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# Analysis of Petri Net of Isolation State and Single-phase Ground Short Circuit Control Device in 6-10 kV Electric Networks

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## Abstract

The present article offers to carry out the analysis of Petri primary net which modals isolation state and single-phase ground short circuit control device in 6-10 kV electric networks. It is used to identify structural and behavioral properties of the system. On the basis of the given analysis of Petri net the modeled system is assessed and the solutions on its perfection and alteration are carried out.

Petri net are one of the most wide spread modern devices meant for modeling, analysis, synthesis and project planning of discreet systems with the processes which are parallel. The primary Petri net which models isolation state and single-phase ground short circuit control device and reflecting the system state and transition from one state to another is given in Fig. 1. The transitions are necessary to carry out in the system in order to identify the values of active and capacitive inductivity of isolation system and single-phase ground short circuit. The necessity to conduct such deep research in the field of Petri nets behavior is conditioned by the modeling of these systems. The methods of property analysis for Petri nets are necessary to carry out such research. This approach offers to investigate the properties of the real system on the basis of analysis of specific properties of Petri net [1, 2].

Main properties of Petri net:

- Safety – the position of Petri net is safe, if the number of marks does not exceed 1. Petri net is safe, if all nets positions are safe.
- Limitation – Petri net is called k-limited, if in any state at any position there are no more than k-marks;
- Saving – Petri net is saving, if it is saving according to some positive non-vanishing vector of weighing;
- Activity – the transition is active, if it is not dead locked. If the transition is active it is always available to transition Petri net from its current marking into the marking with allowed transition activation;
- Achievement and coverness of marks.

There are two main methods of Petri nets analysis: matrix methods; methods based on tree of coverness and column of approachability construction. The first group of methods is based on the matrix representation of marks and transitions activation. The alternative method according to the identification of Petri nets (T, P, F, $M_0$) is identification of two matrixes $D^-$ and $D^+$ which present input and output functions. Every matrix has *m* lines (one for a transition) and *n* columns (one for a position). $D^-$ identifies inputs into transitions, $D^+$ outputs. The matrix form of Petri net identification allows to identify vectors and matrixes in terms

$$(T, P, D^-, D^+) . \qquad (1)$$

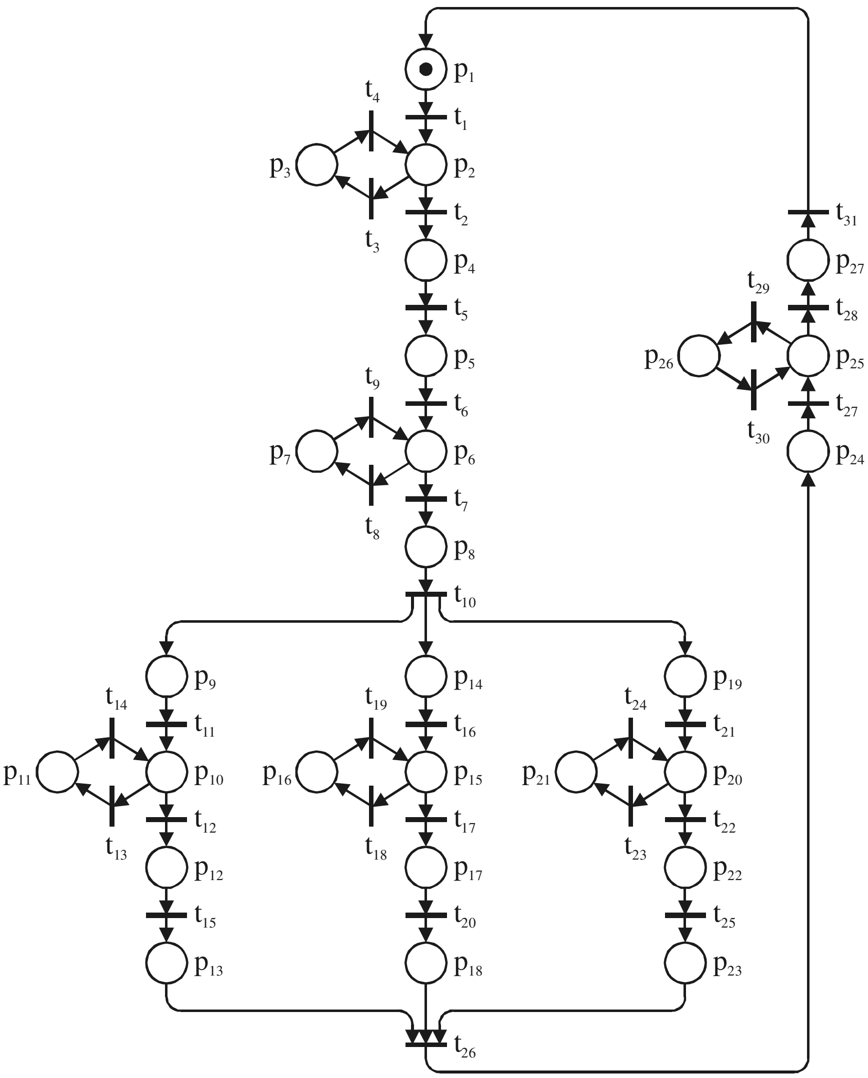


Fig. 1. Petri net which models isolation state and single-phase ground short circuit control device

Let's identify the unit vector e[j] of m dimension, containing nulls at every position, except the one which correlates the activated transition. It is obvious, that the transition is allowed, if

$$\mu \geq e[j] \cdot D^{-}. \tag{2}$$

Then the result of j-transition activation could be written as

$$\mu' = \mu + e[j] \cdot D, \tag{3}$$

where $D = (D^{+} - D^{-})$ – incidence matrix.

Then

$$\mu = \mu_0 + \sigma D, \tag{4}$$

where $\mu$ – investigating mark.

σ – vector, its components show how many times every transition activates (vector of sequence activation).

As the result of decomposition of the primary Petri net functional Petri subnets are calculated (Fig. 2), as well as the column of functional subnets which coordinate subnets working is presented (Fig. 3).

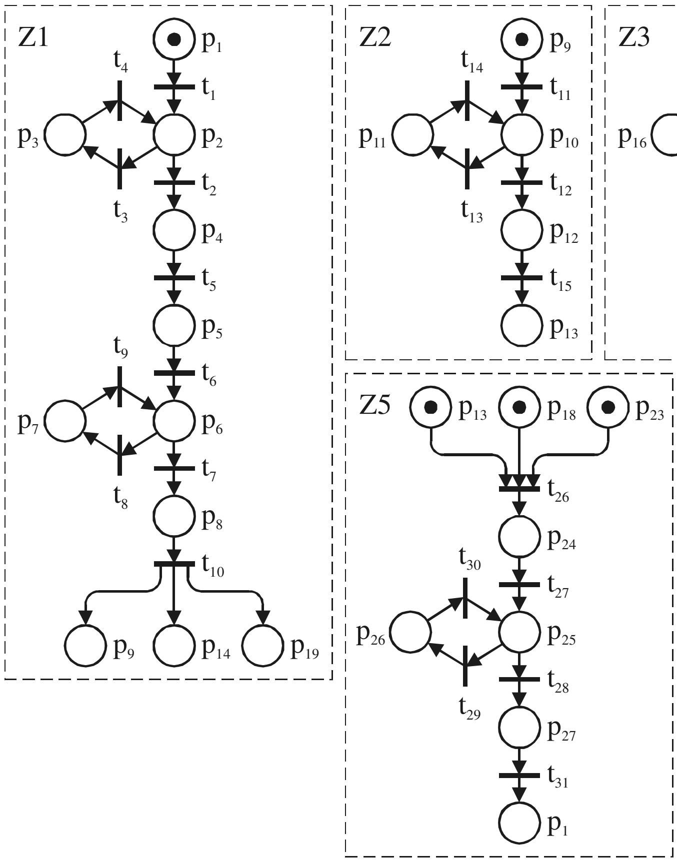


Fig. 2. Functional Petri subnets

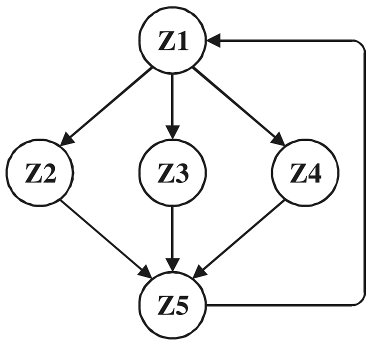


Fig. 3. The column of functional Petri subnets of primary Petri net of isolation state and single-phase ground short circuit control device

Z1 subnet, Fig. 2, has 11 positions ($p_1$ – $p_9$, $p_{14}$, $p_{19}$) and 10 transitions ($t_1$ – $t_{10}$).There is a matrix of inputs, where every element is equal to the number of marks, which come from *j*-position, when *i*-transition is activated. There is the outputs matrix where every element is equal to the number of marks which come into *j*-position, when *i*-transition is activated. Incidence matrix is identified as difference between outputs matrix and inputs matrix

$$D = \begin{vmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 1 & 1 \end{vmatrix}. \quad (5)$$

We have got incidence matrix and could write matrix equation of marks changing. The vector of primary marking of Z1 subnet could be defined as $\mu_0 = (10000000000)$. The achievement of arbitrary marking of Z1 subnet according to (4) is defined as follows

$$\mu = (10000000000) + \sigma \begin{vmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 1 & 1 \end{vmatrix}. \quad (6)$$

For example, it is necessary to define the achievement of marking $\mu = (00001000000)$ from primary marking $\mu_0 = (10000000000)$. In (6) we put X vector instead of $\sigma$ and $\mu$ will be changed into the marking we need. The (6) does not have unambiguous solution; it could be solved in a multiple way

$$f(\sigma) = (1, 1, x_3, x_4, 1, 0, 0, x_8, x_9, 0), \quad (7)$$

where $x_3$, $x_4$, $x_8$, $x_9$ – any number.

The (7) defines the bound between transition activations. When $x_3 = x_4 = 1$, $x_8 = x_9 = 0$

$$f(\sigma) = (1, 1, 1, 1, 1, 0, 0, 0, 0, 0). \quad (8)$$

The received decision shows the achievement of marking and specifies which transitions and how many times they should be started for this purpose.

To define property of convertibility of Z1 subnet works the equation will be as follows

$$X \cdot D = 0. \quad (9)$$

The (9) also has no unequivocal decision

$$f(\sigma) = (0, 0, x_3, x_4, 0, 0, 0, x_8, x_9, 0). \quad (10)$$

The matrix approach to the analysis of Petri nets is very perspective, but also has the following lacks:

- The incidence matrix – D does not reflect structure of Petri net, the transitions having both inputs and outputs from one position (loop), are represented by corresponding elements of matrixes $D^-$ and $D^+$, but then are mutually destroyed in the matrix $D = (D^+ - D^-)$;
- Absence of the information on sequence of start of transitions;
- The decision of the (4) is necessary for approachability, but insufficient;
- An opportunity of void decisions of the (4) that is decisions which do not correspond to possible sequences of transitions.

The tree of approachability is the most universal remedy of the analysis of properties practically of any class of Petri nets. Almost all basic properties of nets can be simple enough received from the tree of approachability. On the basis of the analysis of the tree of approachability the following properties of Petri nets are defined:

- Safety and limitations. Petri net is limited in only case when symbol ω is absent in its tree of approachability. Absence of symbol ω in a tree of approachability means that set of achievable marks are certainly finished. With simple searching it is possible to find the top border, as for each position separately, and the general top border for all positions. The last means limitation of Petri net. If the border for all positions is equal to 1, Petri net is safe;
- Preservations. As the tree of approachability certainly, for each mark is possible to calculate the sum of initial marks. If this sum is identical to each achievable marks Petri net is keeping. If the sums are not equal, the net is not keeping;
- marks coverness;
- Vivacity – *t* transition of Petri nets is potentially alive, in only case when some arch is marked in the tree of approachability of this net.

Columns of approachability is the arch to transition of a net from one marks to another when each top corresponds to the certain marks of Petri net, and as a result of operation of any transition. Arches and the column are marked with numbers of these transitions. The peculiarity of the column is that there can not be identical tops, that is tops with identical marks. Columns of approachability is represented as follows

$$GD = (V, E), \quad (11)$$

where $V = \{M_1, M_2, \ldots, M_q\}$ – file of tops (the marks corresponding to tops);

$E = \{e_1, e_2, \ldots, e_p\}$ – file of the arches connecting tops.

The tree of coverness of marks of a net represents connected columns in which tops there are marks which are reached as a result of consecutive start of the resolved transitions, and on the arches connecting tops – started transitions. The way from a root to each mark reflects the sequence of start resulted in it. A root of the tree is initial mark. At unlimited accumulation of labels in a position there is a loop on the tree, and in marks on a place corresponding to the gone in cycles position is formed, put "ω" – a symbol of indefinitely big number. The tree of coverness is convenient for issuing as the column (Fig. 4). Thus going in cycles transitions are more evidently visible, and deadlock marks are characterized by absence of the arches which are starting with the given marks. At achievement of old marks it is enough to connect an arch the previous marks and already existing "old".

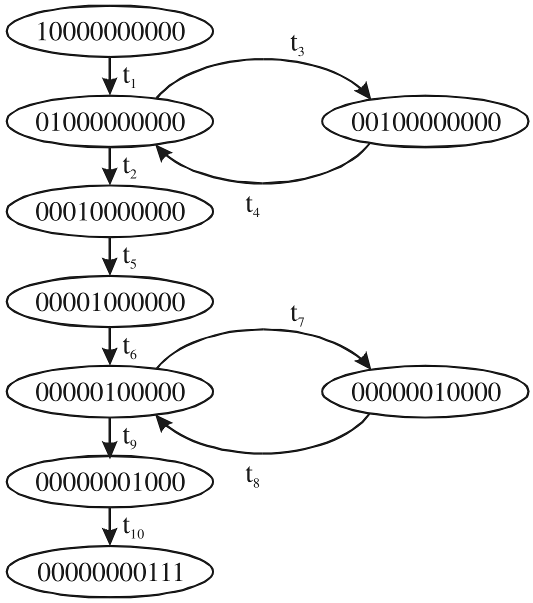


Fig. 4. Columns of approachability of Z1 subnet marks

With the help of the columns of approachability the following properties of Z1 – Z5 subnets are defined: Lifeless (there is a deadlock condition); Limited (the net is limited if the symbol “w” does not enter into one top the column); Safe (the net is safe if into labels of tops enter only “0” and “1”), absence of cycling; Wrong (if the net is safe and alive, it is correct); Irreversible (the net is convertible if in the column there is even one arch directed to initial marks); Absence of passive transitions.

On the basis of the carried out analysis of Z1 – Z5 subnets and the column of functional subnets of initial Petri nets resulted in Fig. 3, properties of full Petri nets (Fig. 1) are defined. Integrated properties of all net are defined by the composition of properties of subnets. All Z1 – Z5 subnets are safe (limited), hence, the whole Petri net is safe (limited). In all subnets there are no passive transitions and in all net of passive transitions is not present. As follows from the column functional subnets, Petri net is alive and convertible as in the column there are no deadlock conditions, and there is an arch directed at initial marks. The received properties of Petri net characterize the modeled system. On the basis of above-stated Petri net modeling of the isolation state and single-phase ground short circuit control device in 6-10 kV electric networks it follows, that it is a correct net.

## References

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