# COMPUTER STIMULATION OF ESTABLISHED MODES OF POWER NETWORKS

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*Integral mathematical model for computer design of established normal and emergency modes in data base control systems is elaborated.*

*Problems of identifying active parameters of normal and emergency modes are based on the same equations, however qualitatively they differ from one another quite significantly. The quality of power is most important in identifying normal mode parameters. Therefore, any decision cannot be considered as satisfactory and consequently it is necessary to have an impact on problem solving process which is reflected in the elaborated model.*

*Based on the proposed model, using symmetrical component method, it is possible to develop algorithm for designing any type of asymmetric emergency mode.*

**Key words:** *established mode, nodal voltages, nodal currents, vector-matrixes, electromotive force.*

**Normal and symmetric emergency mode parameters are designed according to the replacement diagram which is drafted for one phase, as in case of symmetric power modes, active parameters of all three phases of one and the same area are displaced from one another by just $120^0$. After determining the power parameters for one phase, the same parameters for the reminder phases are sought by means of the obtained results and vector displacement operator $a = e^{j120}$ .**

**Symmetry of the currents and voltages during the asymmetric modes are broken and it is possible to solve the problem of the determination of the active mode parameters as a result of splitting the asymmetric modes of the network into the symmetric ones which will be realized direct, reverse and zero succession diagrams and all the laws defined for active parameter relation for the established symmetric networks will be fair for each succession diagram. So, our primary task is the computer modeling of the established, symmetric (normal and emergency) modes in the data base control system.**

**These two tasks, determination of the active parameters of normal and emergency modes, are based on one and the same equations, but by character they are quite different from each other. During determining the normal mode parameters, the key role is plaid by the energy quality. Given this, any decision is not satisfactory and it is necessary to imitate system automation effect and to have an impact on the initial data, for instance such as voltage regulation, implementation of longitudinal and latitudinal compensation, consideration of load voltage dependence, etc. All this requires that free participants in nodal voltage equations are presented in form of generation and consumer load capacities rather than by the currents. The obtained nonlinear equations are solved by any iterative method and it is possible to affect solution process by controlling reactive capacity flows.**

**When designing the emergency modes we are dealing with other problems, especially when analyzing the asymmetric modes, as the parameters of all three phases differ and it is impossible to draft just one-phase replacement diagram and to operate with the parameters of this phase. In this case, as already mentioned, the symmetric component method which actually means presentation of asymmetric mode by three symmetric modes, and the relation of the active parameters in each succession diagram is described by linear equations. Division in symmetric components increases the amount of unknowns. Besides,**

it becomes complicated to define the relation of the active parameters. Given this, it is necessary to develop the respective algorithms for the effective application of the symmetric component method.

The sum of emergency components of the active parameters and currents of the normal modes provides the values of emergency currents and voltages in the network. Except for the above mentioned, the normal mode parameters are the initial information for calculating the emergency components.

Before determining the emergency components, it is necessary to calculate the normal mode parameters by any equation describing the system condition. The unified equations interconnecting four main parameters $\dot{U}_{uz}, \dot{I}_{uz}, \dot{I}_{vet}, \dot{E}_{vet}$ of the power mode have the following form [1]:

$$\begin{bmatrix} M Y_d M^T & M Y_d \\ Y_d M^T & Y_d \end{bmatrix} \begin{bmatrix} \dot{U}_{uz} \\ \dot{E}_{vet} \end{bmatrix} = \begin{bmatrix} \dot{I}_{uz} \\ \dot{I}_{vet} \end{bmatrix}; \tag{1}$$

i.e.

$$\begin{aligned} M Y_d M^T \dot{U}_{uz} + M Y_d \dot{E}_{vet} &= \dot{I}_{uz} \\ Y_d M^T \dot{U}_{uz} + Y_d \dot{E}_{vet} &= \dot{I}_{vet} \end{aligned} \tag{2}$$

where, $\dot{U}_{uz}, \dot{I}_{uz}$ – vector-matrixes of nodal voltages and nodal currents;

$\dot{I}_{vet}, \dot{E}_{vet}$ –vector-matrixes of currents and voltages flowing into the branches; $Y_d$ - diagonal matrix of branch conductivity; M - I matrix of incidence in which the diagram topology is reflected.

Unknowns and free members of the equation (1) are determined according to the task as to which active parameters are to be calculated or the initial information we posses. If both nodal currents $\dot{I}_{uz}$ and electromotive forces switched to the branches $\dot{E}_{vet}$, from (2) will obtain:

$$\dot{U}_{uz} = [M Y_d M^T]^{-1} \dot{I}_{uz} - [M Y_d M^T]^{-1} M Y_d \dot{E}_{vet}. \tag{3}$$

if $\dot{I}_{uz}$, is given and $\dot{E}_{vet} = 0$, then the nodal voltage equation is obtained [2]:

$$M Y_d M^T \dot{U}_{uz} = \dot{I}_{uz}, \tag{4}$$

i.e.

$$\dot{U}_{uz} = [M Y_d M^T]^{-1} \dot{I}_{uz},$$

where,

$$Z_{uz} = [M Y_d M^T]^{-1} \tag{5}$$

is the nodal resistance matrix.

From (2) we receive the equation which connects the electromotive forces switched to the branches to the currents flowing into the branches:

$$\left[Y_d - [Y_d M^T][M Y_d M^T]^{-1}[M Y_d]\right] \dot{E}_{vet} = \dot{I}_{vet}. \tag{6}$$

here

$$Y_d - [Y_d M^T][M Y_d M^T]^{-1}[M Y_d] = Y_{uec}. \quad (7)$$

is private and mutual conductivity matrix.

Active normal mode parameters are found by the above equations. Mathematical model implemented by us is based on the equation (4):

$$Y_{uz} \dot{U}_{uz} = \dot{I}_{uz} -,$$

where,

$$Y_{uz} = M Y_d M^T. \quad (8)$$

The mentioned equation considering the nodal capacities and base voltage becomes nonlinear and has the following form [2]:

$$Y_{uz}(U'_{uz} - U_B) = [S_i^*/U_i^*]. \quad (9)$$

i.e.

$$Y_{uz} U'_{uz} = [S_i^*/U_i^*] + Y_{uz} U_B, \quad (10)$$

here $U_B$ –vector-matrix of the base voltages; $S_i^*, U_i^*$ – conjunct complexes of $i$ – elements of the vector-matrixes of the nodal capacities and voltages.

From the equation (10), by multiplying both sides by $Y_{uz}^{-1}$, we obtain the iteration form which is realized in our routine.

$$U'_{uz} = Y_{uz}^{-1}[S_i^*/U_i^*] + U_B \quad (11)$$

The nodal voltages of the active normal mode parameters and the capacity (current) flows within the lines being one of the main problems for providing normal functioning of the power system are determined with the mentioned routine. Imitation of voltage controller operation, the source of implementing the latitudinal and longitudinal compensation, etc. are realized in the routine.

So, except for the difficulties relating to the development of the mathematical model describing physical processes, there are the difficulties relating to the resolution of large dimension network problems. First of all this relates to the problem of regulating the voltage on the generator buses, consideration of static properties of loads, capability of implementing reactive capacity compensation. In order to develop effective algorithm, it is also necessary to select the method of solving complex numerical equations.

Compared to Seidel method, we achieved better result when applying simple iteration method as at this time we were able to relate every iteration pitch to the respective transient process power mode which was not successful in using Seidel method. Obtaining such a mathematical model was appropriate in case of using $Z_{uz}$ matrix, which we failed to achieve when using the nodal conductivity, i.e. initial equation form, as in case of using $Z_{uz}$ matrix (compared to $Y_{uz}$ matrix), the nodal voltages obtained at each pitch are close to unknown quantities and the rapidity of convergence is provided.

For the realization of the iteration process (4) complex value equation is split into two equation systems – true and complex value equation systems and the iteration process continues under reactive capacity correction conditions. After determining the nodal voltages, distribution of the currents and capacities in the network is defined.

**Besides, the obtained nodal voltages and currents flowing into the branches represent the initial information for designing various symmetric and asymmetric emergency mode parameters [3] which is also necessary for normal functioning of the power system.**

**Calculation of the emergency mode (short circuits and line decisions) parameters are done by the same unified linear equations (2) where unknown variables and free members change places, i.e. the nodal currents and electromotive forces in the lines ($\dot I_{uz}, \dot E_{vet}$) are presented as unknowns and the given values are precalculated pre-emergency nodal voltages and currents $\dot U'_{uz}, \dot I'_{vet}$ flowing within the branches.**

**As a result of the respective transformations, from (2) will obtain:**

$$[M\,Y_d M^T]^{-1}\dot I_{uz} - [M\,Y_d M^T]^{-1}[M\,Y_d]\dot E_{vet} = \dot U_{uz}; \tag{12}$$

$$[Y_d\,M^T][M\,Y_d\,M^T]^{-1}\dot I_{uz} + \left[Y_d - [Y_d\,M^T][M\,Y_d\,M^T]^{-1}[M\,Y_d]\right]\dot E_{vet} = \dot I_{vet},$$

**The power mode for any compensation of the so called latitudinal and longitudinal damages is described by (12) equations:**

**When calculating the short circuit currents, i.e. when there are the decisions and $\dot E_{vet} = 0$, one matrix equation with one unknown – reverse form of the nodal equation is left:**

$$[M\,Y_d M^T]^{-1}\dot I_{uz} = \dot U_{uz}.$$

**Just in the decision case, the emergency parameters are calculated with the following equation:**

$$\left[Y_d - [Y_d\,M^T][M\,Y_d\,M^T]^{-1}[M\,Y_d]\right]\dot E_{vet} = \dot I_{vet}.$$

**As mentioned above:**

$$[M\,Y_d M^T]^{-1} = Z_{uz},$$

$$Y_d - [Y_d\,M^T][M\,Y_d\,M^T]^{-1}[M\,Y_d] = Y_{vet}.$$

**If symbols are introduced:**

$$-[M\,Y_d M^T]^{-1}[M\,Y_d] = H;$$

$$[Y_d\,M^T][M\,Y_d\,M^T]^{-1} = T,$$

**Will get:**

$$\left.\begin{aligned} Z_{uz}\,\dot I_{uz} + H\dot E_{vet} &= \dot U_{uz} \\ T\,\dot I_{uz} + Y_{vet}\dot E_{vet} &= \dot I_{vet} \end{aligned}\right\}. \tag{13}$$

**From the obtained equations it is possible to calculate the active parameters of the symmetric emergency mode for any quantity of the concurrent symmetric short circuit and line decision case. In asymmetric damage, the method developed for the symmetric systems is considered with regards to the symmetric components, i.e. the mentioned equations are designed by direct, reverse and zero succession currents and voltages by passive**

**parameters of such succession diagrams taking into the account the boundary conditions characteristic for each accident.**

## R E F E R E N C E S


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