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Integration Of Fuzzy Set Approach For Comprehensive Study Of Sustainable Functioning Of The Telecommunication System Of Uzbekistan

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ABSTRACT

In the article the methods of evaluation based on fuzzy logic and network modelling based on the theory of fuzzy sets to the challenges of sustainable operation of telecommunications systems. The factors affecting the sustainable operation of telecommunication systems using fuzzy sets.

KEYWORDS

Telecommunication networks, uncertainty sets theory, logical model, telecommunication systems, complex model, linguistic variables, state of TN, the influence of external factors, the influence of internal factors, influence of energy factors.

INTRODUCTION

Today, the stage of development of telecommunication technologies, networks and communication infrastructure of the country is carried out by expanding fixed and mobile broadband access networks, modernizing and expanding backbone optical telecommunication networks, as well as creating infrastructure for the development of multimedia services. Today information technologies are actively developing, and in parallel, the problems of ensuring the stable operation of backbone optical networks continue to grow.

Means and telecommunication networks of the Republic of Uzbekistan are the main arteries for sustainable development of all sectors of the country's economy and today more than 97% are digitalized.

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A telecommunication system is understood as an organizational and technological system that includes telecommunication facilities and networks (communication lines, transmission lines, physical circuits, line-cable communication facilities), power supply systems, information security, information protection, technical operation and maintenance, subscriber terminals, training and retraining of personnel [1-4].

It is known that the creation of a digital telecommunication system is a complex and capital-intensive task, at the same time it is quite conservative. Conservatism lies in the fact that the capital invested in the creation of a digital telecommunication system is returned for years, through the creation and sale of telecommunication services [5-8].

In these conditions, it is urgent to solve the problem of ensuring the stable functioning of the digital telecommunication system [9-12].

An interruption in the operation of the telecommunication system, even for a short period, causes the loss of a large amount of transmitted information, which, being a violation of the stability of the functioning of the system, can lead to serious technical and financial consequences [13-15].

Another important task that determines the stability of the functioning of the telecommunications system as a whole is the requirement for the delivery to the subscriber (consumers of services) of reliable information transmitted through communication channels. With modern ultra-high-speed fibre-optic information transmission systems, even short-term external and internal factors of influence can cause the so-called "data packet loss". Detection of such packets necessitates their retransmission. This first of all causes a delay in the message delivered to the subscriber for the time of detection and retransmission of the "lost data packet", degrades the quality of the services provided and, therefore, negatively affects the market image of a telecommunications operator, especially an international operator.

MATERIALS AND METHODS

In recent years, it is especially important to resolve the issue of the integrity of the transmitted information, which led to the creation of a system for protecting information transmitted via a digital telecommunications system.

The stability of the telecommunication network (TN) functioning is understood as the structural stability of the TN, which ensures the performance of the established functions in the event of failure of a part of the system elements as a result of the influence of destabilizing factors. Such a substantiation of the term for the stability of the functioning of the telecommunication system is explained by the fact that when external and internal destabilizing factors act on the PT - the deterioration of the reliability of individual elements and nodes, the violation of survivability, short-term interruptions and changes in the power supply voltage, short-term traffic overload, etc., the topology and structure of the TN in the whole is preserved [14].

The main task of the basic components of telecommunication systems (hardware, software and service systems) is to ensure or restore the normal functioning of the telecommunication system during a standard period of time [15]. The structural diagram of the TN functioning is presented in the form of a set of dispersed objects and subsystems functioning individually or as a whole (Figure 1).

The given structural scheme of TN functioning presupposes consideration of the problem of stability of functioning as a whole, in a complex, which is much more difficult, broader than the system approach. Research and operational assessment of the degree of stability of TN functioning should be based on a systematic approach that provides operational accounting of the influence of each factor on the stable operation of the system [15].

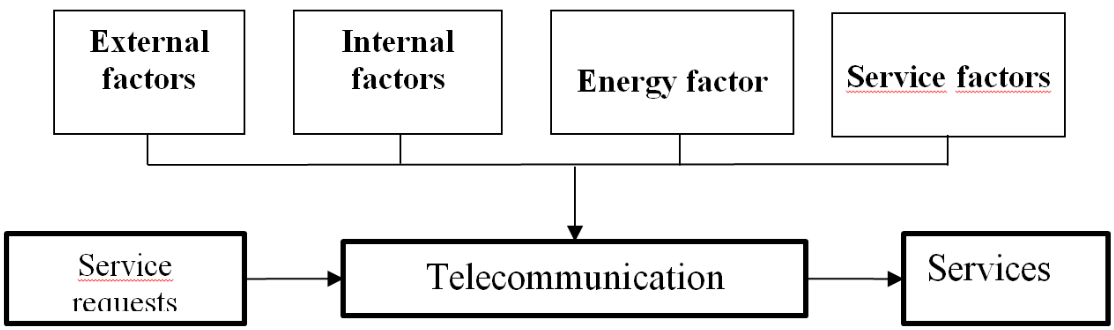

Figure. 1 - Structural diagram of the functioning of the telecommunication system

However, the complexity and ambiguity of the relationships between the parameters and characteristics of the TN, the influence of internal and external factors on the stability of the functioning of the TN, which have a heterogeneous character and different attribute spaces, is decisive when choosing an integrated approach based on a systematic consideration of the components of TN with their subsequent aggregation within a single TN [14].

The classification of factors affecting the stability of the functioning of telecommunications systems, taking into account the degree of their impact and the decisions made to eliminate them, is a complex and multi-parameter problem (Figure 2). Therefore, for a quick assessment of the state of the TN functioning, an assessment concept is proposed based on an integrated model based on a systematic consideration of the elements and components of the TN. The complex model includes the following basic components:

- Identification (assessment) of the technical state of TN, taking into account external and internal influencing factors;
- Making decisions to regulate the elimination of the influence of influencing factors.

Application of the principles of the theory of fuzzy sets.

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Due to the fact that the factors influencing the stability of the telecommunication system (Figure 2) are characterized by heterogeneity, i.e. different subject scales of measurements and the nature of information (quantitative, qualitative, mixed), then for the implementation of such a concept it seems expedient to apply the principles of the theory of fuzzy sets (TFS), which makes it possible to make decisions in conditions when the goals, limitations and consequences of possible impacts on the ST are considered to be not known.

Let us assume that S1, S2, S3, S4 are TN states, defined linguistically in the following order:

S1 - <steady state of TN >;

S2 - <more or less stable state of TN >;

S3 - <unstable state of TN >;

S4 - <absolutely stable state of TN >.

The formulated states S1, S2, S3, S4 are considered to be the types of assessment of the state of ST, to be determined based on the results of their study.

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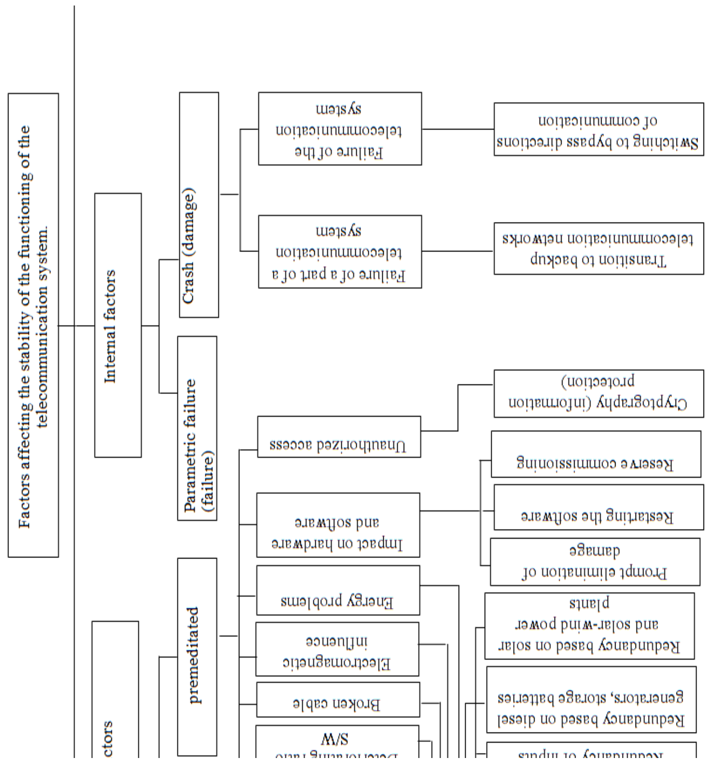

Figure. 2 - Classification of factors affecting the stability of the functioning of the telecommunications system.

The structure of the model for carrying out a comprehensive assessment of the stability state of the vehicle is presented in the form of a tree (Figure 3) inference according to the following relationships:

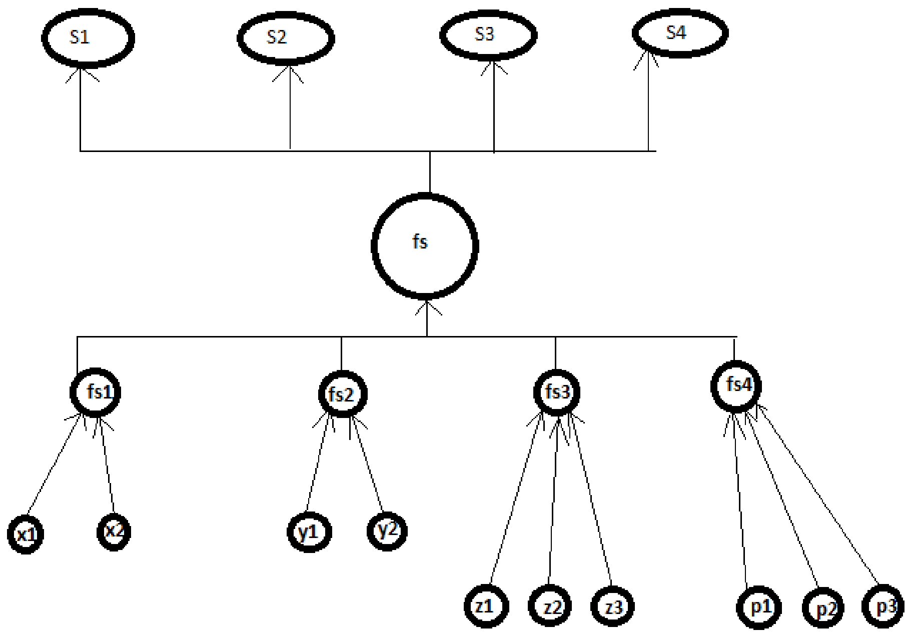

Figure. 3 - Fuzzy inference tree for a comprehensive assessment of the state of the telecommunications system.

In the integrated model, the following designations are adopted:

S - < state of TN>;

X - <influence of external factors>;

Y - <influence of internal factors>;

Z - <influence of energy factors>;

P - <service>;

$$S = f_s(X, Y, Z, P), \qquad (1.1)$$

$$S_1 = f_{s_1}(X_1, X_2), \qquad (1.2)$$

$$S_2 = f_{s_2}(Y_1, Y_2), \qquad (1.3)$$

$$S_3 = f_{s_3}(Z_1, Z_2, Z_3), \qquad (1.4)$$

$$S_4 = f_{s_4}(P_1, P_2, P_3). \qquad (1.5)$$

X1 - the influence of factors of physical origin;

X2 - the influence of intentional factors;

$$X_1 = f_{X1}(X_{11}, X_{12}, X_{13}, X_{14}, X_{15}), \qquad (1.6)$$

$$X_2 = f_{X2}(X_{21}, X_{22}, X_{23}, X_{24}, X_{25}), \qquad (1.7)$$

Y1 - impact in the form of parametric failure;

Y2 - impact in the form of catastrophic failure;

$$Y_1 = f_{Y1}(Y_{11}, Y_{12}, Y_{13}), \qquad (1.8)$$

$$Y_2 = f_{Y2}(Y_{21}, Y_{22}). \qquad (1.9)$$

Z1 - impact in the form of short-term outages;

Z2 - emergency shutdown;

Z3 - use of renewable energy sources;

P1 - prompt elimination of ST instability;

P2 - programmed elimination of ST instability;

P3 - restoration of work;

X11 - deterioration of the S / W ratio;

X12 - cable aging;

X13 - cable break;

X14 - electromagnetic influences;

X15 - energy problems;

Y11 - <off parameters from the norm>;

Y12 - <traffic congestion>;

Y13- <synchronization violation>;

Y21 - <failure of a part of TN>;

Y22- <TN failure>;

To assess the values of the linguistic variables X, Y, Z, P and S and their components, a single scale of qualitative terms is introduced: L - low; BA - below average; M - medium; AA - above average; H- high.

Implementation of an integrated model for assessing the stability of TN.

To implement a comprehensive model for assessing the stability of ST, a knowledge base is being designed (table №1 - №5):

Table 1. Knowing about the ratio $S = f_s(S_1, S_2, S_3, S_4)$

S	S_1			S_2			S_3			S_4	
X	L	BA	M	BA	BA	BA	M	AA	H	H	H
Y	L	L	BA	BA	BA	BA	M	AA	H	M	AA
Z	L	L	L	BA	L	BA	M	AA	H	AA	AA
P	H	H	H	BA	L	BA	L	AA	H	L	BA

Table 2. Knowing about the ratio. $S_1 = f_{S_1}(X_1, X_2)$

S_1	L			BA			M			AA			H		
X_1	L	BA	BA	L	BA	M	M	M	M	M	AA	M	AA	AA	H
X_2	L	BA	L	M	M	M	L	BA	M	M	M	AA	AA	H	H

Table 3. Knowing about the ratio. $S_2 = f_{S_2}(Y_1, Y_2)$

S_2	L			BA			M			AA			H		
Y_1	L	L	BA	BA	M	BA	BA	BA	M	M	M	AA	AA	H	H

Y_2	L	M	M	BA	BA	M	M	BA	BA	AA	AA	AA	H	AA	H

Table 4. Knowing about the ratio. $S_3 = f_{s_3}(Z_1, Z_2, Z_3)$

S_3	L			BA			M			AA			H		
Z_1	L	L	L	L	L	M	L	BA	M	M	M	M	M	M	M
Z_2	L	BA	M	BA	M	M	M	BA	M	L	L	L	L	BA	L
Z_3	L	BA	L	M	M	L	M	M	BA	AA	M	AA	AA	H	H

Table 5. Knowing about the ratio $S_4 = f_{s_4}(P_1, P_2, P_3)$

S_4	L			BA			M			AA			H		
P_1	L	L	L	BA	BA	BA	M	M	M	M	M	AA	AA	AA	H
P_2	L	BA	BA	BA	L	BA	BA	M	M	AA	M	M	AA	AA	H
P_3	L	L	BA	L	BA	BA	BA	BA	M	M	AA	M	M	AA	AA

Based on tables No. 1 - No. 5 and using the principles of TNM, a system of fuzzy logical equations is obtained, which allows determining the state of the telecommunication system:

$\mu^{S_1}(s) = [\mu^{H}(x) \times \mu^{M}(y) \times \mu^{AA}(z) \times \mu^{L}(p)] \vee [\mu^{H}(x) \times \mu^{AA}(y) \times \mu^{AA}(z) \times \mu^{BA}(p)];$

$\mu^{S_2}(s) = [\mu^{BA}(x) \times \mu^{M}(y) \times \mu^{BA}(z) \times \mu^{BA}(p)] \vee [\mu^{BA}(x) \times \mu^{BA}(y) \times \mu^{L}(z) \times \mu^{L}(p)] \vee [\mu^{M}(x) \times$
$\mu BAy\times\mu BAz\times\mu BAp]$;

$\mu^{S_3}(s) = [\mu^{M}(x) \times \mu^{M}(y) \times \mu^{M}(z) \times \mu^{L}(p)] \vee [\mu^{AA}(x) \times \mu^{AA}(y) \times \mu^{AA}(z) \times \mu^{AA}(p)] \vee [\mu^{H}(x) \times$
$\mu Hy\times\mu Hz\times\mu Hp]$;

$\mu^{S_4}(s) = [\mu^{L}(x) \times \mu^{L}(y) \times \mu^{L}(z) \times \mu^{H}(p)] \vee [\mu^{BA}(x) \times \mu^{L}(y) \times \mu^{L}(z) \times \mu^{H}(p)] \vee [\mu^{M}(x) \times$
$\mu BAy\times\mu Lz\times\mu Hp]$;

$\mu^L(S_1) = [\mu^L(x_1) \times \mu^L(x_2)] \vee [\mu^{BA}(x_1) \times \mu^{BA}(x_2)] \vee [\mu^{BA}(x_1) \times \mu^L(x_2)];$

$\mu^{BA}(S_1) = [\mu^L(x_1) \times \mu^M(x_2)] \vee [\mu^{BA}(x_1) \times \mu^M(x_2)] \vee [\mu^M(x_1) \times \mu^M(x_2)];$

$\mu^M(S_1) = [\mu^M(x_1) \times \mu^L(x_2)] \vee [\mu^M(x_1) \times \mu^{BA}(x_2)] \vee [\mu^M(x_1) \times \mu^M(x_2)];$

$\mu^{AA}(S_1) = [\mu^M(x_1) \times \mu^M(x_2)] \vee [\mu^{AA}(x_1) \times \mu^M(x_2)] \vee [\mu^M(x_1) \times \mu^{AA}(x_2)];$

$\mu^H(S_1) = [\mu^{AA}(x_1) \times \mu^{AA}(x_2)] \vee [\mu^{AA}(x_1) \times \mu^H(x_2)] \vee [\mu^H(x_1) \times \mu^H(x_2)];$

$\mu^L(S_2) = [\mu^L(y_1) \times \mu^L(y_2)] \vee [\mu^L(y_1) \times \mu^M(y_2)] \vee [\mu^{BA}(y_1) \times \mu^M(y_2)];$

$\mu^{BA}(S_2) = [\mu^{BA}(y_1) \times \mu^{BA}(y_2)] \vee [\mu^M(y_1) \times \mu^{BA}(y_2)] \vee [\mu^{BA}(y_1) \times \mu^M(y_2)];$

$\mu^M(S_2) = [\mu^{BA}(y_1) \times \mu^M(y_2)] \vee [\mu^{BA}(y_1) \times \mu^{BA}(y_2)] \vee [\mu^M(y_1) \times \mu^{BA}(y_2)];$

$\mu^{AA}(S_2) = [\mu^M(y_1) \times \mu^{AA}(y_2)] \vee [\mu^M(y_1) \times \mu^{AA}(y_2)] \vee [\mu^{AA}(y_1) \times \mu^{AA}(y_2)];$

$\mu^H(S_2) = [\mu^{AA}(y_1) \times \mu^{AA}(y_2)] \vee [\mu^H(y_1) \times \mu^{AA}(y_2)] \vee [\mu^H(y_1) \times \mu^H(y_2)];$

$\mu^L(S_3) = [\mu^L(z_1) \times \mu^L(z_2) \times \mu^L(z_3)] \vee [\mu^L(z_1) \times \mu^{BA}(z_2) \times \mu^{BA}(z_3)] \vee [\mu^L(z_1) \times \mu^M(z_2) \times \mu^L(z_3)];$

$\mu^{BA}(S_3) = [\mu^L(z_1) \times \mu^{BA}(z_2) \times \mu^M(z_3)] \vee [\mu^L(z_1) \times \mu^M(z_2) \times \mu^M(z_3)] \vee [\mu^M(z_1) \times \mu^M(z_2) \times \mu^M(z_3)];$

$\mu^M(S_3) = [\mu^L(z_1) \times \mu^{BA}(z_2) \times \mu^M(z_3)] \vee [\mu^{BA}(z_1) \times \mu^{BA}(z_2) \times \mu^M(z_3)] \vee [\mu^M(z_1) \times \mu^M(z_2) \times \mu^{BA}(z_3)];$

$\mu^{AA}(S_3) = [\mu^M(z_1) \times \mu^L(z_2) \times \mu^{AA}(z_3)] \vee [\mu^M(z_1) \times \mu^L(z_2) \times \mu^M(z_3)] \vee [\mu^M(z_1) \times \mu^{BA}(z_2) \times \mu^{AA}(z_3)];$

$\mu^H(S_3) = [\mu^M(z_1) \times \mu^L(z_2) \times \mu^{AA}(z_3)] \vee [\mu^M(z_1) \times \mu^{BA}(z_2) \times \mu^H(z_3)] \vee [\mu^M(z_1) \times \mu^L(z_2) \times \mu^H(z_3)];$

$\mu^L(S_4) = [\mu^L(p_1) \times \mu^L(p_2) \times \mu^L(p_3)] \vee [\mu^L(p_1) \times \mu^{BA}(p_2) \times \mu^L(p_3)] \vee [\mu^L(p_1) \times \mu^{BA}(p_2) \times \mu^{BA}(p_3)];$

$\mu^{BA}(S_4) = [\mu^{BA}(p_1) \times \mu^{BA}(p_2) \times \mu^L(p_3)] \vee [\mu^{BA}(p_1) \times \mu^L(p_2) \times \mu^{BA}(p_3)] \vee [\mu^{BA}(p_1) \times \mu^{BA}(p_2) \times \mu^{BA}(p_3)];$

$\mu^M(S_4) = [\mu^M(p_1) \times \mu^{BA}(p_2) \times \mu^{BA}(p_3)] \vee [\mu^M(p_1) \times \mu^M(p_2) \times \mu^{BA}(p_3)] \vee [\mu^M(p_1) \times \mu^M(p_2) \times \mu^M(p_3)];$

$\mu^{AA}(S_4) = [\mu^{M}(p_1) \times \mu^{AA}(p_2) \times \mu^{M}(p_3)] \vee [\mu^{M}(p_1) \times \mu^{M}(p_2) \times \mu^{M}(p_3)] \vee [\mu^{AA}(p_1) \times \mu^{M}(p_2) \times \mu^{M}(p_3)]$;

$\mu^{H}(S_4) = [\mu^{AA}(p_1) \times \mu^{AA}(p_2) \times \mu^{M}(p_3)] \vee [\mu^{AA}(p_1) \times \mu^{AA}(p_2) \times \mu^{AA}(p_3)] \vee [\mu^{H}(p_1) \times \mu^{H}(p_2) \times \mu^{AA}(p_3)]$.

To simplify calculations for all linguistic variables of the complex model, a single form of the membership function for fuzzy terms(L, HC, M, BC, H) is used using a universal substitution [27].

$$\mu^{j}(u): u = 4\frac{x_i - \underline{x}_i}{\overline{x} - \underline{x}_i}$$; j= L; BA; M; AA; H; u→[0,4].

The analytical membership function has the form;

$$\mu^{j}(u)\frac{1}{1-\left(\frac{u-b}{c}\right)^{2}}.$$

Intuitively, based on experience, for the parameter b for the terms L, BA, M, AA, H, the values are taken as 0,1,2,3,4, respectively, and the parameter M for all terms is taken equal to 0.9 [27]. The proposed fuzzy-logical models make it possible to assess the stability of the ST and are implemented according to the following algorithm:

1. The values of the state parameters are fixed:

$$U^{*} = \{x_1^{*}, x_2^{*}, y_1^{*}, y_2^{*}, z_1^{*}, z_2^{*}, z_3^{*}, p_1^{*}, p_2^{*}, p_3^{*}\}.$$

2. The values of the membership function (MF) are determined at fixed values of U^{*}.

3. Based on the system of fuzzy-logical equations, the FP values are calculated for the states S1, S2, S3, S4.

4. By ranking the values of the MF by states in descending order, specific states are determined from the sets of possible S = {S1, S2, S3, S4}.

CONCLUSIONS

We have investigated fuzzy multiple approaches to the process of functioning of telecommunication networks. It is shown that the integration of fuzzy multiple approaches into the process of assessing the stability of the functioning of telecommunications facilities and networks seems promising in terms of representing ST as a whole, within the framework of a single integrated model of telecommunications facilities and networks.

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