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# COMMON ALGORITHM OF STATIC STABILITY ESTIMATION AND COMPUTATION OF STEADY STATES OF POWER SYSTEMS

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*Generators with automatic control of excitation at studying static stability of electric system modes have been considered by transfer functions. Free number match conditions of the characteristic equation and matrix of Jacobi used in steady state calculations by the Newton method for various generator idealized models are analyzed. Features of using practical criteria of stability are examined.*

## Introduction

Rigorous solution of the research task of static stability in complex power systems is connected with the analysis of the characteristic equation root. It is known that loss of stability may occur in the form of self-oscillation or aperiodic character of changing mode parameters (mode mobility or its slide). Sharing this task: determination of boundary of oscillation and aperiodic loss of stability is conventional. Considering that loss of oscillation stability is removed by a correct adjustment of excitation automatic control system (EAC), zero crossing of absolute term of characteristic equation ($a_n$) or practical criteria corresponds to the boundary of static aperiodic stability [1, 2].

In order to study aperiodic stability the calculations of steady states and absolute term of the characteristic equation are required. In its turn, $a_n$ is obtained from the characteristic determinant (at differential operator $p=d/dt$ conversion into zero), corresponding to the linearized equation system of transients of the studied power system. Use of Newton method for steady state calculation requires computation of coefficient matrix of steady state linearized equations (matrices of Jacobi).

In the work [3] the coincidence of $a_n$ and Jacobian for special conditions is discussed. In this paper a possibility of closest approach of $a_n$ structure and matrix of Jacobi in general case is analyzed. Solution of the problem is based on presentation of generators with EAC by their static characteristics. In matrix $a_n$ the generators are represented by steepness coefficients of their static characteristics. In this case the matrix of Jacobi may be obtained from matrix $a_n$ taking into account those conditions which are accepted in computations of steady states that allows estimating conditions of their adequacy.

## Characteristic determinant of complex electric system

Let us consider that electric system contains nodes to which two-terminal networks substituting generators and loads are connected. In transient or steady state for each node $i$ in general case the equations in the form of increments:

$$\Delta P_i - \Delta P_{\Gamma i} + \Delta P_{\text{H}i} = 0,\ \Delta Q_i - \Delta Q_{\Gamma i} + \Delta Q_{\text{H}i} = 0, \quad (1)$$

are valid. Here power positive direction for generator (G) is accepted to the node; for the load (L) and passive part of the circuit – from the node. A number of equations of the type (1) equals $n$ and their summands in general case are operator functions. For short of notations let us accept $F(p)=\overline{F}$. We obtain functional dependences of the expressions included into (1).

*1. The increment equations of powers of generator with EAC.*

The expressions of active ($P$) and reactive ($Q$) powers of generator in transient state may be introduced as a stress function ($U$) and absolute phase ($\delta_U$) at its terminals:

$$P = \overline{P}(U, \delta_U),\ Q = \overline{Q}(U, \delta_U)$$

and properly, in the form of increments

$$\Delta P = \overline{\alpha}\Delta U + \overline{\sigma}\Delta\delta_U,\ \Delta Q = \overline{\beta}\Delta U + \overline{\gamma}\Delta\delta_U. \quad (2)$$

The transfer functions $\overline{\alpha}$, $\overline{\sigma}$, $\overline{\beta}$, $\overline{\gamma}$ are found from the linearized system of algebraic and operational equations of generator transient state. There is a following system [4, 5], Table for their founding.

***Table.*** *The equations of EAC generator transient*

| Mathematical expression | Physical meaning | № of equation |
|---|---|---|
| $P = \frac{E_q U}{X_d}\sin\delta_\Gamma$, $Q = -\frac{U^2}{X_d} + \frac{E_q U}{X_d}\cos\delta_\Gamma$ | Generator powers | (3) |
| $T_j \frac{d^2\delta_\Gamma}{dt^2} = P_T - P$ | Electromechanical transient | (4) |
| $E_q = E_{qe} - T_{d0}\frac{dE'_q}{dt}$ | Transient of generator excitation circuit | (5) |
| $E_{qe} = E_{q0} + \overline{W}_U(U_0 - U) + \overline{W}_I(I - I_0)$ | Forced emf at EAC by при АРВ по *U* and *I* | (6) |
| $\overline{W}_\Pi = \frac{1}{(1+pT_e)(1+pT_p)} \times \left[\frac{K_{O\Pi}}{1+pT_u} + \frac{pK_{1\Pi}}{1+pT_\partial}\right]$ | EAC transfer function by П=*U*,*I* | (7) |
| $E'_q = E_q\frac{X'_d}{X_d} + U\frac{X_d - X'_d}{X_d}\cos\delta_\Gamma$ | Connection of transient and synchronous internal voltage | (8) |
| $I = \frac{1}{X_d}\left[E_q^2 + U^2 - 2E_q U\cos\delta_\Gamma\right]^{1/2}$ | Generator stator current | (9) |

where $E_q$, $X_d$, $X'_d$ are the synchronous internal voltage, synchronous and transient reactivity; $T_j$, $P$, $P_T$ are the constant of machine inertia, electromagnetic power and turbine power; $\delta_\Gamma=\delta_E-\delta_U$ is the generator interior angle; $E'_q$, $E_{qe}$, $T_{d0}$ are the transient, forced internal voltage and time constant of excitation winding at starter open circuit; $E_{q0}$, $U_0$, $I_0$ are the adjusting values of the controlled parameters; $T_e$, $T_p$, $T_u$, $T_\partial$ are the time constants of load-bearing rectifying, measuring and differentiating elements of the EAC system; $K_{0\Pi}$, $K_{1\Pi}$ are the gain coefficients by deviation and deviation rate of the controlled parameter $\Pi$ (positive values).

Paying attention to computation of functions $\overline{\alpha}$, $\overline{\beta}$, we substitute the expression $E_{qe}$ from (6) considering (9) into equation (5) and linearize the equation system (3–5, 8) by independent variables $E_q$, $E'_q$, $U$, $\delta_E$. The obtained system subject to substitution of differential equations by the operator ones is written down as:

$$\begin{bmatrix} -1 & 0 & \frac{\partial P}{\partial E_q} & 0 & \frac{\partial P}{\partial \delta_E} \\ -1 & 0 & 0 & 0 & -T_j p^2 \\ 0 & -1 & \frac{\partial Q}{\partial E_q} & 0 & \frac{\partial Q}{\partial \delta_E} \\ 0 & 0 & -1+\sum^{\Pi}\overline{W}_{\Pi}\frac{\partial \Pi}{\partial E_q} & -T_{d0}p & \sum^{\Pi}\overline{W}_{\Pi}\frac{\partial \Pi}{\partial \delta_E} \\ 0 & 0 & \frac{\partial E'_q}{\partial E_q} & -1 & \frac{\partial E'_q}{\partial \delta_E} \end{bmatrix} \begin{bmatrix} \Delta P \\ \Delta Q \\ \Delta E_q \\ \Delta E'_q \\ \Delta \delta_E \end{bmatrix} = -\begin{bmatrix} \frac{\partial P}{\partial U} \\ 0 \\ \frac{\partial Q}{\partial U} \\ \sum^{\Pi}\overline{W}_{\Pi}\frac{\partial \Pi}{\partial U} \\ \frac{\partial E'}{\partial U} \end{bmatrix} \Delta U. \quad (10)$$

From (10) we obtain the desired functions

$$\frac{\Delta P}{\Delta U} = \frac{\overline{A}_{pU}}{\overline{D}_U} = \overline{\alpha}, \quad \frac{\Delta Q}{\Delta U} = \frac{\overline{A}_{qU}}{\overline{D}_U} = \overline{\beta}. \quad (11)$$

Here and then owing to bulkiness of the obtained expressions they are introduced in structural form with selection of those summands which contain factor $p$. B (11) $\overline{D}_U$ is the main determinant of the system (10); $\overline{A}_{pU}$, $\overline{A}_{qU}$ are the determinants obtained from the main one by substitution, properly, the columns of coefficients at $\Delta P$ and $\Delta Q$ by the coefficients of the right part at $\Delta U$. In structural form the given determinants may be introduced so:

$$\overline{D}_U = \overline{C}_0 + \overline{C}_1 p, \; \overline{A}_{pU} = \overline{C}_2 T_j p^2, \; \overline{A}_{qU} = \overline{C}_3 + \overline{C}_4 p. \quad (12)$$

Computation of the operator functions $\overline{\sigma}$, $\overline{\gamma}$ according to (2) are carried out if $U$=const; $\delta_U$ acts as independent absolute angle. Linearizing the equation (4) by an argument $\delta_U$ and passing to operator notation, we have:

$$\frac{\Delta P}{\Delta \delta_U} = \overline{\sigma} = -T_j p^2. \quad (13)$$

Linearizing the rest equations (3), (5), (8) subject to (6), (9) by independent variables $E_q$, $E'_q$, $\delta_U$ and passing to operator form, we have the system:

$$\begin{bmatrix} 0 & \frac{\partial P}{\partial E_q} & 0 & \frac{\partial P}{\partial \delta_U} \\ -1 & \frac{\partial Q}{\partial E_q} & 0 & \frac{\partial Q}{\partial \delta_U} \\ 0 & -1+\sum^{\Pi}\overline{W}_{\Pi}\frac{\partial \Pi}{\partial E_q} & -T_{d0}p & \sum^{\Pi}\overline{W}_{\Pi}\frac{\partial \Pi}{\partial \delta_U} \\ 0 & \frac{\partial E'_q}{\partial E_q} & -1 & \frac{\partial E'_q}{\partial \delta_U} \end{bmatrix} \begin{bmatrix} \Delta Q \\ \Delta E_q \\ \Delta E'_q \\ \Delta \delta_U \end{bmatrix} = \begin{bmatrix} \Delta P \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad (14)$$

we find

$$\frac{\Delta Q}{\Delta P} = \frac{\overline{A}_{q\delta}}{\overline{A}_{p\delta}} = \overline{\eta}, \quad (15)$$

where $\overline{A}_{p\delta}=\overline{C}_5+C_6T_{d0}p$ is the determinant of the system (14); $\overline{A}_{q\delta}=\overline{C}_7+C_8T_{d0}p$ is the determinant obtained from the main one by substitution of coefficients at $\Delta Q$ by coefficients at $\Delta P$. Content of coefficients $C_0$–$C_8$ is introduced in [6]. On the basis of (15) subject to (13) the desired function is found:

$$\frac{\Delta Q}{\Delta \delta_U} = \overline{\eta}\overline{\sigma} = \overline{\gamma}. \quad (16)$$

*2. Increment equations of multipole powers.*

Multipole state is described by the equations of network power in trigonometric representation [7]: $P=P(U,\delta)$, $Q=Q(U,\delta)$. Developing them by independent variables $U_i$, $\delta_i$ ($i$=1,...,$n$) we obtain the system of power increment:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial U} & \frac{\partial P}{\partial \delta} \\ \frac{\partial Q}{\partial U} & \frac{\partial Q}{\partial \delta} \end{bmatrix} \begin{bmatrix} \Delta U \\ \Delta \delta \end{bmatrix}. \quad (17)$$

*3. Increment equations of load power.*

Load is taken into account by voltage static characteristics: $P_H=P(U)$, $Q_H=Q(U)$, and in linearized form:

$$\Delta P_H = \alpha_H \Delta U, \; \Delta Q_H = \beta_H \Delta U. \quad (18)$$

In order to obtain the characteristic determinant the power increments in equations (1) are substituted by the equal expressions: fro generators from the equations (2); for multipole according to (17) and for the load from (18). As a result we obtain matrix equation (19), where:

$$\overline{\alpha}_i = \sum \overline{\alpha}_{\Gamma j} - \sum \overline{\alpha}_{Hj}, \; \overline{\beta}_i = \sum \overline{\beta}_{\Gamma j} - \sum \overline{\beta}_{Hj}, \; j=1,...,k,$$

where $k$ is thee number of single-type two-terminals networks abutting on node $i$.

$$\begin{bmatrix} \frac{\partial P_1}{\partial U_1}-\overline{\alpha}_1 & \cdots & \frac{\partial P_1}{\partial U_n} & \frac{\partial P_1}{\partial \delta_1}-\overline{\sigma}_1 & \cdots & \frac{\partial P_1}{\partial \delta_n} \\ \frac{\partial P_n}{\partial U_1} & \cdots & \frac{\partial P_n}{\partial U_n}-\overline{\alpha}_n & \frac{\partial P_n}{\partial \delta_1} & \cdots & \frac{\partial P_n}{\partial \delta_n}-\overline{\sigma}_n \\ \frac{\partial Q_1}{\partial U_1}-\overline{\beta}_1 & \cdots & \frac{\partial Q_1}{\partial U_n} & \frac{\partial Q_1}{\partial \delta_1}-\overline{\gamma}_1 & \cdots & \frac{\partial Q_1}{\partial \delta_n} \\ \frac{\partial Q_n}{\partial U_1} & \cdots & \frac{\partial Q_n}{\partial U_n}-\overline{\beta}_n & \frac{\partial Q_n}{\partial \delta_1} & \cdots & \frac{\partial Q_n}{\partial \delta_n}-\overline{\gamma}_n \end{bmatrix} \begin{bmatrix} \Delta U_1 \\ \Delta U_n \\ \Delta \delta_1 \\ \Delta \delta_n \end{bmatrix} = 0. \quad (19)$$

Let us note that for submatrices $\partial P/\partial\delta$, $\partial Q/\partial\delta$ (17) and (19) the identity:

$$\frac{\partial P_i}{\partial \delta_i} = -\sum \frac{\partial P_j}{\partial \delta_j}, \; \frac{\partial Q_i}{\partial \delta_i} = -\sum \frac{\partial Q_j}{\partial \delta_j}, \; j=1,...,n, \; j \neq i. \quad (20)$$

is valid.

It allows getting rid of zero summands in determinant (19). Let us add the columns to numbers $n$+1, $n$+2, $n$+2,...,2$n$. As a result subject to (20) we obtain a new column (2$n$), the elements of which are the transfer functions ($-\overline{\sigma}_i$) for $i$=1,2,...,$n$ and ($-\overline{\gamma}_i$) for $i$=$n$+1,...,2$n$. Taking into account that $\overline{\sigma}_i=-T_{ji}p^2$ and

$\overline{\sigma}_i = -T_{ji}p^2$ we note that all the elements of a new column contain factor $p^2$. For its deletion let us exchange the variables according to connection (13):

$$\Delta\delta_n = \frac{-\Delta P_n}{T_{jn}p^2}. \quad (21)$$

As a result the elements of the column $2n$ in (19) have the same form as in (26), on condition:

$$K_{j(in)} = T_{ji} / T_{jn} \quad (22)$$

and coefficients $\overline{\eta}_i$ are operating.

The carried out substitution of the variables results in attachment of the coordinate $\Delta\delta_n$. The coefficients of a newly formed column at $\Delta P_n$ have certain physical content that will be noted below. The determinant $D'(p)$ obtained in this way is connected to the following characteristic relation:

$$D(p) = D'(p)T_{jn}. \quad (23)$$

On condition $p=0$ the transfer functions $\overline{\alpha}$, $\overline{\sigma}$, $\overline{\beta}$, $\overline{\gamma}$ become real values and represent the steepness coefficients.

From the first equation (1) subject to (12), as well as from (13) and (16) at $p=0$ we have: $\alpha=0$, $\sigma=0$, $\gamma=0$. Coefficient $\beta_Г$ is obtained from (11) subject to the content $\overline{A}_{qU}$ and $\overline{D}_U$ at $p=0$:

$$\beta_Г = \frac{\partial Q_Г}{\partial U} = \frac{E_q - 2U\cos\delta_Г - K_{0U}U - K_{0I}I}{x_d\cos\delta_Г - K_{0I}\sin\varphi_Г}. \quad (24)$$

Referring to (15), on condition $p=0$, we have:

$$\eta_Г = \frac{\partial Q_Г}{\partial P_Г} = \frac{K_{0I}\cos\varphi_Г - x_d\sin\delta_Г}{x_d\cos\delta_Г - K_{0I}\sin\varphi_Г}. \quad (25)$$

Accepting $p=0$ in (19) and taking into account the substitution of the variables carried out before, we obtain the linearized equation system of steady state

$$\left[\begin{array}{ccccc|cccc}
\frac{\partial P_1}{\partial U_1}-\alpha_1 & \cdots & \frac{\partial P_1}{\partial U_i} & \cdots & \frac{\partial P_1}{\partial U_n} & \frac{\partial P_1}{\partial \delta_1} & \cdots & \frac{\partial P_1}{\partial \delta_{n-1}} & K_{j(1n)} \\
\frac{\partial P_i}{\partial U_1} & \cdots & \frac{\partial P_i}{\partial U_i}-\alpha_i & \cdots & \frac{\partial P_i}{\partial U_n} & \frac{\partial P_i}{\partial \delta_1} & \cdots & \frac{\partial P_i}{\partial \delta_{n-1}} & K_{j(in)} \\
\frac{\partial P_n}{\partial U_1} & \cdots & \frac{\partial P_n}{\partial U_i} & \cdots & \frac{\partial P_n}{\partial U_n}-\alpha_n & \frac{\partial P_n}{\partial \delta_1} & \cdots & \frac{\partial P_n}{\partial \delta_{n-1}} & 1 \\
\hline
\frac{\partial Q_1}{\partial U_1}-\beta_1 & \cdots & \frac{\partial Q_1}{\partial U_i} & \cdots & \frac{\partial Q_1}{\partial U_n} & \frac{\partial Q_1}{\partial \delta_1} & \cdots & \frac{\partial Q_1}{\partial \delta_{n-1}} & \eta_i K_{j(1n)} \\
\frac{\partial Q_i}{\partial U_1} & \cdots & \frac{\partial Q_i}{\partial U_i}-\beta_i & \cdots & \frac{\partial Q_i}{\partial U_n} & \frac{\partial Q_i}{\partial \delta_1} & \cdots & \frac{\partial Q_i}{\partial \delta_{n-1}} & \eta_i K_{j(in)} \\
\frac{\partial Q_n}{\partial U_1} & \cdots & \frac{\partial Q_n}{\partial U_i} & \cdots & \frac{\partial Q_n}{\partial U_n}-\beta_n & \frac{\partial Q_n}{\partial \delta_1} & \cdots & \frac{\partial Q_n}{\partial \delta_{n-1}} & \eta_n
\end{array}\right]
\left[\begin{array}{c}
\Delta U_1 \\ \Delta U_i \\ \Delta U_n \\ \hline \Delta\delta_1 \\ \Delta\delta_{n-1} \\ -\Delta P_n
\end{array}\right] = 0, \quad (26)$$

the main determinant of which gives the coefficient $a'_n$, connected with the absolute term of the characteristic equation by the relation similar to (23): $a_n = a'_n T_{in}$. As $T_{jn} > 0$ then the power system stability may be judged by the determinant zero crossing (26) at state weighting from knowingly stable state. Let us note that a sign $a_n$ ($a'_n$) in stable region depends on the accepted positive direction of flows in a circuit.

#### Estimation of static aperiodic stability of power systems

Coefficients $K_{j(m)}$ at $\Delta P_n$ in determinant (26) may attach value of weighting coefficients determining fractional participation of generating nodes in covering active power unbalance occurring at state deformation. This fractional participation is expressed in the ratio relative to unbalance accepted by node $n$.

If $P$, $Q$ are accepted as independent variables for generators in calculations of steady states and they are taken into account by static characteristic $Q_Г = Q(U_Г, P_Г)$, then matrix of Jacobi ($W$) may be obtained from matrix (26) at its slight updating: accept node $n$ as a balancing by active power i.e. consider all $K_{j(m)} \equiv 0$. At these conditions $a_{n,2n}=1$, $a_{2n,2n}=\eta_n$ are nonzero elements of the last column of matrix $W$. This implies, that in general case, the matrix of Jacobi and $a'_n$ do not coincide. Such coincidence is possible in a special case: $T_{jn} >> T_{ji}$ i.e. $K_{j(m)}=0$, that corresponds to the presence of «infinite» buses in electromechanical sense (frequency constancy in node $n$). Computing the states in balancing node ($n$), voltage is specified as a rule. Analyzing stability the voltage constancy in the node $n$ is adequate to this. At these conditions the order of matrices $W$ and $a'_n$ decreases by two: a line $2n$ and column $n$ may be excluded and therefore, a line n and column $2n$.

Let us refer to the conditions of coincidence of $W$ and $a'_n$ at information assignment for generating nodes in the form of $P$, $U$. Computing the states such presentation is more preferable by a number of reasons.

The circumstance that voltage for generator node is known allows decreasing the order of the main determinant of the system (26) excluding the column of coefficients corresponding to specifying voltage and line of reactive power coefficients of the same node. A number of such exclusions equals the number of generating nodes with specified $P$, $U$. Studying static stability the floating voltage control $U_i$=const corresponds to this. As applied to the accepted model of generator with EAC it means that coefficient $\beta_{Гi}$ characterizing «stiffness» of voltage control tends to infinity. It is fulfilled at $K_{0U} \to \infty$ and $K_{0I} \neq \infty$. Let us note that the real value $\beta_Г$ (24) depends considerably on the value of $K_{0I}$. As magnitudes of $K_{0U}$ amount to 50...200 units of excitation/units of voltage and $K_{0I}$ is 1...5 units of excitation/units of current for EAC of dramatic effect then virtually in (26) the condition:

$$\beta_{Гi} >> \frac{\partial P_j}{\partial U_i};\ \frac{\partial Q_j}{\partial U_i};\ \alpha_i,\ j = 1,...,n. \quad (27)$$

may be accepted.

Let us note that the highest value have the relation

$$\frac{\partial Q_i}{\partial U_i} \Big/ \beta_{Гi} \le 0,07.$$

Using (24), we carry out substitution of variables in $\Delta U_i = \Delta Q_i / \beta_{Гi}$ in matrix (26). Subject to (27) all elements of the column $i$ may be considered equal zero except $a_{n+i,i} = -1$, that allows decreasing the order of matrix $a'_n$ by a number of generating nodes providing $U_i$=const.

In states approximate to the limiting ones the restriction $Q_Г = Q_{Г\max}$ is probable. In this case condition $U$=const is not valid for the given generators that requires their modeling by static characteristics.

Along with the noted estimation techniques of stability the practical criteria are used [1] in particular $dQ/dU$. Applying external disturbance $\Delta Q_{i(\text{BH})}$ to the node $i$ on condition that $\Delta P_{i(\text{BH})}=0$ the reaction in the form of $\Delta U_i$ is found that on the basis of (26) gives

$$\beta_{i(BH)} = \frac{\Delta Q_{i(BH)}}{\Delta U_i} = \frac{D_n}{A_{n+i,i}}, \qquad (28)$$

where $D_n$ is the main determinant of the matrix (26); $A_{n+i,i}$ is the cofactor.

It should be noted that attachment of noninertial coordinate $U_i$ in matrix $a_n'$ corresponds to $A_{n+i,i}$ calculation. It allows drawing a conclusion that $A_{n+i,i}$ is the determinant of absolute term of the characteristic equation of the studied power system in which the condition $U_i$=const is provided. It is naturally that in this case the power system is more stable (have higher safety factor) than the initial one. Therefore, when moving from knowingly stable state to the boundary, then first of all the determinant $D_n$ crosses zero (in this case $A_{n+i,i}\neq 0$) that involves a change of sign $\beta_{i(\text{BH})}$. At the next state weighting in unstable region for the studied power system $A_{n+i,i}$ and sign $\beta_{i(\text{BH})}$ cross zero and in this case the latter coincides with the sign in stable region. The results obtained in [8] by calculation without their validating confirm this. Thus, stable region with the boundary $A_{n+i,i}=0$ is larger than the region with the boundary $D_n=0$. Their difference is determined by electric remoteness of the node $i$ from the node with $U$=const. Criterion $dP_i/d\delta_i$ is not subjected to the above mentioned duality and changes its sign once on stability boundary. Use of the criterion (28) by calculation of two determinants is more time consuming than using $W$ or $a_n'$. Calculation of $\beta_{i(\text{BH})}$ by numerical differentiation method on the basis of controlled state is of practical interest. Accepting $U_i \pm \Delta U_i$ in the node $i$ at constancy of operating conditions in all the other system nodes the perturbed mode ($\Delta Q_{i(\text{BH})}$) is calculated provided that the infinite buses are the balancing ones by $P$. If positive direction $\Delta Q_{i(\text{BH})}$ is accepted to the node $i$, then inequality $\beta_{i(\text{BH})}>0$ corresponds to stable state by (28). This method of estimating stability is not connected with the method and algorithm of state calculation.

### Conclusion

The matrix of Jacobi of steady state equations of the electric system coincides with the absolute term of the characteristic equation at the following conditions.

1. In the design diagram there should be a node considered as the infinite buses which is accepted a balancing one by the active power.
2. The same static characteristics of the loads that at stability estimation should appear in state calculations.
3. In state calculations and stability estimation the generators are taken into account by the same static characteristics $Q_\Gamma = Q(U_\Gamma, P_\Gamma)$; in this case $Q_\Gamma$, $P_\Gamma$ are the independent variables for generators.

If the constant-error behavior of EAC generators are neglected at stability calculation i. e. consider $U_i$=const, that is almost unacceptable, then the condition 3 is modified: $U_\Gamma$, $P_\Gamma$ are accepted as the independent variables for generator nodes in state calculation.


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