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Modelling the flow of electrical energy through high voltage system using generalized net

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Abstract. Modelling the flow of electrical energy through high voltage system can help improving the efficiency of the whole energy system. The model reflects the relation between the power plants, transmission system, substations, consumation and the power plants control. This paper focuses on the flow of electrical energy in the system and the power plant generation control.
Keywords: Energy System, Generalised Net.

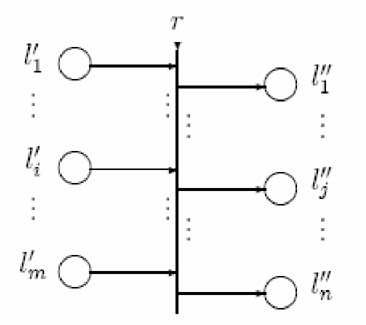
1. Introduction

Typically, power transmission is between the power plant and a substation near a populated area. This is distinct from electricity distribution, which is concerned with the delivery from the substation to the consumers. Due to the large amount of power involved, transmission normally takes place at high voltage (110 kV or above). Electricity is usually sent over long distance through overhead power transmission lines. The whole process of generating, transimitting and distributing the electrical energy is controlled and monitored from the energy companies and modelling the main flow is essential for better understanding and improving the system. For example increased consumation of energy should reflect in releasing and reserving more power generation resources, as these power resources may vary in their type, availability, power rate, reaction time etc.

2. Short remarks on GN

The concept of a Generalized Net (GN) is described in Atanassov (1991). The GNs are defined in a way that is principally different from the ways of defining the other types of Petri nets. The first basic difference between GN and the ordinary Petri nets is the "place - transition" relation. Here, the transitions are objects of a more complex nature. A transition may contain m input places and n output places where $m, n \geq 1$. In [1] is noted that the GN can have only a part of its components. In this case it is called a reduced GN. Here we shall give the formal definition of a reduced GN without temporal components, place and arc capacities, and token, place and transition priorities.
Formally, every transition in the reduced GN below is described by a three-tuple:

$$Z = \langle L', L'', r \rangle,$$



where

(a) *L'* and *L"* are finite, non-empty sets of places (the transition's input and output places, respectively); for the transition these are

$L' = \{l'_1, l'_2, \ldots, l'_m\}$ and $L'' = \{l''_1, l''_2, \ldots, l''_n\}$;

(b) *r* is the transition's *condition* determining which tokens will pass (or *transfer)* from the transition's inputs to its outputs; it has the form of an Index Matrix (IM):

$$r = \begin{array}{c|ccccc} & l''_1 & \ldots & l''_j & \ldots & l''_n \\ \hline l'_1 & & & & & \\ \ldots & & & r_{i,j} & & \\ l'_i & & (r_{i,j} & - & \text{predicate}) & \\ \ldots & & (1 \le i \le m, & & 1 \le j \le n) & \\ l'_m & & & & & \end{array}$$

$r_{i,j}$ is the predicate that corresponds to the *i*-th input and *j*-th output place. When its truth value is *"true",* a token from the *i*-th input place transfers to the *j*-th output place; otherwise, this is not possible;

The ordered four-tuple

$E = \langle A, K, X, \Phi \rangle$

is called a *Generalized Net* if:

(a) *A* is a set of transitions;
(b) *K* is the set of the GN's tokens;
(c) *X* is the set of all initial characteristics which the tokens can obtain on entering the net;
(d) *Φ* is the characteristic function that assigns new characteristics to every token when it makes the transfer from an input to an output place of a given transition.

Operations and relations are defined over the transitions, as well as over the GN in general (in their full or reduced forms). The operations defined over the GN - "union", "intersection", "composition" and "iteration" do not exist anywhere else in the Petri net theory. They can be transferred to virtually all other types of Petri nets (obviously with some modifications concerning the structure of the corresponding nets). These operations are useful for constructing GN models of real processes.
The operator aspect has an important place in the theory of GN. Six types of operators are defined in its framework. Every operator assigns to a given GN a new GN with some desired properties. The *global operators* transform, according to a definite procedure, a given entire net or all its components of a certain type. There are operators that alter the form and structure of the transitions, the temporal components of the net; the duration of its functioning, the set of tokens, the set of the initial characteristics; the characteristic function of the net; the evaluation

function, or other functions of the net. The second type of operators are *local operators*. They transform single components of some of the transitions of a given GN. The third type of operators are the *hierarchical operators.* These are of 6 different types and fall into two groups according to their way of action: *extending* or *shrinking* a given GN. The next (fourth) group of operators defined over the GN produces a new, reduced GN from a given net. They allow the construction of elements of the classes of reduced GN. These operators are called *reducing operators.* Operators from the fifth group extend a given GN. These operators are called *extending operators.* The extending operators are associated with every one of the GN extensions. Finally, the operators from the last - sixth - group are related to the ways the GN functions, so that they are called *dynamic operators.* These change the way that GN functions.
The operators of different types, as well as the others that can be defined, have a major theoretical and practical value. On one hand, they help us study the properties and the behaviour of GN. On the other hand, they also facilitate the modelling of many real processes.

3. A GN model

The proposed GN model represents a general abstraction of the electrical energy flow in the high voltage(440 kV) system. Power plants convert different resources into electrical energy. The transmission system transmits the electrical energy. The substations decrease the voltage while increasing the current for domestic and commercial distribution.
The power plants control uses the information about the energy in the system – mainly the voltage in the transmission system and decides which power plant to increase or decrease its power generation.
The electrical energy is generated in the power plants, it is transmitted through the high voltage transmission system, transformed into the substations and consumed. The produced/consumed electrical energy is synchronized with the consumation .

The GN contains 9 transitions and 26 places (see Fig.1).

GN–tokens represent the system energy. They have the following characteristics with values:
type – resource/electricity/consumation/controlling
voltage – nominal values are 400/220/110 kV and can vary according to the consumation,
power – depends on the consumation, [MW]
control sum – defines the difference between the produces and required energy

GN-tokens enter the net through places l_3 l_6 l_9 l_{12} N l_{16} l_{21} and l_{26} with type consumation and through places l_{14} l_{19} and l_{24} with type resources.

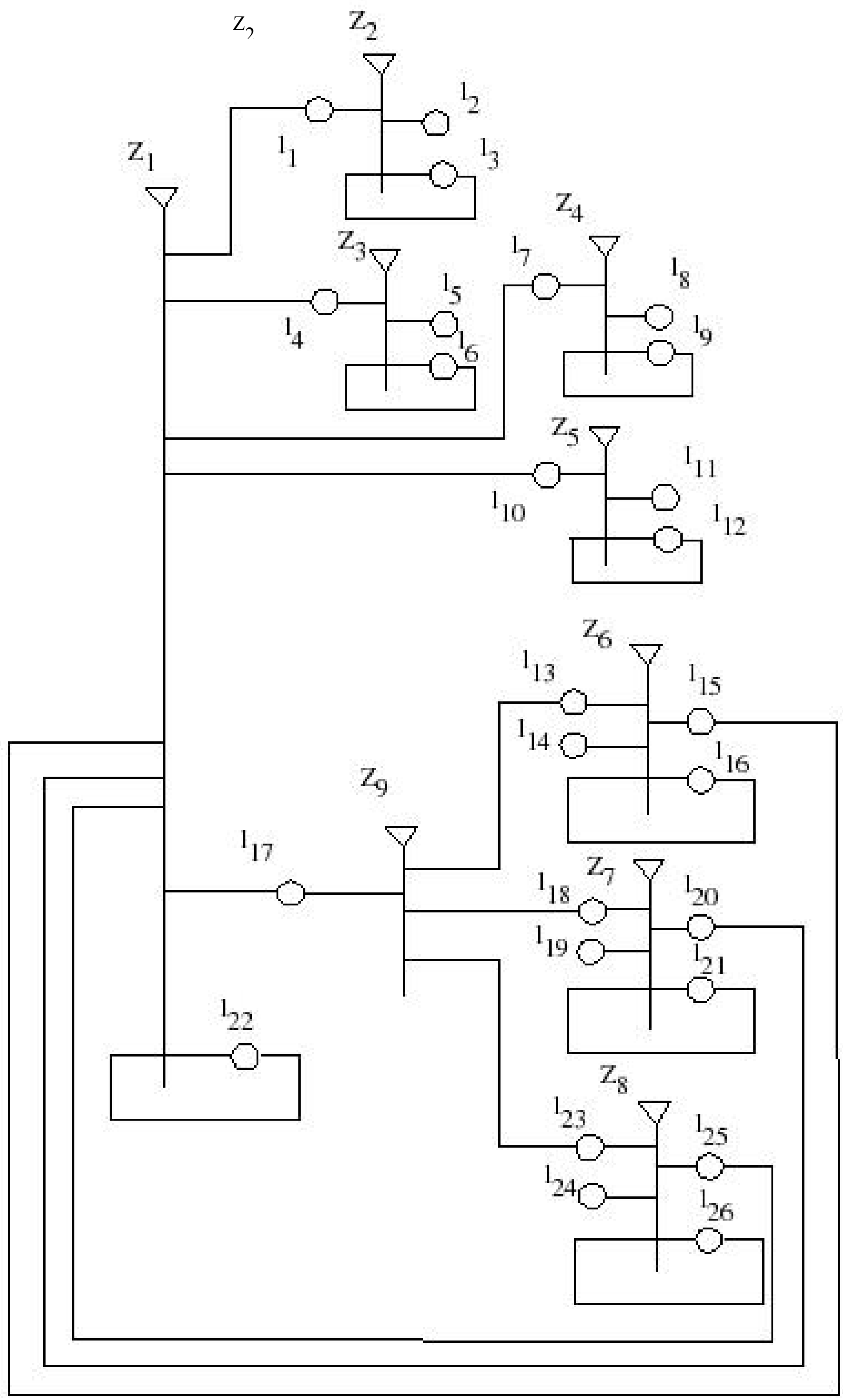


Fig.1. The GN model

Let's track the path of the tokens through the different GN-places.

Transition Z_1 represent the main high voltage transmission system.

Tokens passing from l_{15} l_{20} and l_{25} to l_1 , l_4 , l_7 and l_{10} represent the transmission of the electrical energy through the high voltage lines.
Tokens passing from l_{22} to l_{17} and l_{22} represent the monitoring of the voltage of the electrical energy.

$Z_1 = <\{l_{15}\ l_{20}\ l_{25}\ l_{22}\},\{l_1, l_4\ l_7, l_{10}\ l_{17}, l_{22}\},$

	l_1	l_4	l_7	l_{10}	l_{17}	l_{22}
l_{15}	T	T	T	T	F	F
l_{20}	T	T	T	T	F	F
l_{25}	T	T	T	T	F	F
l_{22}	F	F	F	F	W_4	T

where
W_4 = <There are voltage deviations in the transmission system >.

Transitions Z_2 Z_3 Z_4 Z_5 represent the four main substations. Tokens circulating from l_3 to l_3 , l_6 to l_6 , l_9 to l_9 and l_{12} to l_{12} represent the consumation in the distribution districts of the respective substations. Tokens passing from l_1 to l_2 , l_4 to l_5 , l_7 to l_8 and l_{10} to l_{11} represent the converting of the electrical energy from 440/220 kV to 110 kV – ready for distribution and consumation.

$Z_2 = <\{l_1\ l_3\},\{l_2, l_3\},$

	l_2	l_3
l_1	T	F
l_3	F	T

$Z_3 = <\{l_4\ l_6\},\{l_5, l_6\},$

	l_5	l_6
l_4	T	F
l_6	F	T

$Z_4 = <\{l_7\ l_9\},\{l_8, l_9\},$

	l_8	l_9
l_7	T	F
l_9	F	T

$Z_5 = <\{l_{10}\ l_{12}\},\{l_{11}, l_{12}\},$

	l_{11}	l_{12}
l_{10}	T	F
l_{12}	F	T

Transitions Z_6 Z_7 Z_8 represent the three main power stations(one from every main resource type – nuclear plant, coil/gas plant and hydro plant). Tokens circulating from l_{16} to l_{16} , l_{21} to l_{21} and l_{26} to l_{26} represent the internal consumation in the power plants. Tokens passing from l_{14} to l_{15} , l_{19} to l_{20} and l_{24} to l_{25} represent the converting the energy from specific resource into electrical energy – ready for transmition. The produced electric power is controlled by the tokens in places l_{13} , l_{18} and l_{23}

$Z_6 = <\{l_{13}\, l_{14}\, l_{16}\}, \{l_{15}\, l_{16}\},$

	l_{15}	l_{16}
l_{13}	F	F
l_{14}	T	F
l_{16}	F	T

$Z_7 = <\{l_{18}\, l_{19}\, l_{21}\}, \{l_{20}\, l_{21}\},$

	l_{20}	l_{21}
l_{18}	F	F
l_{19}	T	F
l_{21}	F	T

$Z_8 = <\{l_{23}\, l_{24}\, l_{26}\}, \{l_{25}\, l_{26}\},$

	l_{25}	l_{26}
l_{23}	F	F
l_{24}	T	F
l_{26}	F	T

Transition Z_9 represents the process of controlling the power generation of the power plants.

$Z_9 = <\{l_{17}\}, \{l_{13}\, l_{18}, l_{23}\},$

	l_{13}	l_{18}	l_{23}
l_{17}	W_1	W_2	W_3

where:
W_1 = < The power generation of power plant Z_6 should be changed >
W_2 = < The power generation of power plant Z_7 should be changed >
W_3 = < The power generation of power plant Z_8 should be changed >

4. Conclusion

The purpose of this paper is to present generalized net approach for modeling the electrical energy flow. This approach allows describing and simulating of the related processes via different scenarios and thus allowing furher improvements of the energy system.

References

[1] Atanassov K. Generalized Nets. World Scientific, 1991.
[2] Bulgarian Electric Company energy transmission and consumation reports, 2005