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Efficiency of Poly-controlled Endotechnologies

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Variants of poly-controlled endotechnologies

Many of the modern electronics technologies (ET), especially flexible (FET), have a complex structures and are composed of several modular components, which are related by various interface variants of stochastic nature. Processes of these FET are activated from one or several initial components (frames). They can have one or even several possible components or the terminal states. Therefore the representation graphs of these technologies are different. This is characteristic to endotechnologies (ENT) and exotechnologies (EKT) [1]. Let's name those ENT graphs, each of which implement one initial component (frame) and one terminal components, as monographs, and those, which provide opportunity to work from many initial terminals, or (and) have several terminal components (states) – as polygraphs. They will characterize the structures of mono-controlled and poly-controlled ENT.

Poly-control in such ENT can be processed from one initial component (frame) (e.g. Fig. 1, *A* variant) or from two and more (e.g., Fig. 1, A and *B* variants).

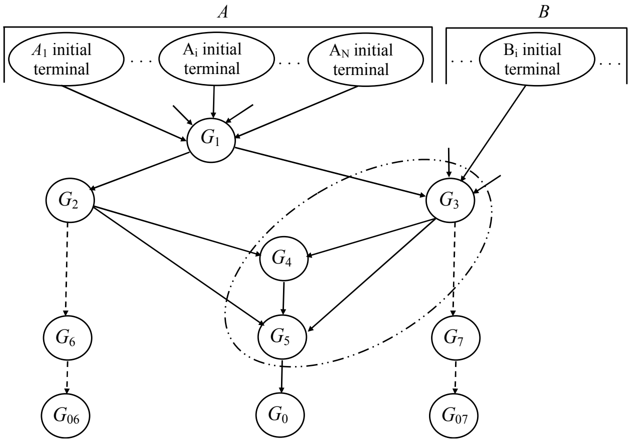

Fig. 1. Example of poly-controlled ENT graph

It can be seen from Fig. 1, that efficiencies of all ENT variants of group *A* (and overall their efficiency) will be determined by all components G_1, G_2,...G_5 and interfaces between them. Efficiencies of all ENT of group *B* (when not considering ENT of group *A*) will depend on the efficiencies of components G_3, G_4 and G_5 and their interfaces. Since ENT of both groups use several components and interfaces at the same time, the efficiency of ENT of each variant will also depend on peculiarities of technologies of the other variant. When ENT versatility and flexibility is increased further, number of graph poles may increase and several terminal components (states) may be formed (e.g., Fig. 1, G_6 and G_{06}; G_7 and G_{07}).

It can be seen in advance, that FET efficiency evaluation techniques presented in [1,2] will be adequate only when creating general calculation principles. When investigating ENT efficiencies of *A* and *B* groups it is also necessary to consider the changes of efficiency of jointly-used components due to increased loads.

Efficiencies of ENT controlled from one initial component (G_1)

When designing most of control systems for manufacturing control of electronic devices (ED), quality control and other application areas, principle of single-control is included among other control principles. Therefore each variant of ENT should be controlled only by one terminal. When speaking about poly-control we should have in mind, that several terminals can use the same components for their own purposes.

At first lets name the *j*-th ENT variant, selected by the terminal $A1$, as the $A1j$ technology (here $j = \overline{1, N_{A1}}$; N_{A1} – number of ENT controlled by $A1$ terminal). By using methodology presented in [1,2] let's state that each $A1j$ in any moment of time *t* is matched by its relative demand function $\eta_{A1j}(t)$. Thus

$$A1j \xleftrightarrow{t} \eta_{A1jv}\,; \qquad (1)$$

here $\eta_{A1jv}(t)$ – average value of $A1j$ demand function, which can be calculated by using Fig. 2.

It is obvious that

$$\eta_{A1jv} = \frac{\int_{t_1}^{t_3} \eta_{A1j}(t)dt}{t_3 - t_1}; \tag{2}$$

here $t_1 \div t_3$ – duration of ENT analysis duration,

$$\sum_{j=1}^{N_{A1}} \eta_{A1jv} = 1{,}0. \tag{3}$$

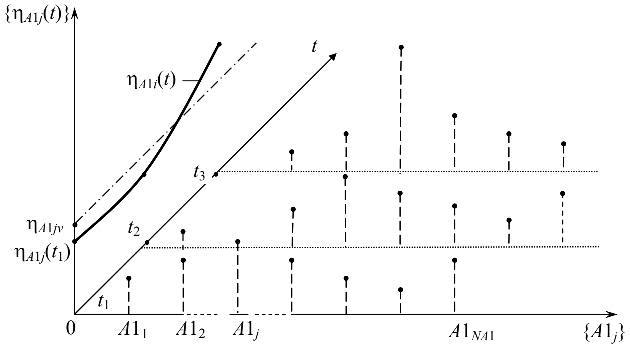

Fig. 2. $\{A1_j\}$ ENT demand functions

When average frequency of any *Ai* technology – ω_{Ai}, the duration of *j*-th task transfer over the interface to the component G_1 is $t_{Aij}^{(')} << t_{Aij}^{(G_1)}$ ($t_{Aij}^{(G_1)}$ – this is the time, which is needed by the component G_1 when performing the task of the technology *Aij*), and $\{N_{Ai}\}$ – a sufficiently large numbers, then coefficient of the readiness of the first component (when it is operative) to perform the task of any technology of group *A* is

$$K_{p1}^{(v)} \approx \frac{(t_3 - t_1) \cdot \left[1 - \sum_{i=1}^{N} \left(\omega_{Ai} \sum_{j=1}^{N_{Ai}} t_{Aij}^{(G_1)} \cdot \eta_{Aijv}\right)\right]}{t_3 - t_1}. \tag{4}$$

When considering the no-failure (no-disturbance) of this component, its general coefficient of readiness is

$$K_{p1} = K_{p1}^{(n)} \cdot K_{p1}^{(v)}; \tag{5}$$

here $K_{p1}^{(n)}$ – the probability, that the component G_1 will be operative and without any disturbances.

$$K_{p1}^{(n)} = \frac{T_{v2}}{T_{v2} + t_{av}}; \tag{6}$$

here T_{v2} – average operative state of the component G_1 between adjacent states of inactivity (failures and disturbances); t_{av} – average component G_1 restoration (repair) duration.

The values of K_{p2}, K_{p3}, K_{p4} and K_{p5}, and also the values readiness coefficients (K_{pA11},...K_{pA1j},...$K_{pG(1\rightarrow2)}$,...) of all interfaces ($A1_1G_1$,...G_1G_2,...) can be calculated analogously. The probability, that any (e.g., G_s) component will not fail or will not be disturbed when performing the task of *Aij* technology when simplest and interindependent flows of failures and disturbances are present is

$$P_s\left(t_{Aij}^{(G_s)}\right) = e^{-\lambda_s \cdot t_{Aij}^{(G_s)}}; \tag{7}$$

here λ_s – intensity of failures and disturbances of the *s*-th component; $t_{Aij}^{(G_s)}$ – time, which is needed by the *s*-th component in order to perform the task of the *Aij* technology.

Let's calculate the implementation efficiency ($E_{Aij}^{(0)}$) of the *Aij* technology (shown in Fig. 1), controlled from one initial component, when there is only one terminal state (G_0).

$$\begin{aligned}
E_{Aij}^{(0)} &= K_{pAij} \cdot P_{Aij}\left(t_{Aij}^{(')}\right) \cdot K_{p1} \cdot P_1\left(t_{Aij}^{(G_1)}\right) \cdot \Big[\alpha_{12}^{(ij)} K_{p12} \times \\
&\times P_{12}\left(t_{Aij}^{(12)}\right) \cdot K_{p2} \cdot P_2\left(t_{Aij}^{(G_2)}\right) \cdot \Big[\alpha_{25}^{(ij)} K_{p25} \cdot P_{25}\left(t_{Aij}^{(25)}\right) \cdot K_{p5} \times \\
&\times P_5\left(t_{Aij}^{(G_5)}\right) + \alpha_{24}^{(ij)} K_{p24} \cdot P_{24}\left(t_{Aij}^{(24)}\right) \cdot K_{p4} \cdot P_4\left(t_{Aij}^{(G_4)}\right) \cdot K_{p45} \times \\
&\times P_{45}\left(t_{Aij}^{(45)}\right) \cdot K_{p5} \cdot P_5\left(t_{Aij}^{(G_5)}\right)\Big] + \alpha_{13}^{(ij)} K_{p13} \cdot P_{13}\left(t_{Aij}^{(13)}\right) \cdot K_{p3} \times \\
&P_3\left(t_{Aij}^{(G_3)}\right) \cdot \Big[\alpha_{34}^{(ij)} K_{p34} \cdot P_{34}\left(t_{Aij}^{(34)}\right) \cdot K_{p4} \cdot P_4\left(t_{Aij}^{(G_4)}\right) \cdot \times \\
&\times K_{p45} \cdot P_{45}\left(t_{Aij}^{(45)}\right) \cdot K_{p5} \cdot P_5\left(t_{Aij}^{(G_5)}\right) + \alpha_{35}^{(ij)} K_{p35} \times \\
&\times P_{35}\left(t_{Aij}^{(35)}\right) \cdot K_{p5} \cdot P_5\left(t_{Aij}^{(G_5)}\right)\Big]\Big]\Big];
\end{aligned} \tag{8}$$

here $\alpha_{12}^{(ij)}$, $\alpha_{13}^{(ij)}$, $\alpha_{24}^{(ij)}$, $\alpha_{25}^{(ij)}$, $\alpha_{34}^{(ij)}$, $\alpha_{35}^{(ij)}$ – the significance coefficients of interfaces when implementing *Aij* technology,

$$\alpha_{12}^{(ij)} + \alpha_{13}^{(ij)} = \alpha_{24}^{(ij)} + \alpha_{25}^{(ij)} = \alpha_{34}^{(ij)} + \alpha_{35}^{(ij)} = 1{,}0. \tag{9}$$

Average processing efficiency of entire *A* group of technologies with one (G_0) terminal state is

$$E_A^{(0)} = \sum_{i=1}^{N} \sum_{j=1}^{N_{Ai}} E_{Aij}^{(0)} \cdot k_{ij}^{(A)}; \tag{10}$$

here $k_{ij}^{(A)}$ – significance coefficient of the *Aij* technology (task), and

$$k_{ij}^{(A)} = \frac{N_{Aij}}{\sum_{i=1}^{N} \sum_{j=1}^{N_{Ai}} N_{Aij}}; \tag{11}$$

here N_{Aij} – number of times the technology *Aij* is used over the time ($t_1 \div t_3$).

In all these cases it is presumed, that the transition from the component G_5 into the stete G_0 is perfectly reliable.

When the flexible ENT has more than one terminal component, e.g., G_0, G_6 and G_7, and terminal states with indexes zero, six and seven are inter-incompatible and equally significant (desired), and transitions from G_6 into G_{06}, from G_5 into G_0 and from G_7 into G_{07} – are perfectly reliable, then

$$\alpha_{26}^{(ij)} + \alpha_{24\cup25}^{(ij)} = 1{,}0; \tag{12}$$

here $\alpha_{24\cup25}^{(ij)}$ – total significance coefficient of the transitions from G_2 into G_4, or from G_2 into G_5, when implementing *Aij* technology.

For this reason

$$\alpha_{26}^{(ij)} + \alpha_{24\cup 25}^{(ij)}\left(\alpha_{24}^{(ij)} + \alpha_{25}^{(ij)}\right) = 1{,}0. \qquad (13)$$

The control efficiency of the *Aij* variant of the flexible ENT with terminal state G_{06} is

$$E_{Aij}^{(06)} = K_{pAij} \cdot P_{Aij}\left(t_{Aij}^{(')}\right) \cdot K_{p1} \cdot P_1\left(t_{Aij}^{(G_1)}\right) \cdot K_{p12} \cdot P_{12}\left(t_{Aij}^{(12)}\right) \times$$
$$\times K_{p2} \cdot P_2\left(t_{Aij}^{(G_2)}\right) \cdot K_{p26} \cdot P_{26}\left(t_{Aij}^{(26)}\right) \cdot K_{p6} \cdot P_6\left(t_{Aij}^{(G_6)}\right), \qquad (14)$$

here all the symbols are analogous to formula (8). The value $E_{Aij}^{(07)}$ is calculated in the same way.

Then the average operation efficiency of any *Aij* technology with three terminal states is

$$\hat{E}_{Aij} = \alpha_{12}^{(ij)}\alpha_{26}^{(ij)} \cdot E_{Aij}^{(06)} + \left[\alpha_{12}^{(ij)}\alpha_{24\cup 25}^{(ij)} + \right.$$
$$\left. + \alpha_{13}^{(ij)}\alpha_{34\cup 35}^{(ij)}\right] \cdot E_{Aij}^{(0)} + \alpha_{13}^{(ij)}\alpha_{37}^{(ij)} \cdot E_{Aij}^{(07)}; \qquad (15)$$

here

$$\alpha_{37}^{(ij)} + \alpha_{34\cup 35}^{(ij)}\left(\alpha_{34}^{(ij)} + \alpha_{35}^{(ij)}\right) = 1{,}0. \qquad (16)$$

So, we have found the average generalized efficiency of the flexible technologies, controlled from one initial component G_1.

With increase of versatility of these technologies, the possibilities arise to use the separate their components to implement the flexible ENT of various purposes. There are plenty of such cases in various information- and control-purpose electronic technologies. Therefore more initial components are used [3] (e.g., Fig. 1, G_3 component is used to perform the tasks of *B* group). In this case the efficiency of entire ENT complex should be evaluated in different way.

Efficiency of ENT controlled from many components

Let's use the ENT complex graph presented in Fig. 1, considering that there is another (*B*) group of tasks. Then the value of the coefficient of the readiness to perform any task of ENT from *A* or *B* groups for the G_3 component (when it is operative) can be calculated analogously to formula (4):

$$K_{p3AB}^{(V)} \approx \frac{t_3 - t_1 - (t_3 - t_1) \cdot \sum\limits_{i=1}^{N}\left(\omega_{Ai} \sum\limits_{j=1}^{N_{Ai}} t_{Aij}^{(G_3)} \cdot \eta_{Aijv}\right)}{t_3 - t_1} -$$
$$- \frac{(t_3 - t_1) \cdot \sum\limits_{i=1}^{M}\left(\omega_{Bi} \sum\limits_{j=1}^{N_{Bi}} t_{Bij}^{(G_3)} \cdot \eta_{Bijv}\right)}{t_3 - t_1}; \qquad (17)$$

here $t_{Aij}^{(G_3)}$ – time, required by the component G_3 to perform the task of the *Aij* technology; *M* – number of terminals of ENT of the *B* group. Other symbols are analogous to earlier described.

The value of the total readiness coefficient (K_{p3AB}) of the G_3 component can be calculated using the expression, which is analogous to the expression presented in formula (5). Then implementation efficiency of the *Bij* technology with one (G_0) terminal state is

$$E_{Bij}^{(0)} = K_{pBij} \cdot P_{Bij}\left(t_{Bij}^{(')}\right) \cdot K_{p3AB} \cdot P_3\left(t_{Bij}^{(G_3)}\right) \cdot \left[\alpha_{34}^{(ij)} K_{p34} \times \right.$$
$$\times P_{34}\left(t_{Aij}^{(34)}\right) \cdot K_{p4AB} \cdot P_4\left(t_{Bij}^{(G_4)}\right) \cdot K_{p45} \cdot P_{45}\left(t_{Bij}^{(45)}\right) \times$$
$$\times K_{p5AB} \cdot P_5\left(t_{Bij}^{(G_5)}\right) + \alpha_{35}^{(ij)} K_{p35} \times$$
$$\left. \times P_{35}\left(t_{Bij}^{(35)}\right) \cdot K_{p5AB} \cdot P_5\left(t_{Aij}^{(G_5)}\right)\right]. \qquad (18)$$

Analogously to the formula (10):

$$E_B^{(0)} = \sum_{i=1}^{M} \sum_{j=1}^{N_{Ai}} E_{Bij}^{(0)} \cdot k_{ij}^{(B)}; \qquad (19)$$

here

$$k_{ij}^{(B)} = \frac{N_{Bij}}{\sum\limits_{i=1}^{M} \sum\limits_{j=1}^{N_{Bi}} N_{Bij}}, \qquad (20)$$

here all the symbols are analogous to the symbols in formula (11).

The implementation (processing) efficiency of the *Bij* variant of flexible EXT with G_{07} terminal state is

$$E_{Bij}^{(07)} = K_{pBij} \cdot P_{Bij}\left(t_{Bij}^{(')}\right) \cdot K_{p3AB} \cdot P_3\left(t_{Bij}^{(G_3)}\right) \times$$
$$\times K_{p37} \cdot P_{37}\left(t_{Bij}^{(37)}\right) \cdot K_{p7} \cdot P_7\left(t_{Bij}^{(G_7)}\right). \qquad (21)$$

Average implementation efficiency of any *Bij* technology (with two terminal states (G_0 and G_{07})) is

$$\hat{E}_{Bij} = \alpha_{24\cup 25}^{(ij)} \cdot E_{Bij}^{(0)} + \alpha_{37}^{(ij)} \cdot E_{Bij}^{(07)}; \qquad (22)$$

here

$$\alpha_{37}^{(ij)} + \alpha_{34\cup 35}^{(ij)} = 1{,}0. \qquad (23)$$

Average efficiency of overall ENT complex (formed of *A* and *B* groups) with one (G_0) terminal state

$$E_{ENT}^{(0)} = \gamma_A E_A^{(0)} + \gamma_B E_B^{(0)}; \qquad (24)$$

here γ_A and γ_B – demand coefficients of ENT of *A* and *B* groups:

$$\gamma_A + \gamma_B = 1{,}0; \qquad (25)$$

$$\gamma_A = \frac{\sum\limits_{i=1}^{N} \sum\limits_{j=1}^{N_{Ai}} N_{Aij}}{\sum\limits_{i=1}^{N} \sum\limits_{j=1}^{N_{Ai}} N_{Aij} + \sum\limits_{i=1}^{M} \sum\limits_{j=1}^{N_{Bi}} N_{Bij}}; \qquad (26)$$

$$\gamma_B = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N_{Bi}} N_{Bij}}{\sum_{i=1}^{N}\sum_{j=1}^{N_{Ai}} N_{Aij} + \sum_{i=1}^{M}\sum_{j=1}^{N_{Bi}} N_{Bij}}. \qquad (27)$$

Average generalized entire implementation efficiency of *A* group technologies

$$E_A = \sum_{i=1}^{N}\sum_{j=1}^{N_{Ai}} \hat{E}_{Aij} \cdot k_{ij}^{(A)} \qquad (28)$$

and for *B* group technologies

$$E_B = \sum_{i=1}^{M}\sum_{j=1}^{N_{Bi}} \hat{E}_{Bij} \cdot k_{ij}^{(B)}. \qquad (29)$$

Average efficiency of entire ENT complex

$$E_{ENT} = \gamma_A E_A + \gamma_B E_B. \qquad (30)$$

After summarizing the received results, for any number (*D*) of terminal groups we have, that

$$E_{ENT} = \sum_{i=1}^{D} \gamma_i E_i. \qquad (31)$$

This expression can be used to evaluate the efficiency of poly-controlled ENT of any level of complexity.

Main advantages of the method

The offered method of poly-controlled ENT efficiency evaluation can be used when evaluating the efficiencies of many complex structures of ET. It is suitable for the efficiency research of information (data acquisition, analysis, transfer and storage) technologies. During calculations the parts of technologies with the least efficiency can be determined, the influence of redundancy on the efficiency and other factors can be also determined.

This method is more similar to the evaluation methodology, therefore it permits creating of various calculation variants considering the ET specifics. This is particularly important when assessing the features of various electronic control technologies, when selecting optimal variants of control systems [4].

When the offered method [2] is applied when investigating the efficiency of poly-controlled flexible ENT, it is possible to take into account the persistence of separate components, to consider the features of ED and processes inside them, to search for the rational combination of the efficiencies of separate components, when the initial conditions are given (e.g., resource input, durations and other).

References

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P. Balaišis, A. Žickis. Efficiency of Poly-controlled Endotechnologies // Electronics and Electrical Engineering. – Kaunas: Technologija, 2007. – No. 3(75). – P. 13–16.

The concept of poly-controlled electronics technologies was formulated. Main variants of endotechnologies were presented. The efficiency evaluation method was created for endotechnologies controlled from one initial component. When gradually increasing the number of initial and terminal components of endotechnologies, the efficiency evaluation method of any poly-controlled flexible technologies was created. Main advantages of the offered method were described. Possibilities to expand this method when considering the persistency of separate parts of the technology were also indicated. Ill. 2, bibl. 4 (in English; summaries in English, Russian and Lithuanian).

П. Балайшис, А. Жицкис. Эффективность полиуправляемых эндотехнологий // Электроника и электротехника. – Каунас: Технология, 2007. – № 3(75). – С. 13–16.

Сформулировано понятие полиуправляемых технологий электроники. Приведены основные варианты эндотехнологий. Составлен способ оценки эффективности эндотехнологий, управляемых из одного начального компонента. Постепенно увеличивая количество начальных и конечных компонентов, составлен метод оценки эффективности комплексов любых полиуправляемых гибких технологий электроники. Приведены основные преимущества предлагаемого метода. Показаны возможности расширить предложенный метод для оценки эффективности эндотехнологий с учетом различной степени упрямости их компонентов. Ил. 2 , библ. 4 (на английском языке; рефераты на английском, русском и литовском яз.).

P. Balaišis, A. Žickis. Polivaldomųjų endotechnologijų efektyvumas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 3(75). – P. 13–16.

Suformuluota polivaldomųjų elektronikos technologijų samprata. Pateikti pagrindiniai endotechnologijų variantai. Sudarytas iš vieno pradinio komponento valdomų endotechnologijų efektyvumo vertinimo būdas. Palaipsniui didinant endotechnologijų pradinių ir galinių komponentų skaičių sudarytas bet kurių polivaldomųjų lanksčiųjų technologijų efektyvumo vertinimo metodas. Pateikti pagrindiniai siūlomo metodo pranašumai. Nurodytos galimybės išplėsti šį metodą, atsižvelgiant į atskirų technologijos dalių atkaklumus. Il. 2, bibl. 4 (anglų kalba; santraukos anglų, rusų ir lietuvių kalbomis).