела струму представлені нелінійною функцією. Математичний апарат використовує рівняння балансу потужності та представлений у матричній формі. Ітераційний процес закінчується за допомогою контролю збіжності, що реалізовано за допомогою вектора небалансів. Докладно представлено принципи та послідовність роботи з ПК. Розглянуто вікно під час запуску програми. Наведено приклад вводу даних для схем з восьми та трьох вузлів. Представлено вікно налаштування параметрів гілок. Розглянуто режим швидкого перегляду. Показано приклад змісту файлу ‘DAN’. Представлено вибір варіантів розрахунку, корегування початкових даних та установка кількості ітерацій. Розглянуто приклад вікна по виводу результатів та виходу з програми. Вивід результатів здійснюється по гілкам мережі. Програма забезпечує швидкий перегляд результатів розрахунку. Апаратне забезпечення ПК: IBM-сумісний комп’ютер з процесором 650 МГц, оперативною пам’яттю від 512 МБ і 10 МБ вільного дискового простору. Програма сумісна з операційними системами Windows. ПК здійснює роботу в режимі реального часу. Розробником розрахункової програми є кафедра передачі електричної енергії НТУ «ХПІ». Початкові версії програми були написані на BASIC, а останні — на Python 3.5. ПК використовується співробітниками у навчальному процесі та в наукових дослідженнях.*
Ключові слова: *програмний комплекс; режим електричної мережі; вузлові рівняння; метод Ньютона; якість електричної енергії.*

Introduction

Calculation of electrical network modes is the basis for its design and operation. The issue of reliability, quality and efficiency of electricity supply is decided on the basis of the results of these calculations. In addition, current problems of mode optimization, energy saving problems, loss reduction, and others are solved thanks to such calculations. These calculations are carried out on the basis of special mathematical programs. They display electrical network models (systems of equations) and means of solving them, as a rule, these are various modifications of Newton's method. Many organizations and specialists are working on the development of such

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software, both in Ukraine and abroad. Among our compatriots, the works of the Institute of Electrodynamics [1], Vinnytsia and Kharkiv Polytechnics [2,3] stand out.

State institutions, like Oblenergo often use software of experienced foreign manufacturers, for example, PawerFactory, KONSOL, MAXWELL, and others. Depending on the tasks, for example, industrial use or use in the educational process, these programs differ significantly in terms of capabilities and technical characteristics [4, 5].

At the same time, in recent years, the interest of leading specialists in the development of theoretical aspects of this issue has increased [6–8]. It should be noted that today the issue of software development, its implementation, development and correct use remains a rather important and difficult scientific and technical problem [9–11]. In recent publications, a tendency to unify this issue can be seen [12]. In addition, in the conditions of widespread use of non-traditional energy sources, specialists pay special attention to this issue. The fact is that over a period of time, load nodes can turn into generation nodes and significantly affect the redistribution of power flows of the electric network. At the same time, the structure of the electrical network almost does not change, or changes partially [13,14]. In addition, the issue of the future development of Ukraine's electrical networks becomes even more complicated due to the ambiguity of such issues as the introduction of 20 kV voltage or complex optimization of reactive power [15,16].

Classical methods of calculating electric network modes are often adapted for special calculations of great practical importance. Examples of such programs, such calculations can be methods of calculating the reliability or levels of higher harmonics of electrical networks [16,17]. The Ukrainian electric power industry has strategic directions for development. Ukrainian scientists, despite all the existing risks, are doing everything possible to ensure the sustainable development of this industry [18-20].

This article describes in detail the structure and basic principles of the software complex “Mode”. The presented calculation program is used in the educational process and in conducting scientific research at the Department of Electricity Transmission of NTU KhPI. This allows analyzing the optimal operating modes of electrical networks based on the calculation of normal modes. The materials of the article were partially used during international conference [3], the general characteristics of the program are given in [21].

The purpose of the work

The purpose of the work is to create an effective, technological and reasonably accessible (at the student level) software product for calculating the modes of electrical networks in real time and explaining its use on a specific example.

Presenting main material

1. Theoretical provisions

The theoretical basis of SP (software package) is knot equations and modifications of Newton's method. With the help of nodal equations, various modes of electrical networks (steady, post-accident, burdensome) are modulated, and they are solved by Newton's method. This information is used to control the electrical network (EN) modes.

Equations of nodal voltages in the form of power balance and matrix notation have the form:

$$\overset{*}{U}_{диаг}(Y_y\overset{*}{U}+Y_б\overset{*}{U}_б)=\overset{*}{S},$$

$\overset{*}{U}_{диаг}$ - diagonal matrix, *k*-diagonal element, which is equal to the even complex of voltage *k* node; $\overset{*}{S}$ - a column vector, the *k* element of which is equal to the even complex of the power of the *k* node.

The modulus and voltage phases at nodes *U* and *δ* are used as variables when solving steady-state equations.

The power balance equation for *k* node with variables *U*, *δ* can be obtained in the following form:

$$\omega_{Pk}=P_k-g_{kk}U_k^2-U_k\sum_{\substack{j=1\\j\neq k}}^{n+1}U_j(g_{kj}\cos\delta_{kj}-b_{kj}\sin\delta_{kj});$$

$$\omega_{Qk}=Q_k-b_{kk}U_k^2-U_k\sum_{\substack{j=1\\j\neq k}}^{n+1}U_j(b_{kj}\cos\delta_{kj}+g_{kj}\sin\delta_{kj}).$$

The nonlinear system of steady-state equations can be written in a simplified form as follows:

$$W(X)=0,$$

where *W* (*X*) is a vector function of order *n*; *X* is a vector of dependent variables of order *n*.

Convergence control is carried out on the vector of imbalances, that is, the condition must be fulfilled for all imbalances.

$$\omega_k(X^{(i)})\le\varepsilon$$

2. Purpose of the computer program

The purpose of the computer program is to implement the algorithm for calculating the normal modes of electrical systems.

The algorithm of the computer program is implemented using the following modules:

- module of input arrays;
- basic module;
- module for outputting results.

Let's consider the conditions of program execution, the minimum composition of technical and the minimum composition of software tools:

The composition of technical means should include IBM - a compatible personal computer (PC), which includes:

- a processor with a clock frequency of at least 650 MHz;
- the amount of RAM is at least 512 MB;
- free disk space of at least 10 MB;
- monitor;
- computer mouse.

System software tools used by the program must be represented by a licensed version of the operating system: Windows 95, Windows 98, Windows NT, Windows XP, Windows 7 and others.

The operator using the program must have practical skills in working with the graphical interface of the operating system.

Work with the program is performed as follows.

The program is downloaded by running the skubko_pr.exe file, which should be located in the D:\SKUBKO folder.

If the program is successfully launched, it will be displayed on the desktop program window (Fig. 1).

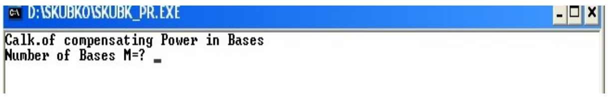

Fig. 1 – The main program window

An input data module is one of three source data files DAN.DAT, S1.DAT, or S2.DAT. These files should contain information about lines and nodes (Fig. 2).

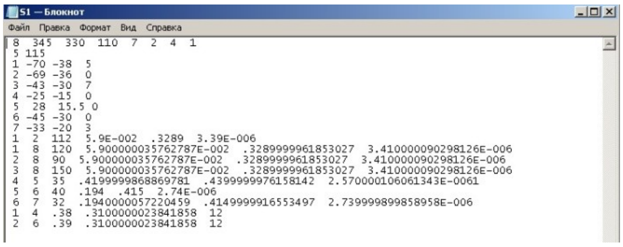

Fig. 2 – Input data module

The basic module is the main one. It consists of a procedure for processing initial data and outputting information at the user's request.

The basic module allows you to quickly change the values of the initial data and perform calculations with new values. The main menu of the program is presented in Fig. 3.

The output of the results is carried out at the user's request in one of the two data files VIVOD.DAT or RESULT.DAT. The output data file looks as follows (Fig.4).

Termination of the program is possible from the main program window by any of the methods listed below:

- by pressing the key combination "Alt+F4";
- by clicking the button to close the window in the upper right corner**;**
- by entering the number 6 in the main menu of the program.

3. Recommendations for operational calculations and management of electric network modes

3.1. Input files

The calculation is carried out using the program SKUBK_PR.EXE. This program is designed to calculate the steady-state operation of the electrical network.

Before starting work, you need to create a SKUBKO folder on the computer's D drive and place files in it that will be input data files (DAN.dat, S1.dat, S2.dat) and output files (VIVOD.dat, RESULT.dat). In addition, the program itself must be placed in this folder. Its address will look like this: D:\SKUBKO\SKUBK_PR.EXE. Calculations use one of three data files, the output data of which can be specified in two ways. To do this, an input data file is previously created using the "Notepad" program, or the data can be output directly to the program itself. In this case, the information entered by us will be saved in the DAN.dat file.

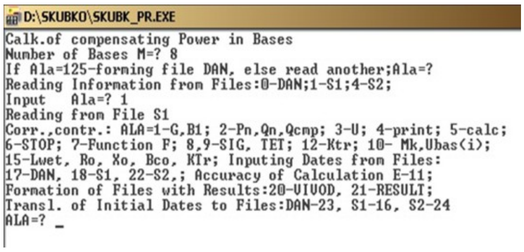

Fig. 3 – The main menu of the program

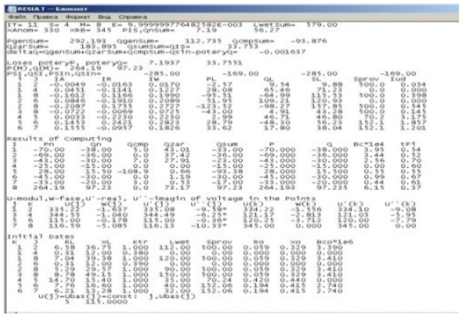

Fig. 4 – Output of results

Consider the operation of the program on the example of a simple network with three nodes, two voltage levels and one node with a transformer connection.

When running, the program will look like this (Fig. 5).

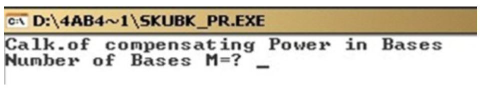

Fig. 5 – Program at startup

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First, the number of network nodes is specified. In the future, these values cannot be changed. If you need to perform another calculation, but with a different number of nodes, it will be necessary to close the program and open it again, entering a new value of M (Fig. 6).

The next step is to select the source data file. In this line, the program asks to read from a ready-made file or enter data directly into the program. Consider entering data directly into the program. For this, in the line If Ala=125-forming file DAN, else read another; Ala=? it is necessary to enter 125 and press ENTER (Fig. 7).

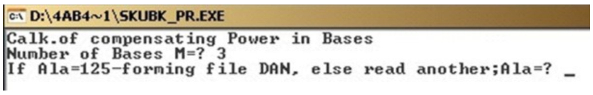


Fig. 6 – Calculation with the new value of M

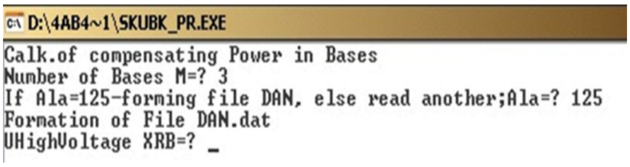


Fig. 7 – Entering data directly into the program

From this moment, the data entered from the keyboard will be saved in the DAN.dat file and will be used in the program's calculations, and will also be available for reuse. The first of the entered parameters will be XRB - the base voltage of the higher voltage network. After entering the value, press ENTER. If several values are entered in one line, they are separated by a space (Fig. 8).

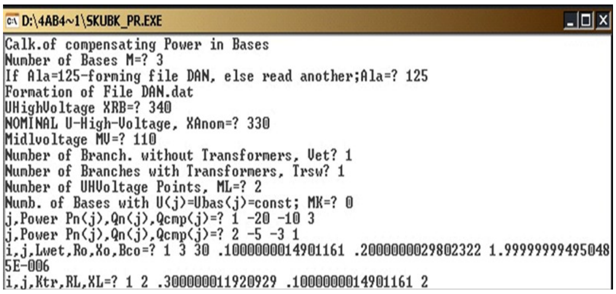


Fig. 8 – Data entry example

Next, the following data are entered: XA nom – nominal voltage of the high-voltage network, MV – nominal voltage, on the lower side of the transformer, Vet – number of branches without transformer connections, Tzsw – number of branches with transformer connections, ML – number of nodes of the high-voltage network voltage, MK – the number of network nodes for which Ubas is specified (except for the base node) (Fig. 9).

The following values are entered with a space. At the beginning of each line, you need to put the number of the node, then the input active and reactive power, related to the node voltages and the power of the compensating devices in the i-th node. Positive value – generation, negative – consumption of reactive power (Fig. 10).

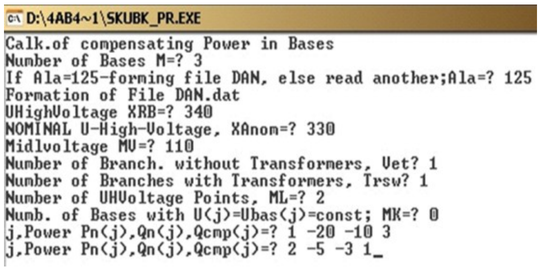


Fig. 9 – Input data

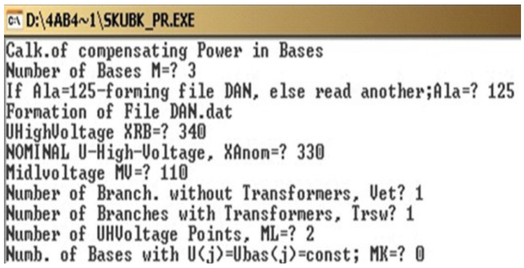


Fig. 10 – Setting parameters in nodes

The next stage will be the entry of information for branches, both with transformer connections and without. First of all, you need to enter the numbers of nodes between which this branch is located. It is important that when entering information, it is necessary to observe $i < j$, and in that case, if the number is very small, it is better to present it as multiplied by 10 to the minus n power. In the program it will look like E-00n. For lines without transformer connections, Lwet is set - the length of branches between nodes; Ro, Xo – specific resistance of the phase wires (for the total section of the phase wires of the branch); Vso is the specific transverse conductivity of the power transmission line, and for lines with transformer connections: Ktr is the transformation coefficient for the transformer connection (<1); RL, XL - branch resistance (Fig. 11).

This ends the entry of input data and then the program offers to choose one of the three available options for input data. All the information that was just entered is saved in the DAN.dat file, so we choose "0".

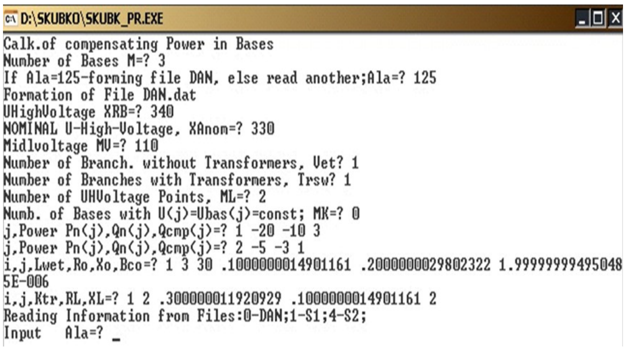
If the input data file is created using the "Notepad" program, the dan.dat output file will have the following form (Fig. 12).

This file has the extension ".dan", which can be opened with a simple text editor "Notepad" or AkelPad (as in this case).

Depending on the number of nodes, the number of lines in this file will change. We can present this file in the form (Fig. 13).

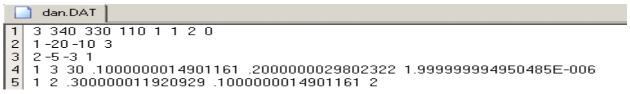
The figure presented above shows the order in which the data is arranged in the file, the description of these conditional designations has already been carried out. Each of the output files will have a first line like this.

MK takes the value 0 and the second line is skipped. In this case, the file will look like in our example. Consider an example of the output data of eight network nodes, with one additional base node. The figure below shows the source data file S2. It is important that there should be no missing values. For example, there are no compensating devices in one of the nodes, in which case Qcmp=0. But the parameters of the lines cannot be equal to zero, for this we set a sufficiently small value of the quantity we are interested in in the output data file (Fig.14).



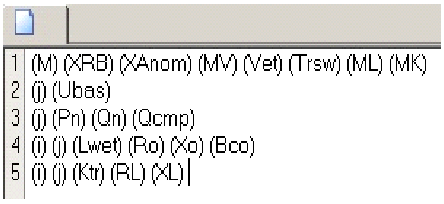
```
D:\SKUBKO\SKUBK_PR.EXE
Calk.of compensating Power in Bases
Number of Bases M=? 3
If Ala=125-forming file DAN, else read another;Ala=? 125
Formation of File DAN.dat
UHighVoltage XRB=? 340
NOMINAL U-High-Voltage, XAnom=? 330
Midlvoltage MV=? 110
Number of Branch. without Transformers, Vet? 1
Number of Branches with Transformers, Trsw? 1
Number of UHVoltage Points, ML=? 2
Numb. of Bases with U(j)=Ubas(j)=const; MK=? 0
j,Power Pn(j),Qn(j),Qcmp(j)=? 1 -20 -10 3
j,Power Pn(j),Qn(j),Qcmp(j)=? 2 -5 -3 1
i,j,Lwet,Ro,Xo,Bco=? 1 3 30 .1000000014901161 .2000000029802322 1.99999999495048
5E-006
i,j,Ktr,RL,XL=? 1 2 .300000011920929 .1000000014901161 2
Reading Information from Files:0-DAN;1-S1;4-S2;
Input   Ala=? _
```

Fig. 11 – Configuring branch settings



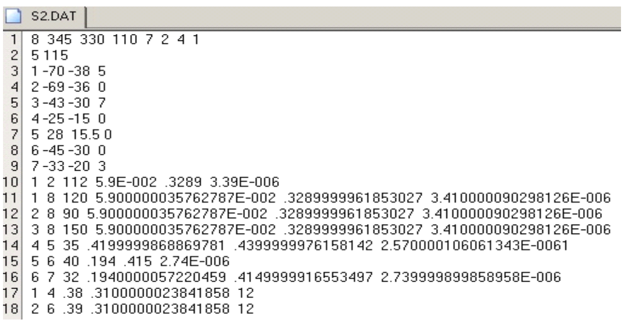
```
dan.DAT
1  3 340 330 110 1 1 2 0
2  1 -20 -10 3
3  2 -5 -3 1
4  1 3 30 .1000000014901161 .2000000029802322 1.999999994950485E-006
5  1 2 .300000011920929 .1000000014901161 2
```

Fig. 12 – Viewing the contents of an input file



```
1  (M) (XRB) (XAnom) (MV) (Vet) (Trsw) (ML) (MK)
2  (j) (Ubas)
3  (j) (Pn) (Qn) (Qcmp)
4  (i) (j) (Lwet) (Ro) (Xo) (Bco)
5  (i) (j) (Ktr) (RL) (XL)
```

Fig. 13 – Example of the content of a file of type "dan"



```
S2.DAT
1  8 345 330 110 7 2 4 1
2  5 115
3  1 -70 -38 5
4  2 -69 -36 0
5  3 -43 -30 7
6  4 -25 -15 0
7  5 28 15.5 0
8  6 -45 -30 0
9  7 -33 -20 3
10 1 2 112 5.9E-002 .3289 3.39E-006
11 1 8 120 5.900000035762787E-002 .3289999961853027 3.410000090298126E-006
12 2 8 90 5.900000035762787E-002 .3289999961853027 3.410000090298126E-006
13 3 8 150 5.900000035762787E-002 .3289999961853027 3.410000090298126E-006
14 4 5 35 .4199999868869781 .4399999976158142 2.570000106061343E-0061
15 5 6 40 .194 .415 2.74E-006
16 6 7 32 .1940000057220459 .4149999916553497 2.739999899858958E-006
17 1 4 .38 .3100000023841858 12
18 2 6 .39 .3100000023841858 12
```

Fig. 14 – Contents of the s2.dat file

3.2 The output data file for the task of calculating power lines

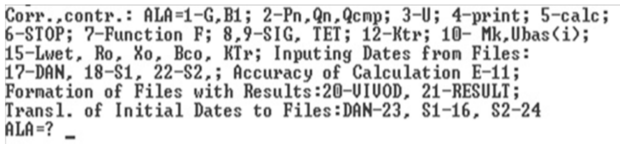
When examining a long-distance power transmission line with the help of the program, it is formed in the data file as a line divided into sections of 50 km. We cannot set zero values of certain elements in the program, we set these values equal to negligibly small numbers. First of all, real nodes are numbered, then imaginary nodes (which we set every 50 km).

For the 750 kV line, we choose: phase 400/51, 5 parallel – 400x5=2000 mm.sq. ro=1.5E-2, xo=0.286, bo=4.11E-6 Cm/km.

For calculations, we choose insignificantly small loads on the site, for example, 0.5 MBt and 1 MVAr.

3.3 The main menu of the program

After selecting the desired output data file, the program takes the user to the main menu (Fig. 15).



```
Corr.,contr.: ALA=1-G,B1; 2-Pn,Qn,Qcmp; 3-U; 4-print; 5-calc;
6-STOP; 7-Function F; 8,9-SIG, TET; 12-Ktr; 10- Mk,Ubas(i);
15-Lwet, Ro, Xo, Bco, KTr; Inputing Dates from Files:
17-DAN, 18-S1, 22-S2,; Accuracy of Calculation E-11;
Formation of Files with Results:20-VIVOD, 21-RESULT;
Transl. of Initial Dates to Files:DAN-23, S1-16, S2-24
ALA=? _
```

Fig. 15 – Main program menu

By functionality, commands in the main menu can be divided into the following groups:

- commands for correcting output data;
- starting the calculation and stopping the program;
- commands for outputting the result;
- commands for operations with source data files.

3.4 Commands for adjusting output data

With the help of these commands, you can change the values of some (necessary for the user) output data while working with the program. Operations in the program will not be considered, you can perform actions in them by following the program prompts, or by changing the output data file using the Notepad program and opening the program again. Below are brief explanations for each command:

1 – change in branch conductivity (real and imaginary part);
2 – change of active, reactive capacities and capacities of compensating devices;
3 – voltage change in the high and low voltage networks;
6 – stopping the program;
8, 9 – an overview of the calculated relative increments of losses of active and reactive power SIGP, SIGQ, TETPQ for generator nodes, brought to the balancing node M;
10 – change in the number of basic nodes and voltage in them;
11 – change of calculation accuracy;
12 – change of the transformation coefficient;
15 – adjustment of such parameters as line length, active and reactive resistance of branches, transverse conductivity of branches and transformation coefficient (Fig. 15).

3.5 Starting the calculation and stopping the program

The calculation is started by selecting item "5" of

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the main menu. When selecting this menu item, the program offers one of three options for the following calculation (Fig. 16).

Option "A" - if the active and reactive power in the network changes. To select this calculation option, you need to enter the number 1. Option "B" - if the active and reactive powers are constant, the number 2 is responsible for this option. Option "C" - for cases when the active powers are constant, and the reactive powers change, in such in this case, you need to enter the number 3. To return to the previous menu, you need to enter the number 0. As an example, consider the option when the active and reactive powers are constants.

```
INFLUANCE of U(i)=0 on S(i) of Points. Selection of REGIMES:
A: in ALL Points P(u)=var, Q(i)=var - INPUT INF=1;
B: in ALL Points P(u)=const, Q(i)=const - INPUT INF=2;
C: in ALL Points P(u)=const, Q(i)=var - INPUT INF=3;
if RETURN to MENU - INPUT INF=0. Also INPUT for Regime INF=?
```

Fig. 16 – Choice of calculation options

The next stage of the calculation is choosing whether the charging power depends on the voltage, if it does, then you need to enter 8, if not, then enter 0. The number 8 should be entered for lines above 35 kV (Fig.17).

```
If Qzar depends from U then Qxvz=8, else 0? _
```

Fig. 17 – Setting task conditions

IT is the number of iterations for the iterative process (Fig. 18). Data entry errors or other unpredictable failures can lead to an endless iterative process. In this case, it is necessary to specify the number of iterations after which the process will stop. The program may need a smaller number of iterations for the calculation, the choice of this number should be based on the number of network nodes.

```
NUMBER OF ITERATIONS IT=?
```

Fig. 18 – Setting the number of iterations

The more nodes, the more iterations we need (Fig.19).

```
PIS,QnSum=       0.017       10.696      P(M),Q(M)=      25.017      2.304
PSI,QSI,PSIn,QSIn=      -25.000          -13.000          -25.000          -13.000
  LwetSum= 30
If LI=6-STOP,else CONT.LI=?
```

Fig. 19 – Example of task display

As you can see from the above figure, it took 4 iterations (S=4) to complete the process. Next, the program outputs the results of calculations with a certain periodicity, pausing for the convenience of viewing the information. To continue viewing the results, press "Enter" (Fig. 20).

If the values entered by the program are the desired ones, we can press "6" and stop working with the program (Fig. 21).

After seeing the information presented in the figure above, you can check the correctness of the iterative process. The quantity to be checked in this case is delta Q. The numerical value of this variable should tend to approach zero because it is the reactive power balance in the network.

```
   NUMBER of ITERATIONS  IT= 11     S=* 1
   NUMBER of ITERATIONS  IT= 11     S=* 2
   NUMBER of ITERATIONS  IT= 11     S=* 3
   NUMBER of ITERATIONS  IT= 11     S=* 4
NUMB OF ITER S= 4 ,IT= 11 ,E=0.0100000, X( 5 )= 340 Number of Points M= 3
NOMINAL UH-Voltage, XAnom= 330
Volt.X(deel)-Real,X(even)-Imag.Here Numb.of Points
Pause? _
```

Fig. 20 – Example of outputting the result

```
U-modul, W-fase (Grad), U'-real, U''-imagin of Volt.in the Bas.
j K   U(j)    W(j)    U'(j)    U''(j)   U(k)    W(k)    U'(k)   U''(k)
1 2  339.68  -0.066  339.68   -0.39*   101.86  -0.120  101.86   -0.21
Pause=?
```

Fig. 21 – Quitting the program

It is equally important to check the value of the voltage in the nodes of the network. The program gives us this information by inserting values for two network nodes in one line. When considering such data, it is necessary to pay attention to the indices of values (Fig.22).

```
U-modul, W-fase (Grad), U'-real, U''-imagin of Volt.in the Bas.
 j  K     U(j)    W(j)     U'(j)     U''(j)    U(k)      W(k)    U'(k)    U''(k)
 1  2   339.68   -0.066   339.68    -0.39*   101.86    -0.120   101.86    -0.21
Pause=?
```

Fig. 22 – Viewing the program's results

When additional basic nodes are assigned, the program at its discretion decides to install compensating devices in the node to maintain the voltage, while the values in the Qcmp column will differ from those previously set.

Finally, the program issues a calculation concerning the branches (Fig. 23).

In this case, special attention should be paid to the specific current in the branches. Then the program will return the user to the main menu.

```
Currents ant Power in the Branches
  I  J   IA        IR       IW          PL         QL       SL      Sprov  Iud
  1  2   0.0085  -0.0034   0.009       5.00       2.00     5.39      0.0  0.000
  1  3  -0.0425   0.0098   0.044     -25.00      -5.74    25.65    295.0  0.148
If LI=6-STOP, ELSE cont.LI=? _
```

Fig. 23 – Output of results by network branches

3.6 Commands for outputting results

Output of information from the program is possible in one of two files and in the program menu. This is done using menu items "20" - output information to the VIVOD file and "21" - output information to the RESULT file. In addition, it is possible to display the results of the calculation on the screen, for this you need to enter "4".

3.7 Commands for operations with source data files

Items 16, 23, and 24 are for entering the output data currently used by the program in files S1, DAN, and S2, respectively. It is possible to select other output data from files: 17–DAN, 18–S1, 22–S2. This function is possible only under the condition that the number of nodes in different source data files is the same.

Discussion of results

The software package was developed and modernized at the Department of Electrical Energy Transmission NTU "KhPI". The first versions are written in the BASIC language, the last ones in Python 3.5. Programs are implemented in the educational process and scientific activity of the department. With the help of a SP, students of senior years carry out calculations of course and diploma projects. At the same time, employees use this software product in their research work. A comparative analysis of the results of calculations carried out with the help of the "Mode" software package and other generally accepted programs gives good matching results. The software product was used in the educational work of other universities (Ukrainian State University of Railway Transport, Kharkiv National University of Urban Economy named after O.M. Beketov and others). At the initial stages of SP development, a significant contribution to software development was made by V. A. Skubko, associate professor of the Department of Electrical Energy Transmission.

Conclusions

The article presents the basic principles of functioning software package "Mode". The SP is used for calculations of normal modes of the electrical network. The theoretical basis of the software package is nodal equations. With their help, normal operating modes of the electrical network are simulated. Nodal equations are calculated using Newton's method. The article presents the general characteristics and main capabilities of the SP. Recommendations for real-time SP operation are considered in detail. These calculations are essential for the analysis and effective management of the electrical network operating modes.

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