

Artificial genetic code of development of electric power system

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Abstract. The paper presents the results of research concerning the identification of electric power system development, which was carried out for the IEEE RST 96 test data [4, 13]. The problem of development was formulated in the form of artificial genetic code, and the results of the research concerning the regularities of the development of the electric power system on the basis of IEEE RST 96 test data, including the obtained coefficient-based artificial code of development.

Keywords. Modern electric power system, unmanned manufactory, self-developing system, control theory, identification of development, MATLAB and Simulink

1 Introduction

1.1 Research concerning regularities in the development

It is convenient to examine structural changes and parametric changes in long time θ in order to conduct research concerning regularities in development of the electric power system (polish: System Elektroenergetyczny: SEE). Movement of roots on the complex variable plane s and the method of Evans' root lines may be used to examine the problem of the SEE system development [2, 10, 11-18].

Parametric changes are connected with movement of roots along the existing root lines, and structural changes are connected with the appearance of new lines or disappearance of the existing ones. Parametric changes are connected with introduction of new values of coefficients, and structural changes are connected with the appearance of a higher order polynomial or the reduction of the order of the polynomial. A sign of structural changes is the appearance of a new coefficient a_3 in the characteristic equation.

As a result, the programming development technique is oriented towards finding not only laws and principles of development but also laws and principles governing the changes of the model of development in long time θ . In the discussed

case, the model of development is a state variables model, described in paper [5, 12], with the parametric changes being connected with the change in the value of the coefficients elements in the matrix th polynomials.

In case of structural changes, the quantities and the number of terms of polynomials $A(q)$ and $B(q)$ as well as their orders change, which results from the fact that the model takes into account new inputs and outputs (or resignation from the existing ones), which may be a result of technological, organizational, etc. changes. Structural changes taking place in the SEE system result both from the change in the number of elements and the relations between the elements. Figure 1 presents an example course of Evans' root lines for the model arx 524 of the

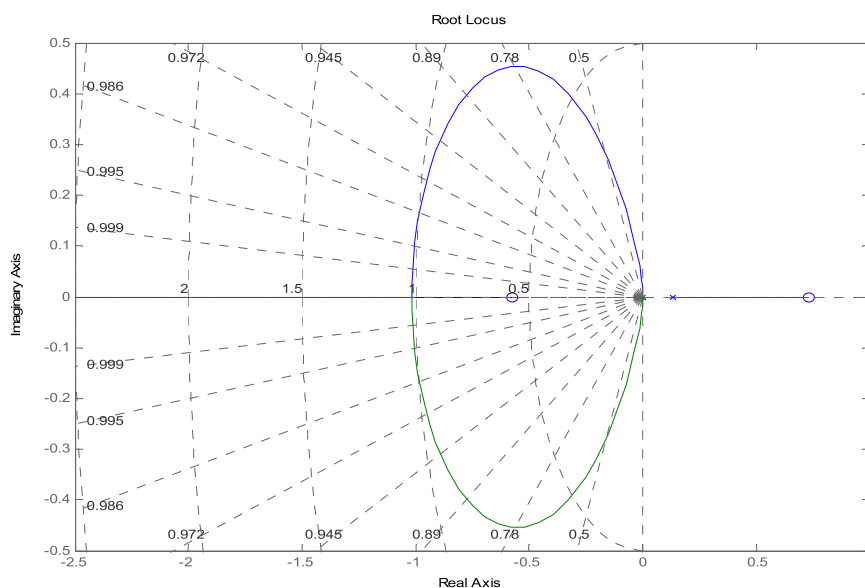


Figure. 1 Evans' root lines courses for the model arx524 of the electric power system development in the years 1946-2007

SEE system. 4 lines are situated on the left half-plane of the complex variable s , and one on the right one. Thus, the models of development used so far, apart from the described root structure situated on the right half-plane, were rather stable. The main goal of development is, first and foremost, shift or removal of the root line situated on the right half-plane of the complex variable s .

On the other hand, the analysis of the SEE electric power system, based on the changes of the matrix th elements indicates, that the SEE system, as a developing system, is characterized by a changeable structure, is dependent on long time θ and is sensitive (susceptible) to changes of the parameters of development.

1.2 Structural and parametric corrections of the development

In order to introduce structural changes, it may be assumed that there is a new state variable $x_{32}(\theta)$, a new input e.g. $u_{15}(\theta)$ or a new output $y_2(\theta)$, and then

appropriately corrected parametric equations, and, in consequence, equations in the state space may be obtained.

The introduced corrections influence the structural changes, which in turn influences at least the following parameters (elements of matrix A), i.e. m_{ij} , k_{ij} , l_{ij} , n_{ij} . In order to establish the value of these parameters it is necessary to estimate the upper and the lower limits of safe development of the SEE system model, and, in consequence, the safe development of the SEE system.

Parameters m_{ij} are elements of matrix A , and parameters k_{ij} are elements of matrix B . Parameters l_{ij} are elements of matrix C , and parameters n_{ij} are parameters of matrix D . The discussed case concerns the change of the order of the matrices A and B .

In case of matrix A there are 21 parameters, for which the values must be estimated, and in case of matrix B there are 15 parameters that need to be estimated. In total, there are 36 parameters that must be estimated, which are necessary to formulate the state equation (6 additional parameters appears in connection with the output equation). Parametric changes do not unbalance the safety of development of the SEE model and the development of the electric power system. However, structural changes unbalance the system and result in unsafe state of both the model and the electric power system (SEE), which, in turn, may result in a sudden change in the quantity characteristics and the values of quantities of state, input and output variables.

In order to examine the stability of linear, continuous systems or impulse-based ones it is necessary to examine the location of the characteristic equation roots using appropriate criteria of stability, which showed that some of the models obtained by means of identification, both arx models or corresponding models in the state space were unstable (some roots of characteristic equation were not located on the left half-plane of the complex variable). There are a lot of possible interpretations of the concept of instability.

It is possible to say, after Robert Staniszewski, that one-dimensional linear model of the development of the electric power system is stable when the values of parameters and the relations between them (structure) do not belong to the critical state of the values of the elements and relations [5, 7-11], which is strictly connected with the concept of development safety, i.e. a system of development such as the electric power system, one-dimensional linear system is unstable when it may reach critical states defined by the physical nature of the processes taking place in the electric power system. The interpretation of this instability may be conducted after the analysis of the nature of the development of the electric power system.

The causes of unstable development might be the physical nature of the development of the electric power system (some physical processes in the development of the system may have a tendency to unstable development, e.g. imposed emission restrictions), faults in the construction of systems and elements of the electric power system as a technical system, technological problems and errors, especially those resulting from the incorporation of new technologies concerning the use of renewable resources of energy into the existing energy system.

Finally, it must be emphasized that parametric changes, allow for the change of zeros and poles on the complex variable plane so as they all were located on the left half-plane of the complex variable in some cases only. However, an efficient method is a method of forced structural changes, which by means of the introduction of new zeros and/or poles result in a new distribution of the existing zeros and poles, and a new distribution of Evans' root lines.

Therefore, the elimination of the instability of the electric power system is connected with the need to introduce parametric changes. If the results are not sufficient, structural changes have to be made or system transformation has to take place. In this case, it is of primary importance to eliminate the cost connected with unstable functioning of the electric power system and the development of the electric power system. In the discussed experiment, structural changes connected, i.a. with technological changes e.g. adding new powers to the SEE system, adding new power lines as well as economic changes e.g. denomination of Polish currency, were the cause of instability of the development. Moreover, the case discussed in the paper is connected with the stability of the SEE system and the model of the SEE system, and positive or negative feedback is responsible for the development. Thus, temporary instability of the development should be treat as a warning to the development designers.

It is also important to notice that state equations describe the transition of the electric power system from one state of development to another. They are usually non-linear, which may be transformed to the linear form by means of differentiation in the neighbourhood of points of the SEE system development as specific points of the electric power system work. Moreover, it is necessary to add characteristic roots of the SEE system and their level as regards their domination (which ones dominate) are the stability identifiers and they measure its level.

They refer to the simultaneous connections represented by the process organization matrices A (so called transition matrices), which take into account the current adjustments within a given unit of long time θ , but they result from matrix C representing connections between periods, which were not strong in the discussed experiments. It is said that the development system approaches the balance if it is stable, and stability is sustained by means of steering to obtain dynamic equilibrium.

In order to reach the stability of development it is necessary to shift the roots (and root lines) located on the right half-plane of the complex variable s to the left half-plane or to the beginning of the co-ordinate system or eliminate them, or introduce new ones. It is connected with the necessity to analyze the system balance and stability of the development.

The SEE system development instability results in critical states, and, it depended on technological, construction or organizational errors in the discussed cases. When designing the SEE system development it is important to ensure such shifts of roots that they do not go beyond the ordinate axis $\text{Im}(s)$ and to maintain appropriate relations between the amplification coefficient and time constants during the SEE development. The source of the information allowing to evaluate the stability of the linear system are amplitude- and phase-based logarithmic characteristics. Changes of these characteristics provide information (warning) concerning the wear or the improvement of the system. In conclusion, the stability of the development as

well as changes in the stability of the development were examined for the presented models of the SEE system by means of the conducted experiments. In this way, the information was obtained about changes of parameters as well as the information concerning the elements of the matrices in the state equations, which facilitated the determination of the reserve of stability of the development safety. This information should be a warning for the designers of future states of development of the electric power system and for future models of the SEE system development to eliminate the risk of the occurrence of states of unstable development of the electric power market.

2 The code of the SEE system development

2.1 Coding of development

Coding of the development of the electric power system is connected with obtaining the model of development in the form of artificial genetic code (development code). In case of the coefficient-based code of development for the SEE system, the following artificial code may be obtained [10-15]:

$$K_s^w(V, a) = [1; -0.395m_{22} + m_{11} \cdot m_{21}, 0.395 - m_{22}, 1]. \quad (1)$$

In case of structural changes, there appears a new artificial gene in the code of development, which may be put down as follows:

$$K_s^w(V, a) = [1; -0.395m_{22} + m_{11} \cdot m_{21}, 0.395 - m_{22}, 1, a_3], \quad (2)$$

and the quantity a_3 may be determined analytically or experimentally, which was described in papers [11-14].

2.2 Coefficient-based codes of development as a reflection of the changes of the SEE system

For the models IEEE RST 96¹, the following artificial genetic codes are obtained, e.g. for $A(q)$ – for the coefficient at the term q^{-1} in accordance with the formula [11-15]:

$$\begin{aligned} K_{gw0}^s(\bar{k}^i, q_0) &= (v_0; a_1, a_2, \dots, a_n; b_1, b_2, \dots, b_m), \\ K_{gw1}^s(\bar{k}^i, q_1) &= (v_0'; a_1', a_2', \dots, a_n'; b_1', b_2', \dots, b_m'), \end{aligned}$$

¹ Tchórzewski J: Artificial Genetic Code as a model of development of Electric Power System. Journal of Artificial Intelligence, AI-26'2010. Siedlce 2010

$$K_{g_{v_2}}^s(\overline{k^i}, q_2) = (v_0^i; a_1^i, a_2^i, \dots, a_n^i; b_1^i, b_2^i, \dots, b_m^i), \quad (3.1)$$

$$\dots\dots\dots \dots\dots\dots \dots\dots\dots \dots\dots\dots \dots\dots\dots \dots\dots\dots \dots\dots\dots$$

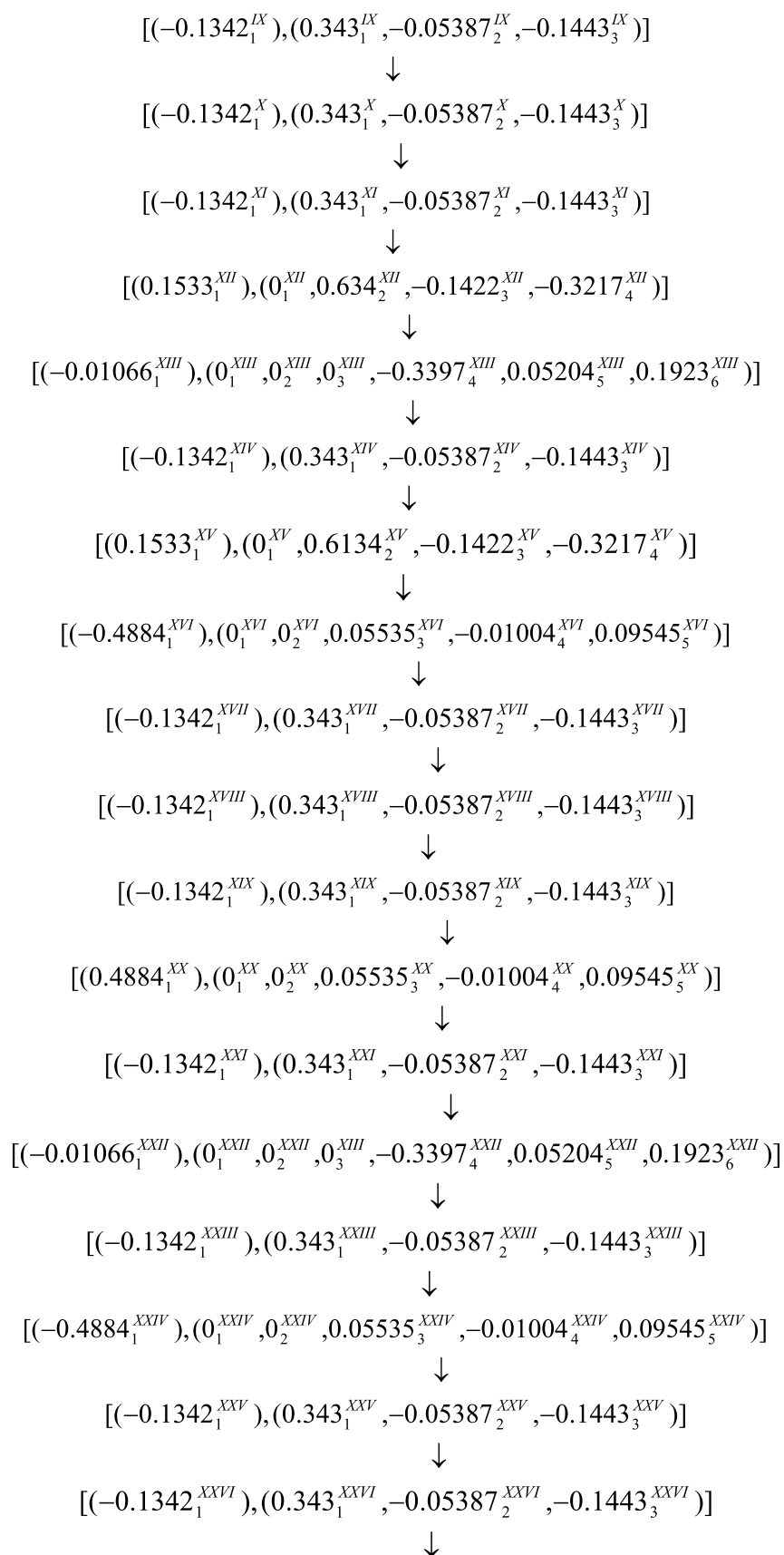
$$K_m(\overline{k^i}, q_m) = (v_0^{(k)}; a_1^{(k)}, a_2^{(k)}, \dots, a_n^{(k)}; b_1^{(k)}, b_2^{(k)}, \dots, b_m^{(k)}),$$

where for example for ch_1 – genetic code connected with parametric changes of the *first* coefficient ($i=1$) in the term $A(q)$ at the time shift operator q^{-1} , for the coefficient-based notation (changes in the value of the coefficient take place in the periods of long time θ and are can be noticed at transitions from one period to another):

$$\begin{aligned} ch_1 : & -0.1342_1^I \rightarrow -0.1342_1^{II} \rightarrow -0.1342_1^{III} \rightarrow -0.1342_1^{IV} \rightarrow -0.09354_1^V \rightarrow -0.09354_1^{VI} \rightarrow \\ & \rightarrow -0.1342_1^{VII} \rightarrow -0.1342_1^{VIII} \rightarrow -0.1342_1^{IX} \rightarrow -0.1342_1^{X} \rightarrow -0.1342_1^{XI} \rightarrow 0.1533_1^{XII} \rightarrow \\ & \rightarrow -0.01066_1^{XIII} \rightarrow -0.1342_1^{XIV} \rightarrow 0.1533_1^{XV} \rightarrow -0.4884_1^{XVI} \rightarrow -0.1342_1^{XVII} \rightarrow \\ & \rightarrow -0.1342_1^{XVIII} \rightarrow -0.1342_1^{XIX} \rightarrow -0.4884_1^{XX} \rightarrow -0.1342_1^{XXI} \rightarrow -0.01066_1^{XXII} \rightarrow \\ & \rightarrow -0.1342_1^{XXIII} \rightarrow -0.4884_1^{XXIV} \rightarrow -0.1342_1^{XXV} \rightarrow -0.1342_1^{XXVI} \rightarrow 0.1533_1^{XXVII} \rightarrow \\ & \rightarrow -0.1342_1^{XXVIII} \rightarrow -0.1342_1^{XXIX} \rightarrow -0.1342_1^{XXX} \rightarrow -0.1342_1^{XXXI} \rightarrow -0.1342_1^{XXXII} \rightarrow -0.7413_1^{XXXIII}. \end{aligned} \quad (3.2)$$

The occurrence of structural changes in accordance with the dependence (3), e.g. for artificial genetic code consisting of coefficients in the polynomial $A(q)$ and $B1(q)$, a may also be noticed, i.e.:

$$\begin{aligned} & [(-0.1342_1^I), (0.343_1^I, -0.05387_2^I, -0.1443_3^I)] \\ & \quad \downarrow \\ & [(-0.1342_1^{II}), (0.343_1^{II}, -0.05387_2^{II}, -0.1443_3^{II})] \\ & \quad \downarrow \\ & [(-0.1342_1^{III}), (0.343_1^{III}, -0.05387_2^{III}, -0.1443_3^{III})] \\ & \quad \downarrow \\ & [(-0.1342_1^{IV}), (0.343_1^{IV}, -0.05387_2^{IV}, -0.1443_3^{IV})] \\ & \quad \downarrow \\ & [(-0.09354_1^V), (0_1^V, 0_2^V, 0_3^V, 0_4^V, -0.03472_5^V, 0.2841_6^V, -0.175_7^V)] \\ & \quad \downarrow \\ & [(-0.09354_1^{VI}), (0_1^{VI}, 0_2^{VI}, 0_3^{VI}, 0_4^{VI}, -0.03472_5^{VI}, 0.2841_6^{VI}, -0.175_7^{VI})] \\ & \quad \downarrow \\ & [(-0.1342_1^{VII}), (0.343_1^{VII}, -0.05387_2^{VII}, -0.1443_3^{VII})] \\ & \quad \downarrow \\ & [(-0.1342_1^{VIII}), (0.343_1^{VIII}, -0.05387_2^{VIII}, -0.1443_3^{VIII})] \\ & \quad \downarrow \end{aligned} \quad (4)$$



$$\begin{aligned}
& [(-0.1533_1^{XXVII}), (0_1^{XXVII}, 0.634_2^{XXVII}, -0.1422_3^{XXVII}, -0.3217_4^{XXVII})] \\
& \quad \downarrow \\
& [(-0.1342_1^{XXVII}), (0.343_1^{XXVII}, -0.05387_2^{XXVII}, -0.1443_3^{XXVII})] \\
& \quad \downarrow \\
& [(-0.1342_1^{XXX}), (0.343_1^{XXX}, -0.05387_2^{XXX}, -0.1443_3^{XXX})] \\
& \quad \downarrow \\
& [(-0.1342_1^{XXX}), (0.343_1^{XXX}, -0.05387_2^{XXX}, -0.1443_3^{XXX})] \\
& \quad \downarrow \\
& [(-0.1342_1^{XXXI}), (0.343_1^{XXXI}, -0.05387_2^{XXXI}, -0.1443_3^{XXXI})] \\
& \quad \downarrow \\
& [(-0.1342_1^{XXXII}), (0.343_1^{XXXII}, -0.05387_2^{XXXII}, -0.1443_3^{XXXII})] \\
& \quad \downarrow \\
& [(-0.7413_1^{XXXIII}), (0_1^{XXXIII}, 0_2^{XXXIII}, 0_3^{XXXIII}, 0_4^{XXXIII}, 0_5^{XXXIII}, 0_6^{XXXIII}, 0_7^{XXXIII}, 0_8^{XXXIII}, -20.12_7^{XXXIII})].
\end{aligned}$$

and, in case of structural changes, the matter concerns the appearance or disappearance of the gene s_i , and in the artificial coefficient-based genetic code, which, in particular, may be the artificial genetic code of a subsystem, converter, element, e.g. in case of transition from period IV to period V, from XII to XIII and from XIII to XIV, or from the period XXXII to the period XXXIII.

3 Conclusion and project development

The artificial genetic codes obtained in this way, may be further use to generate the initial population for the System Evolutionary Algorithm SAE [1, 3, 6, 16], that may be used to search for more robust population, i.e. for the conditions of the discussed task of a more robust model of electric power system. As a result of using the SAE algorithm, polynomial $A(q)$ and polynomials $B_i(q)$ or the elements of matrices in the equations in the state space may be obtained.

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