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A SIGN MODEL OF THE CHOICE OF EFFECTIVE PULSE DEVICES FOR INFORMATION TRANSMISSION LINES DIAGNOSTICS BASED ON CONDITIONAL SIMILARITY CRITERIA

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System analysis of characteristics of modern pulse devices of information transmission lines diagnostics is conducted. A list of modern pulse reflectometers and their main technical and economic indexes based on heuristic method is made. Sign model of the choice of effective pulse devices of information transmission lines diagnostics is offered, that will allow to optimize the choice of the most effective pulse device of information transmission lines diagnostics for a specific task on the basis of developed conditional similarity criteria.

Keywords: *information-communication networks, information transmission lines, pulse reflectometers, technical and economic indexes, conditional similarity criteria.*

INTRODUCTION

Today, communications networks do not become slower – even faster, aren't made easier – even more complicated and constantly develop. Timely diagnostics and rapid error recovery are important elements of reliable work of communications networks, for this purpose pulse devices of information transmission lines diagnostics – reflectometers, by which it is possible to analyze the availability of defects and damages location, are used.

The basic principle of reflectometer's work is analogical to that of radar. It is connected to the cable under test from one side, pulses in it and fixes the form of reflected signal – reflectogram. If the cable along the full length has constant impedance and is correctly loaded, all energy is dissipated. Any discontinuity of impedance, generated by defects, reflects its part or all of it back to a device and the value of the reflected signal is proportional to the deviation of impedance, i.e. the size of a defect. At the next stage, when the results are analyzed, the device determines the distance to the discontinuity, coming from the velocity of signal propagation in the cable and the time of its passing to the discontinuity and back. The velocity is usually represented as a coefficient, indicating how much the velocity of signal propagation in the cable differs from the velocity of light, and is taken from tables or empirically determined. In foreign devices a "coefficient of velocity", shown in percents (<100), is often used, in domestic ones it is a "coefficient of shortening" (>1) [1-4].

It is possible to mention among well-known classical capabilities of reflectometers:

– the search for breaks and short circuits in a cable;
– the detection of problems associated with excessive attenuation of high-frequency signal in the information transmission line;
– length measuring and entrance control of a cable in coils;
– the detection of latent defects of a cable;
– finding of low-quality connections;
– the diagnostics of cores misconnections in connection points;
– the search for components included in the information transmission line;
– the detection of the drenched places in a cable;
– the determination of an exact location of a cable fault during excavation works;

– the acceptance of the information transmission lines from contractors after the installation;
– the search for undocumented connections;
– documentation recovery, lock-on of a cable run to a locality;
– the detection of taps, illegal connection points and "bugs" [5-7, 14].

The use of reflectometers allows to organize the complex of procedures, directed at planned quality improvement of information transmission lines and simplification of fault diagnostics:
– preliminary operations – the collection and storage of information in a computer, mapping the run with lock-on to a locality by graphic editors;
– periodic maintenance – the collection and storage of information in a computer, its comparison with an existing one, the search for changes and determination of their numerical values, the analysis of defects and their causes, planning of repair works based on objective data;
– fault diagnostics – the collection and storage of information in a computer, its comparison with an existing one, the search for changes and value determination, estimation of the most significant change and place of repair on a run.

A number of papers [1-10] of such scientists as V. L. Aksenov, I. G. Baklanov, A. V. Kocherov, V. E. Kravtsov, A. M. Luk'yanov, N. F. Melnikova, N. I. Tarasov, S. G. Sharonin and others are devoted to the diagnostics of information transmission lines, electrical supply networks and their fault tracing. In those papers they consider various methods and physical models for accurate positioning of fault location in information transmission lines and electrical supply networks, and also for analysing these lines concerning defects by means of pulse reflectometry. However, in these papers a whole set of main parameters is scarcely represented; there is no single viewpoint which would allow to optimize the choice of the most effective pulse device of information transmission lines diagnostics.

PROBLEM STATEMENT

The **goal of the work** is a construction of a sign model of the choice of the effective pulse devices of information transmission lines diagnostics for choice optimization of the most effective pulse device of information transmission lines diagnostics on the basis of developed conditional similarity criteria.

To achieve this goal it is necessary to solve the following tasks:
– to make a list of modern pulse reflectometers and their main technical and economic indexes;
– to develop conditional similarity criteria after appropriate technical and economic indexes and to work out criterion equations;
– to construct sign model of dependences of main technical parameters of modern pulse reflectometers in dimensionless coordinates;
– to determine the most effective pulse devices of information transmission lines diagnostics.

RESULTS

To solve this task a list of main technical and economic indexes of modern reflectometers (Table 1) is made. Conditional similarity criteria, in which maximum measurement range, measuring inaccuracy, a coefficient of shortening, a price of a device are main determining quantities, are developed.

The coefficient of shortening shows how many times the velocity of signals propagation in a line is less than the velocity of light in vacuum and is determined by an expression

$$g = \frac{C}{V},$$

where g – the coefficient of shortening;

C – velocity of light in vacuum ($3 \cdot 10^8$ *м/с*);

V – velocity of pulse signal propagation in a line [10-12].

The coefficient of shortening and the coefficient of propagation (the coefficient of propagation is specified in foreign reflectometers) are connected by the following relation:

$$g = \frac{1}{V_{op}},$$

where V_{op} – the part of the velocity of light in vacuum [13].

Table 1 – Main technical and economic indexes of modern pulse reflectometers

№	Type and model of a device	Maximum measurement range, *m*	Measuring inaccuracy, %	Coefficient of shortening	Price of a device, UAH
1	Rejs-105M1	25 600	0,20	1.00...7.00	10 840
2	Rejs-100	6 400	0,20	1.00...4.00	7 536
3	RI-10M1	50 000	0,40	1.00...3.00	16 176
4	RI-10M2	50 000	0,40	1.00...3.00	18 296
5	RI-303T	4 800	0,21	1.00...3.00	8 376
6	RI-307	64 000	0,20	1.00...3.00	22 488
7	RI-307USB	64 000	0,20	1.00...3.00	12 080
8	Tempo TS 90	10 000	0,01	300-1000 (1.00...3.00)	19 800
9	Tempo TS 100	15 000	0,03	300-1000 (1.00...3.00)	45 960
10	Riser Bond 3300	19 400	0,15	30-999 (1.00...3.00)	15 416
11	Riser Bond 1270A	19 400	0,01	30-999 (1.00...3.00)	39 432
12	Riser Bond 1550T	3 000	0,90	1.00...3.00	12 203

It is offered to use the theory of incomplete similarity and dimensions, physical modeling and to create conditional similarity criteria based on heuristic method.

Generalized description of conditional similarity criterion through determining quontaties takes the following form:

$$K_i = \frac{Q_{\max} - Q_{\min}}{Q_{\max}}, \tag{1}$$

where K_i – dimensionless quantity, which characterizes the chosen parameter, indexes max and min correspond to maximum and minimum quantities from Table 1.

Criterion equation for pulse reflectometers according to determining quantities will take the following form:

$$\psi\left(\frac{L_{\max} - L_{\min}}{L_{\max}}; \frac{P_{\max} - P_{\min}}{P_{\max}}; \frac{Q_{\max} - Q_{\min}}{Q_{\max}}; \frac{C_{\max} - C_{\min}}{C_{\max}}\right) = 0.$$

Let’s denote $K_L = \frac{L_{\max} - L_{\min}}{L_{\max}}$ as the quantity which characterizes measurement range, it is better at $K_L \to 1$;

$K_P = \frac{P_{\max} - P_{\min}}{P_{\max}}$ as the quantity which characterizes measuring inaccuracy, minimum one is preferable;

$K_Q = \frac{Q_{\max} - Q_{\min}}{Q_{\max}}$ as the quantity which characterizes measuring range of cable types, it is better at $K_Q \to 1$;

$K_C = \frac{C_{\max} - C_{\min}}{C_{\max}}$ as the quantity which characterizes a price of a device.

These quantities will characterize appropriate technical and economic indexes.

The results of the calculation of appropriate coefficients are presented in the Table 2.

Table 2 – Conditional similarity criteria for modern pulse reflectometers

Conditional criterion \ Type	Rejs	RI	Tempo	Riser Bond
	1	2	3	4
K_L	0,75	0,925	0,333	0,845
K_P	0,5	0,5	0,98	0,98
K_Q	0,857	0,667	0,667	0,667
K_C	0,305	0,628	0,569	0,691

Using the data of the Tables 1-2 and π-theorem, the dependences of main technical parameters in dimensionless coordinates are constructed.

Comparative analysis, given in Fig. 1, shows that the devices of foreign manufacturers have a larger measuring inaccuracy after four quadrants, than those of domestic producers. Also reflectometers of domestic producers have an advantage in the coefficient of propagation, that allows to test a larger range of the variety of cables.

The results of the calculation of appropriate coefficients according to formula (1) are shown in the Table 3.

On the example of pulse reflectometer of “RI" type the dependence of pulse duration on measurements range in dimensionless coordinates, which is presented in Fig. 2, is built.

Comparative analysis of the dependence of pulse duration on measurement range (Fig. 2) shows that measurement accuracy depends on pulse duration in its range and at the choice of other duration, which doesn’t correspond to the Table 3, of pulses in the range it will result in the distortion of end result.

In addition, from the graph (Fig. 2) one can draw a conclusion that at short measurement range the range of pulses is small and the farther measurement range is, the wider pulses range becomes.

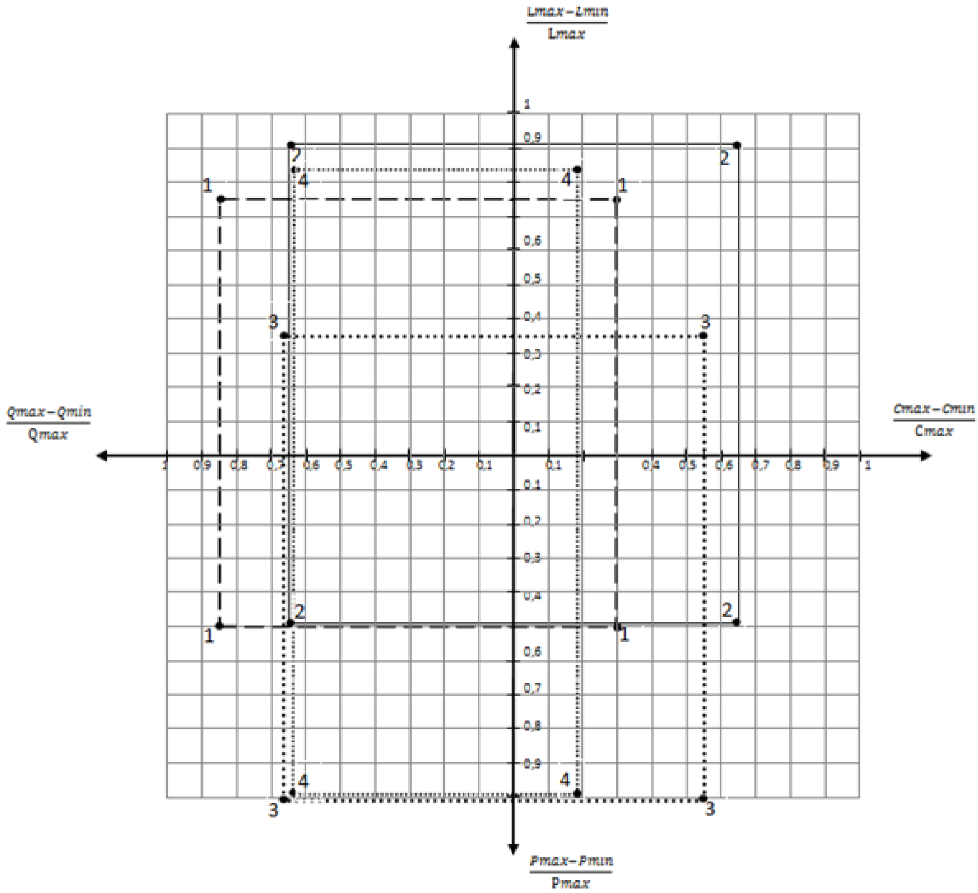

Figure 1 – Sign model of dependences of main technical parameters of modern pulse reflectometers in dimensionless coordinates
Note: numbers 1, 2, 3, 4 correspond to sequence number of pulse reflectometers, shown in Table 3.

Table 3 – Recommended pulse duration for measurements subrange

№	Maximum range of measurements subrange	Variants of pulse duration					K	Distance, $L_i/L_{\max}$
1	250 m		10 ns	20 ns	40 ns	60 ns	0,83	0,01
2	500 m	10 ns	20 ns	30 ns	60 ns	90 ns	0,89	0,02
3	1000 m	20 ns	30 ns	50 ns	100 ns	150 ns	0,87	0,04
4	2500 m	50 ns	100 ns	200 ns	400 ns	600 ns	0,92	0,1
5	5000 m	100 ns	250 ns	500 ns	1 mcsc	1,5 mcs	0,93	0,2
6	12500 m	500 ns	1 mcs	2 mcs	4 mcs	6 mcs	0,92	0,5
7	25000 m	1 mcs	2,5 mcs	5 mcs	10 mcs	15 mcs	0,93	1

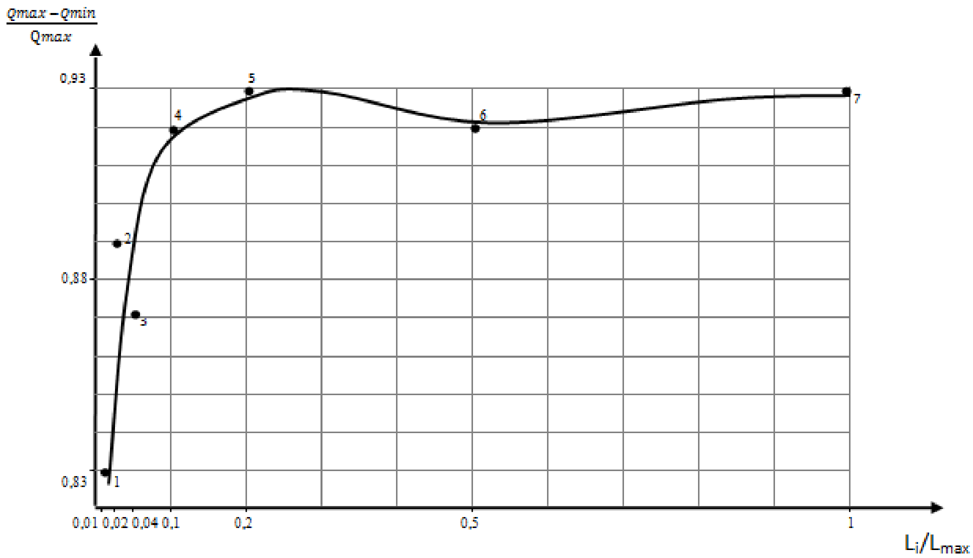

Figure 2 – Sign model of pulse dependence on measurements range in dimensionless coordinates
Note: numbers 1-7 correspond to sequence number of measurement ranges of pulse reflectometers, shown in Table 3

CONCLUSIONS

1. On the basis of the heuristic method a list of modern pulse reflectometers and their main technical and economic indexes, such as: maximum measurement range, measuring inaccuracy, the coefficient of shortening, the price of a device, which are determining quantities at the use of the theory of incomplete similarity, is made.
2. Conditional similarity criteria are developed, multicriterion sign model after four quadrants in dimensionless coordinates, which characterizes current parameters of reflectometers, is built. Modern pulse reflectometers of domestic production have an advantage of wide propagation coefficient at a small price with average characteristics of measurement range. Foreign devices have an advantage of low measuring inaccuracy, a disadvantage consists in heavy weight of pulse reflectometer. Any type of modern pulse reflectometers needs updating of its main parameters for entering the reference model combining all the best features.
3. On the example of pulse reflectometer of "RI" type one can see the limits of pulse change for every measurement subrange, as well as the dependence and limitations of pulse duration on the distance.

РЕЗЮМЕ

ЗНАКОВА МОДЕЛЬ ВИБОРУ ЕФЕКТИВНИХ ІМПУЛЬСНИХ ПРИСТРОЇВ ДІАГНОСТИКИ ЛІНІЙ ПЕРЕДАЧІ ІНФОРМАЦІЇ НА ОСНОВІ УМОВНИХ КРИТЕРІЇВ ПОДІБНОСТІ

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Проведено системний аналіз характеристик сучасних імпульсних пристроїв діагностики ліній передачі інформації. На основі евристичного методу складено перелік сучасних імпульсних рефлектометрів та їх основних техніко-економічних показників.

Запропонована знакова модель вибору ефективних імпульсних пристроїв діагностики ліній передачі інформації, що дозволить оптимізувати вибір найбільш ефективного імпульсного пристрою діагностики ліній передачі інформації для конкретного завдання на основі розроблених умовних критеріїв подібності.

Ключові слова: *інформаційно-комунікаційні мережі, лінії передачі інформації, імпульсні рефлектометри, техніко-економічні показники, умовні критерії подібності.*

РЕЗЮМЕ

ЗНАКОВАЯ МОДЕЛЬ ВЫБОРА ЭФФЕКТИВНЫХ ИМПУЛЬСНЫХ УСТРОЙСТВ ДИАГНОСТИКИ ЛИНИЙ ПЕРЕДАЧИ ИНФОРМАЦИИ НА ОСНОВЕ УСЛОВНЫХ КРИТЕРИЕВ ПОДОБИЯ

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Проведен системный анализ характеристик современных импульсных устройств диагностики линий передачи информации. На основе эвристического метода составлен перечень современных импульсных рефлектометров и их основных технико-экономических показателей. Предложена знаковая модель выбора эффективных импульсных устройств диагностики линий передачи информации, что позволит оптимизировать выбор наиболее эффективного импульсного устройства диагностики линий передачи информации для конкретной задачи на основе разработанных условных критериев подобия.

Ключевые слова: *информационно-коммуникационные сети, линии передачи информации, импульсные рефлектометры, технико-экономические показатели, условные критерии подобия.*

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