UDK 621.391.3

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THE FORMALIZED CORRELATIONS AND INTERCONNECTIONS OF TELECOMMUNICATION SYSTEMS AND TELECOMMUNICATION ROUTES FROM THE STANDPOINT OF SYSTEM THEORY

Problem Statement

The nowadays stage of development of world civilization is characterized by the transition from the industrial to the information type society, which involves new forms of social and economic activity based on the widespread use of information and telecommunication technologies. The technological basis of such a society is the Global Information Infrastructure (GII) that should provide every inhabitant of the planet with a free access to the information resources.

In its turn, the tangible and at the same time the system-forming basis of such an infrastructure are telecommunication systems. The major national problem is a creation of a highly efficient telecommunication environment. Without solving it, the building of an information society and the application of information technology achievements to the fields of production, business, science, education, medicine and culture will turn out to be problematic [1].

In the process of formation and development of computerized systems, the term “telemechanics system” was indicated as a set of technical means for a distance transmitting of commands from the operator or controlling computer to the control objects by radio channels or wire lines, as well as control information in the feedback [1]. So, telemechanics was meant to be the management at a distance.

In the process of developing digital data transmission systems the standardization of devices, processes, information flows, processing and presentation procedures became relevant. This gave impetus to the development and implementation of telecommunication systems (TCS) in practice.

Telecommunication systems are the systems of communication of the corresponding level of management. Telecommunication routes (TCR) and data channels are the constituent parts of TCS. TCS and data channels implement data support of computerized systems.

Today, the theory of systems satisfies the needs of sociology, ecology, biology, military science, groups of interacting computers, radio equipment, and others. The system theory studies the formal interrelationships between the constituent parts of the material world phenomena abstracting from their specific nature.

In general terms, the system is a set of interconnected elements that form a corresponding integrity, unity.

Telecommunication systems and telecommunication routes are integral parts of computerized systems and therefore it is appropriate to consider the correlation between TCS and TCR.

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In the process of developing digital data transmission systems the standardization of devices, processes, information flows, processing and presentation procedures became relevant. This gave impetus to the development and implementation of telecommunication systems (TCS) in practice.

Analysis of publications, the purpose of elaboration

The general definition of TCS literally coincides with the definition in the case of macroapproach to the classification of TCS, i.e. to the classification and study of communication systems. In the case of macroapproach, TCS is the communication system itself of the corresponding level of management, and all the lines and communication means are the elements of this system. So TCS is a communication system. The distance between subscribers does not matter. The lines and communication means are telecommunication routes. They are implemented for the exchange of information between the control object and the processing system, which characterizes the state of the object.

Telecommunication route is a communication path, a transmission path, a complex of technical equipment and communication lines intended to form specialized channels for information transmission [2]. The notion of "route" is broader than the channel. The communication route is characterized by certain standard indicators: the frequency band, the information transmission rate, etc.

 ISSN 1562-9945

Consequently, the optimization of parameters and characteristics of the electronic TCR circuit devices is a priority task. To do this, it is necessary to clearly identify the correlations and interconnections of the concepts of telecommunication systems and telecommunication routes from the standpoint of the theory of systems.

Subject of elaboration

The focus of the theory of systems lies in the study of cause-and-effect relationships.

The most general definition of the theory of systems [1] is the analytic one according to which the system is called the reflection on abstract sets

$$S \subset \cdot * \{V_i : i \in I\}, \quad (1)$$

where * is the symbol of the direct (Cartesian) product;

V_i is the system element with index i;

I is the set of indexes.

For a finite set of element the mapping (1) can be rewritten in the form

$$S \subset V_1 *_2 *V_n. \quad (2)$$

The expression (2) emphasizes the fact that the system is a set of elements V_i that interact with each another.

One and the same object at different stages can be considered in various aspects. In some cases, it can act as a system. In others, the same object can be regarded as an element of a more general system – the metasystem. The relations or links between certain objects can also be the elements of the system.

Thus, the level of consideration of being a system can be varied.

When describing a system, one can proceed from two basic assumptions:

– the system's behavior is purposeful, its function is subordinated to certain formal rules of decision-making and management (purposeful, controlling or controlled systems);

– there are cause-and-effect relationships in the system, they are characterized by the dependence of its response on the corresponding outputs from the influences on the inputs (‘input – output” or “black box” systems).

There are open and closed systems. Open systems are those connected with the environment by incoming and outgoing channels. Closed systems do not have such channels.

Open systems have inputs

$$X = x\{V_i : i \in I_x\}. \quad (3)$$

The influences come through them. Their outputs

$$Y = x\{V_i : i \in I_y\}. \quad (4)$$

At the outputs the reactions to incoming influences are observed. For the open systems, the more specific definition is as follows

$$S =\subset X * Y. \quad (5)$$

System (5) is called the “input – output” or “black box” system. The system element (V_i, $i \in I$) is understood as the simplest undivided part of the system. Indivisibility means that the further division is inappropriate because it destroys the properties of the element, or does not provide any additional information when studying the specific system properties and structure which should be considered.

The general definition of TCS literally coincides with the definition in the case of macroapproach to the classification of TCS, i.e., to the classification and study of communication systems [4].

Macroapproach, microapproach and mesaapproach are classified to the study of communication systems, i.e., to the classification of TCS.

In the case of macroapproach, TCS is the communication system of the corresponding control unit itself, and all lines and communication means are system elements.

In the case of a microapproach TCS is considered as a separate device or junction that consists of elements (such as radio components) which interact with each other.

Mesapproach is applied at the level of interacting means and communication systems.

Also, when studying TCS it is necessary to consider it in the process of interaction with other systems, or with the environment. TCS elements

 ISSN 1562-9945

can be independent of each other. In this case, their entropy, that is their common uncertainty, is the sum of separate uncertainties:

$$H_{V_1V_2} = H_{V_1} + H_{V_2}, \quad (6)$$

where H_{V_i} – the uncertainty of one system element. The general system uncertainty with n independent elements

$$H_{\Sigma} = \sum_{i=1}^{n} H_{V_i}. \quad (7)$$

In case the elements v_1 and v_2 are dependent then

$$H_{V_1V_2} = H_{V_1} + H_{V_2/V_1}, \quad (8)$$

or

$$H_{V_1V_2} = H_{V_1/V_2} + H_{V_2}, \quad (9)$$

where H_{V_1/V_2} and H_{V_2/V_1} are the conditional entropies.

The mutual uncertainty of the dependent elements is smaller compared to the independent, i.e.

$$H_{V_2} \geq H_{V_2/V_1}. \quad (10)$$

TCS has its own functional and structural characteristics and properties.

The functional characteristic of TCS is its behavior characteristic in time. It can be represented by a mathematical description of the system reaction to some influences. The functional properties of TCS include:

– current traffic parameters;

– loading of resources;

– the size of the reserves;

– deviation of working parameters of network elements.

The structural characteristic of TCS is a conditional display of a set of its elements and interconnections between these elements. An adequate mathematical model of this structure is mathematical graphs, matrices, incidents, complexities, compatibilities.

The structural properties of the TCS include the existing configuration of the TCS network, which should be restructured in accordance with the change of functional capabilities state.

It is appropriate to draw attention to the following definitions: telecommunication systems and telecommunication routes.

In the case of a macroapproach to the classification of TCS above it was noted the following. TCS is the system of communication of the corresponding control unit, and all lines and means of communication are the system elements. The lines and communication means are called telecommunication routes. They are used to exchange information between the object of management and the data processing system.

The following definition is given in [5]. The telecommunication route is a communication path, a transmission path, a complex of technical equipment and communication lines for the formation of specialized channels for information transmission. Consequently, the concept of a "route" is broader than of a "channel". The routes are usually multichannel. The term "tone frequency channel" is used as a standard channel. The frequency clarity band width in it is within 300Hz – 3400Hz. The main characteristics of the channels are the clarity band and the kind of signals in them.

When defining the notion of "route", the main thing is its functional purpose. For example, the routes of reception – transmission of telemetry signals (TM), telesignaling (TS), telecontrol (TC), telegraphy (TG), alphanumeric arrays (ANA), radio link communication path, a group path of pulse-code modulation equipment, line channel of the compression system (organizing a large number of channels).

To organize the automatic control of the object nowadays the information management systems (IMS) are widely used. There the object of management is connected with the devices for processing information (including computers) with the help of lines and means of communication. Lines and communications are telecommunication routes. They transmit information of telemetry (TM), telesignaling (TS), telecontrol (TC), alphanumeric arrays (ANA).

In the case of a macroapproach to the classification of telecommunication systems, the information-control system is a telecommunication system itself. That is, the communication system of the corresponding control unit itself, and all the lines and means of communication are elements of this system.

In the case of a microapproach to the classification of TCS, i.e. with a more detailed consideration of its constituent parts, telecommunication routes can also be called telecommunication systems.

 ISSN 1562-9945

Taking into account that the mesoapproach is used at the level of interacting means and communication complexes, we can say that one of the possible variants of TCS is a certain number of IMSs, which are united in one whole. The information in them is transmitted in the form of numeral arrays and circulates in accordance with the protocols of exchange. And the tasks to be solved are:

– changes in the topology of TCS (tree-like, star-shaped, circular, general "tire", annular, multi-link);

– routing;

– defining and providing current traffic parameters;

– loading of resources;

– providing acceptable working parameters of the network elements, etc.

Telecommunication systems can be called weakly structured. The relationships between the elements in them are quite general and can be set, for example, by graphs, tables, logical connections. These relationships cannot be functionals or analytic functions.

A weakly structured system can be conditionally divided into a certain number of levels [6]. System levels can be considered as its elements, among which are communications, interfaces (real channels, electrical or logical connections). Seven-level models of TCS are also known. The list of levels of such a TCS is: applied, representative, sessional, transport, network, channel, physical.

The physical level is the physical environment (ether, fiber optic, wire, etc.), through which the signals are distributed from one consumer to another.

The channel level is providing of the interference protection, synchronization, signal coding.

The network level provides switching, routing the information packets. At this level, packet forwarding through the network as well as routing are implemented in accordance with the protocols.

The transport level serves to communicate with the upper levels that are responsible for organizing the information exchange.

The sessional level provides identification of connections, management of the dialogue between the applied processes of information processing.

The applied level is the upper level. It provides the quality of service, the availability of a partner to the transmission environment, the management of applied processes, terminals, network in general.

The representative level provides the choice of forms, the language of the alphabet and the format of presenting the information to the user, and in the opposite direction the transformation of information from the form of the upper level into the one that is required for its further transmission by the transport network takes place.

The seven-level model of the interaction of open TCS provides communication between TCS in accordance with interactions protocols.

The channel, physical, network and transport levels of the TCS combine the traditional notion of communication.

Three-level model of TCS is also known, according it the system performs three main functions: subscriber access, distribution of information flows and their transmission through the highways. This TKC model is quite constructive in the stages of studying or designing a particular system.

Most technical objects simulation can be fulfilled on the micro, macro and metalevels, which differ in the grain size of the considered processes in the object. Level methods differ from each other in type and dimensionality of the obtained system of equations. For the complex technical objects the dimensionality of a mathematical model (MM) becomes extremely high and it is efficient to proceed to the metalevel for simulation. At the meta-level, two categories of technical objects are mainly modeled: the objects that are the subject of the study of the theory of computerized control and the objects that is the subject of the theory of mass service. The objects that are the subject of the study of the theory of computerized control can be represented as a set of blocks, performing augment, integration, transmission of a signal with a given coefficient. We can say that these objects also include telecommunication channels of computerized information processing and management systems. For the first category of objects it is possible to use the mathematical apparatus of the macrolevel. Enough large elements can be distinguished when modeling at the macrolevel in the technical system, which are further considered as an indivisible unit. On the macrolevel the elements are an amplifier, modulator, etc. At the meta-level structural object schemas are used, which include the elements selected at the macrolevel. For each

 ISSN 1562-9945

structural element the transmitting functions are defined. The transmitting function of the whole topological model of a complex technical object, in this case of a telecommunication path, is determined with taking into account the functions of the transmission of separate constituent parts – structural elements. It is a mathematical model of a complex technical object itself. Therefore, due to the nature of the research and taking into account the requirements for the simplicity and reliability of the set problem solution, it is most appropriate to select and use mathematical models in the form of transmitting functions of telecommunication paths elements.

The receiving-transmitting path of informational sending of telecontrol and telesignaling has the following generalized mathematical model:

$$Y = F(X,Q), \quad (11)$$

where Y, X, Q are the vectors of output, internal and external parameters, F is the operator of the object. We can record

$$Y = (y_1, y_2, ..., y_m),$$
$$X = (x_1, x_2, ..., x_n),$$
$$Q = (q_1, q_2, ..., q_l),, \quad (12)$$

where m, n and l are the number of output, internal and external parameters.

By the nature of the operator, the object of the model can be in the form of: a linear differential equation of the nth degree, a differential equation in separate derivatives, systems of linear differential equations, finite-difference equations, a system of regressive equations, transfer functions, weight functions.

An alternative to mathematical modeling is a physical breadboarding, but mathematical modeling has a number of advantages: less time to prepare an analysis, a possibility to perform experiments on critical behaviours that would lead to the destruction of the physical prototype and others. Most technical objects simulation can be fulfilled on the micro, macro and metalevels, which differ in the grain size of the considered processes in the object. Level methods differ from each other in type and dimensionality of the obtained system of equations by sampling the components of the equations of reactive branches, by the permissible types of interconnected branches. For the complex technical objects the dimensionality of a mathematical model (MM) becomes extremely high and it is efficient to proceed to the metalevel for simulation. At the meta-level, two categories of technical objects are mainly modeled: the objects that are the subject of the study of the theory of computerized control and the objects that is the subject of the theory of mass service. The basic provisions for obtaining mathematical models of technical objects at the macrolevel are as follows. When modeling at the macrolevel rather large elements are singled out in the technical system, they are further considered as an indivisible unit. For each element of a simulated technical object the component equations must be obtained. The systems obtain MM by combining component and topological equations. Component equations can be linear, nonlinear, algebraic, ordinary differential or integral. The analogy of the component equations is as follows.

In most technical systems and telecommunication tracts, in particular, three types of elementary elements can be distinguished.

1. The element of R-type. This element transforms energy into heat energy.

2. Elements C and L (accumulation of kinetic and potential energy).

The mathematical models of almost any complexity technical objects can be received by combining these elementary elements, as well as the sources of phase variables. The phase variables of the electrical subsystem are the currents I and the voltages U. The resistance equation: $I = U/R$. Capacity equation: $I = C(dU / dt)$. Inductance equation: $I = L(dI / dt)$. The analogies of the topological equations are as follows. The topological equations in most physical subsystems are based on the equilibrium equation and the continuity equation. In electrical subsystems the connections between separate elements are established on the basis of Kirchhoff's law. The topological equations of subsystems are written down for junctions and contours of the equivalent circuit. The objects that are the subject of the study of the theory of computerized control can be represented as a set of blocks, performing addition, integration, transmission of a signal with a given coefficient. The connection between separate phase variables (currents and voltages) related to different subsystem elements is given by the topological equations derived from the information about the subsystem structure (L, R, C, active elements). The procedure for obtaining topological equations is fulfilled for each modulated object (amplifier, modulator, digital analog converter, quasi-optimal receiver, etc.) because the object structures are different. At the macrolevel the objects are an amplifier, a modulator, etc. At the metalevel structural schemas of an object are used instead of topological equations of the whole structure. The transfer function is determined for each structural element.

We consider it most efficient to choose and use the mathematical models in the form of transmitting functions. That is, they must be theoretical by the way of obtaining models, analytical – by way of displaying the object properties, belonging to the meta hierarchical level, complete – by the nature of the detailed description within a single level, functional – by the nature of the object mapping properties.

Taking into account all the given above, we can say that the variety of models confirms that TCS belongs to complex organizational-technical systems.

Conclusions

It is shown in which relations the notions of telecommunication systems, information-control systems, telecommunication paths, communication channels stand. A clear understanding of this becomes the basis for:

– ensuring the correspondence of the national information infrastructure to the international standards and recommendations of the International Telecommunication Union (MCE), the European Conference of Postal and Telecommunication Administrations (CEPT) and the International Organization of Standardization/International Electrotechnical Commission (ISO/IEC), which will promote the interaction of its technical means, information devices and services with those operating in the global information space within the European and Global information infrastructure;

– creating a single national integrated multiservice broadband communication network;

– TV and radio networks optimization and distribution of information and channels flows, increasing the efficiency of these networks usage, their modernization and development with providing the necessary level of functioning quality;

– creating and implementing domestic secure information technologies and systems for protecting information from unauthorized access and unauthorized distribution.

The following definition is given: “Telecommunication system is a communication system of the corresponding control level”.

Telecommunication path is a complex of technical equipment and communication lines intended to form specialized channels for information transmission. In defining the concept of a path the main thing is its functional purpose (for example, “the compression system path”, etc.).

The main characteristics of the channels are the frequency clarity band width and the type of signals in them (for example, the “tone frequency channel” with a frequency band width of 300 Hz - 3400 Hz).

Information-control systems in some cases can be considered telecommunication systems, and in other cases they can be considered as the elements of telecommunication systems. It all depends on the macro, micro and mesaapproach to the classification of TCS.

Telecommunication systems can be called weakly structured.

The multitude of the models confirms that TCS belongs to complex organizational-technical systems. That is, the main technological tasks of the information society development strategy are the development of modern telecommunication infrastructure, since the creation of a highly efficient telecommunication environment is a major national problem [2]. Without solving it, the building of an information society and the application of information technology achievements to the fields of production, business, science, education, medicine and culture will turn out to be problematic. The amounts of data flows transmitted by the modern telecommunication systems grow in geometric progression within the simultaneous acceleration of the process of combining heterogeneous information flows. Therefore, as a part of creating and developing the national information infrastructure for the building an integrated telecommunication environment of the information sphere it is necessary to provide:

– a balanced development of all types of telecommunications with the priority use of digital technologies;

 ISSN 1562-9945

– a preference for telecommunication provision of national, sectoral and regional information poles and their association with interregional communication channels;

– a creation of telecommunication systems supporting the information interaction of the person with the state and public structures of all levels.

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