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DEVELOPMENT OF THE ALGORITHMS AND PROGRAMS OF HIGH SPEED METHODS FOR THE CALCULATION OF LARGE ELECTRIC ENERGY SYSTEMS (EES) AND POWER UTILITIES OPERATION MODES FOR THE SIMULATORS

Important problems, dealing with the development of the algorithms and programs of high speed methods for the calculation of large electric energy systems and power utilities (PU) operation modes for the application in remote mode simulators for the staff of substations and EES are considered. For operation modes calculation modern virtual technologies and distributed modeling environment are used. The example of the developed simulator for staff training is suggested.

***Key word**: energy systems and power utilities, modes calculation algorithms, remote full-scale mode simulators.*

Introduction

Modern electric energy system is a complex man-machine system. For the similar systems stable formation, support and development of the most important (key) competences of dispatching staff of large EES and PU can be provided mainly by means of large-scale usage of mode simulators [1].

The most important (key) competences include the competences, connected with on-line switchings in normal and emergency modes, recognition of the conditions for failures emergence and their liquidation. Formation, control and support of these competences are the main goals of staff management system.

In modern conditions it is practically impossible to achieve these goals without using the mode simulators.

Support and development of the efficient skills and methods of the rapid liquidation of the conditions for emerging and development of various failures stipulates the necessity to improve the techniques and technologies of staff training.

Insufficient level of staff qualification and lack of the readiness of quick liquidation of the failure leads to large system and intersystem failures, followed by considerable material and financial losses, that is why, for organization of the efficient simulator-based training, it is important to have the possibility of the round-the-clock remote access to the base of emergency prevention trainings, supplied by teaching aids and qualitative working programms of advanced training.

The given research suggests the usage of modern electronic (e-learning) technologies in energy sector of national economy, based on new achievements in this sphere, enabling to provide the support of the required skills of the staff and high quality of training at working places, simulation locations and centers.

The most promising methods of teaching and simulator-based training of the staff in all the economically-developed countries of the world are considered to be the remote teaching and simulator- based training facilities, universally binding for usage and able to model normal and emergency operation modes of EES and PU in real time [2, 3].

The accumulated experience of the operation of full-scale foreign mode simulators showed that the important conditions for the efficient work with the dispatching staff is the creation of the general distributed information environment of EES and/or PU modeling and application of the high speed algorithms for modes parameters calculation.

Modern full-scale mode simulators, used for simulator based-training in greater part of the developed countries, as a rule, provide comfortable response time on the actions of the trained dispatchers.

The most comfortable response time on different disturbing impacts in the modeled large EES and/or PU is assumed to be the time up to 2 sec, that enables the staff to make adequate and efficient decisions.

This requirement to modeled system for large EES and PU to provide comfortable response time, causes the necessity of searching, study and development of new algorithms of modes calculation for simulators.

The given paper is devoted to the analysis, study and development of the fast acting algorithms for the calculation of operation modes of large EES and PU, suitable for the application in mode simulators.

The suggested algorithms enable to perform the short-term and long-term forecast calculations of the normal and emergency operation modes of large EES and PU in the production rate that will contribute to the formation in the dispatching staff stable skills of maximally rapid and adequate reaction on various violations of the operation modes.

Application of such algorithms for the remote mode simulators will enable to improve considerably the quality and efficiency of EES staff training in Ukraine.

Operation mode of any electric grid (or its part) can be described by the system of equations, using known [4] expressions for each i^{th} node.

$$\begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \\ \dots \\ \dot{U}_{s-1} \\ \dot{U}_s \end{bmatrix} = \begin{bmatrix} \dot{Y}_{11} & \dot{Y}_{12} & \dots & \dot{Y}_{1(S-1)} & \dot{Y}_{1S} \\ \dot{Y}_{21} & \dot{Y}_{22} & \dots & \dot{Y}_{2(S-1)} & \dot{Y}_{2S} \\ \dots & \dots & \dots & \dots & \dots \\ \dot{Y}_{(S-1)1} & \dot{Y}_{(S-1)2} & \dots & \dot{Y}_{(S-1)(S-1)} & \dot{Y}_{(S-1)S} \\ \dot{Y}_{S1} & \dot{Y}_{S2} & \dots & \dot{Y}_{S(S-1)} & \dot{Y}_{SS} \end{bmatrix}^{-1} \cdot \begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \\ \dots \\ \dot{I}_{s-1} \\ \dot{I}_s \end{bmatrix}, \tag{1}$$

where $\left[\dot{U}_s\right]$ – is column-vector of the target phase voltage of the nodes; $\left[\dot{Y}_{ss}\right]^{-1}$ – is inverse matrix of the node conductivity of the electric grid; $\left[\dot{I}_s\right]$ – is column vector of the set (known) nodes currents.

It is known that the matrix of node conductivity $\left[\dot{Y}_{ss}\right]$ in general form is a singular matrix and does not have the inverse matrix. For the solution of (1) it is necessary to delete, at least one row for the reference node with the known (set) voltage and carry over the corresponding column-vector in the right part of the equation.

In matrix form the system of equations (1) can be written as:

$$\left[\dot{U}_s\right] = \left[\dot{Y}_{ss}\right]^{-1} \cdot \left[\dot{I}_s\right]. \tag{2}$$

If the powers of the nodes are known or set, then the formula (2) can be rewritten in the form of the scalar product of nodes currents vector $\left[\dot{I}_s\right]$ on the bounded vector of nodes voltage $\left[\hat{U}_s\right]$:

$$\left[\dot{S}_s\right] = \left(\left[\hat{U}_s\right], \left[\dot{I}_s\right]\right), \tag{3}$$

where $\left[\dot{S}_s\right]$ – is column vector of the set powers of the nodes.

There exist numerous research and publications [5, 6, 7], devoted to the problem of the solution of the systems of non-linear equations (3), that is why, we will limit ourselves only by the description of their main properties. Elements of nodal conductivity matrix $\left[\dot{Y}_{ss}\right]$ and the vector of the preset powers of the nodes $\left[\dot{S}_s\right]$ in such problems are known values and $\left[\dot{U}_s\right]$ – unknown values. As a result of the solution of the system of non-linear equations (3) the target voltage of the grid nodes $\left[\dot{U}_s\right]$ is calculated. Nowadays Neuton-Raphon, Gauss, Seidel methods are used as basic methods of mode calculation [8, 9, 10]. Thus, calculation of the operation mode of random electric network with the preset load and configuration is in the determination of nodes voltage vector $[\dot{U}_s]$. The drawback of such methods of calculation is large time of calculation of large EES and/or PU operation modes, including the complete absence of iteration calculations convergence guarantee, that is absolutely unacceptable for the application in the remote mode simulators.

For the solution of the system (3) the algorithm of multiresistance method of loop currents calculation that differs from the known methods by the account of degenerate(nonzero) loops, created between the sources of energy and /or PU . The whole network is presented by separate trees with chords, that form complete or degenerate loops while their switching. Speed of mode calculation, applying this method for the networks, consisting of up to 1000 nodes, is less than 1 sec, and it is acceptable for its usage in mode simulators.

The suggested algorithm of modes calculation within the mode simulators of any EES and/or PU uses three basic sets of the initial data in the form of tables with the information, concerning the parameters of nodes, branches and general information of electric grid. These sets obligatory contain nodes and branches of energy systems, operating in parallel. Thus, each sets of the initial data identical nodes and branches are available. As a result of the calculation of the operation mode of one of the parallel operating EES the value of boundary nodes (the currents of the adjacent branches) of the first EES are used for the calculation of operating mode of the second EES. Any changes of circuit parameters or operation mode of the separate EES automatically (by means of flip-flop system) start the operation of the programs of operation mode calculation of the adjacent EES operating in parallel , initial data of these systems are located in the distributed virtual modeling environment on the side of data bases services, with the built-in programs of mode calculation. This greatly decreases the time of EES operation modes calculation. The developed flip-flop system provides stable balancing of the operation mode of all EES and/or PU, operating in parallel during a short period of time applying, as a rule, 3 – 4 iterations of the external iteration process.

The algorithm operates in the following way.

The set or the known voltage of the circuit nodes is used for the determination of the values of nodes currents, taking into account the currents of the chords, that enables to present the initial closed circuit in the open form. Chords currents, being iterated in such circuit are added to nodes currents. The voltage of nodes can be found by means of the solution of the system of linear equations (1), which describe the operation mode of the random electric grid, relatively the nodes voltage or by means of reiterated (not more than 5 – 7 iterations) calculation of power flow distribution with further calculation of new mode of nodes voltage. For the new values of the voltage chords currents are calculated each time. Contours currents are iterated until the voltage difference in them becomes less than the preset value, that enables to reset the circuit to the initial closed form. For the closed circuit new values of the node currents are determined and internal cycle of chords currents iteration is repeated. Modes calculations are over when new values of nodes voltage or nodes power do not change greatly from iteration to iteration.

The example of the fragment of training remote simulator interface is shown in Fig. 1. User's browser contains the results of the calculation of nodes voltage, power flow (blue color), current of the transmission line and frequency (yellow) for the current disturbance, caused by load increase.

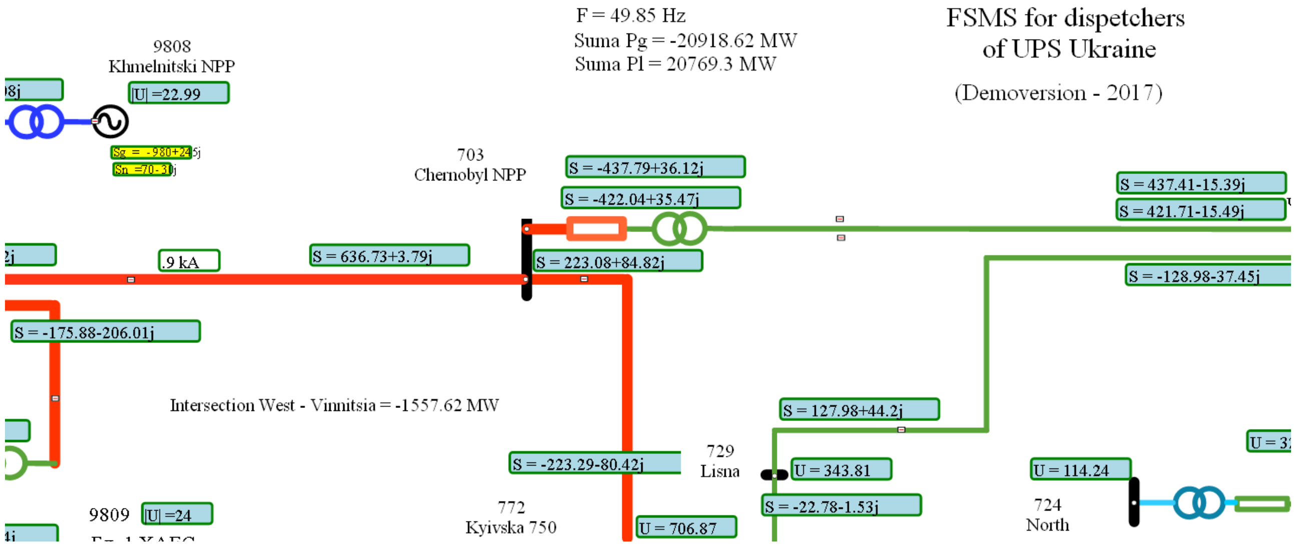

Fig. 1. Fragment of training remote simulator interface

Conclusions

1. Algorithm of the high speed multiresistance method of large EES and/or PU operation mode calculation for application in remote mode web-oriented simulators is developed and realized. The corresponding calculation program is tested on the example of Unified Energy System of Ukraine and is intended for operation in the data bases of ORACLE or PostGreSQL type in the form of special built-in function on the side of the server.

2. The developed high speed calculation method guarantees comfortable response time of the mode simulator on the actions of the training dispatchers. The program is used in full-scale mode simulator (FSMS) for the substations staff and dispatchers of EES and UES of Ukraine.

3. The suggested calculation method enables to perform transient electric mechanical calculations and can be recommended for the creation of various scenarios of emergency response exercises of operating and dispatching staff of EES and/or PU.

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