Information-resource and cognitive concept of threat’s influence identification on technogenic system based on the cause and category diagrams integration

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Abstract

The system analysis of the aggregate structure of the energy-active object is carried out in the article, adding multilevel complexity of system description. The complexity of the functioning tasks, mode management are substantiated. An important task is to solve the problem of identifying the risks level and crises causes as well as emergencies by operational personal of ACS-TP.

The problem and its solution requires a certain level of adequate thinking, which would allow the operator to imagine the scheme of all object units interaction from input to output, physical and energy transformations during technological process in his point of view, as well as the ability to assess the content of the situation and to form the basis of decision-making.

The concepts of the image are substantiated and the information image, situations and the influence cause-effect diagram of control actions and disturbance factors on an object mode functioning of technogenic system are formed.

The basic models of systems description are considered, which are based on the description concepts and connections reflection between objects and components: structural analysis; theoretical-multiple representations; categorically-function models.

In these models, the basic are the sets of components and the relationship between them, which reflect the system organization as a whole, which must be perceived by the operator while management tasks performance of the aggregate object according to the target task as in logical-graph and algebraic representation but also in block representation.

Structural images in the conceptual basis are formed, which highlights the most significant aspects of the structure and functioning of the object, parameters, characteristics, connections, resource factors areas of influence, actions on the design of units, which must be mastered and reflected in the field of attention and memory (operational, deep) cognitive system of the operator with appropriate training and knowledge base necessary to perform control actions in the operational management of energy-intensive object in the structure of a thermal power plant, which is a component of technogenic and ecological systems.

Keywords

Object, parameters, structure, mode, management, accident, information, risks, system, hierarchy.

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1. Introduction

To solve the management problem in technogenic systems, that operate under extreme loads and risks, it is necessary to consider approaches, methods, models of knowledge description about system structure with energy-intensive objects that are carriers of environmental pollution from waste slag, heat and gases.
Substantiate the interpretation schemes of terminal, categorical and Ishikawa diagrams for physical and chemical processes stages analysis, in the technological unit, aquatic environment, atmosphere and soil, ecological environment of energy-active objects. This is an informational and systemic basis for creating the structure of the environmental ecosystem monitoring system, which should take into account the peculiarities of technological processes, chemistry of reagents, modes of operation of facilities in accordance with state directives and laws.

2. References analysis

In [1] the basics of intelligent control systems are stated. In the fundamental work [2] for the first time a whole oriented approach to the construction of cybernetic systems was formed.

In [3] the basics of complex systems systemology are stated. The monograph [4] substantiates the ecosystems principles.

In the articles [5-7] the basics of information-measuring and control systems are stated.

In [8-11] logical-linguistic models of the situational management analysis in difficult systems are stated.

The monographs [12, 13-17] outline the basics of management decision theory in complex systems and the basic foundations of management risk assessment.

In [18-23] the human factor problems in control systems are considered.

In [24-27] cognitive concepts of managerial decision-making in terms of risk and action of active factors on management systems, [28] – structure identification methods, [29-30] – strategic analysis methods are shown.

3. Presentation of the main research material

Technogenic systems are characterized by a complex hierarchical structure that reflects the essence of the production process, data selection on the object state and mode, situation assessment, selection and decision-making system for pollution compensation and correction and management of operation modes, technological management, automated operational and administrative management. For the formation of management goals and current tasks, the strategic level (Figure 1) of the structure and dynamics analysis, goals orientation is used [24-27].

Under the disturbances action, internal conflicts in the operational management system, technogenic influences, environmental disasters, information attacks on the strategic management level, it is necessary to ensure high reliability and stability of technogenic structures (active and passive types) and prevent accidents in the system [1, 3, 7].

3.1. Analysis of dynamic processes in complex systems

To analyse the dynamics of dynamic processes and management, it is necessary to form a clear management problem and the concept of its solution. Based on the system analysis and the balance procedure of material and energy transformations using the construction methods of causal relations and situational management, the balance structural scheme is developed as a basis for risk assessment while disturbances actions on the technological system [10, 12, 15]. The balance scheme [resources –

management – threats] is the basis of analysis in the state space and the target management system (Figure 2) [5, 6].

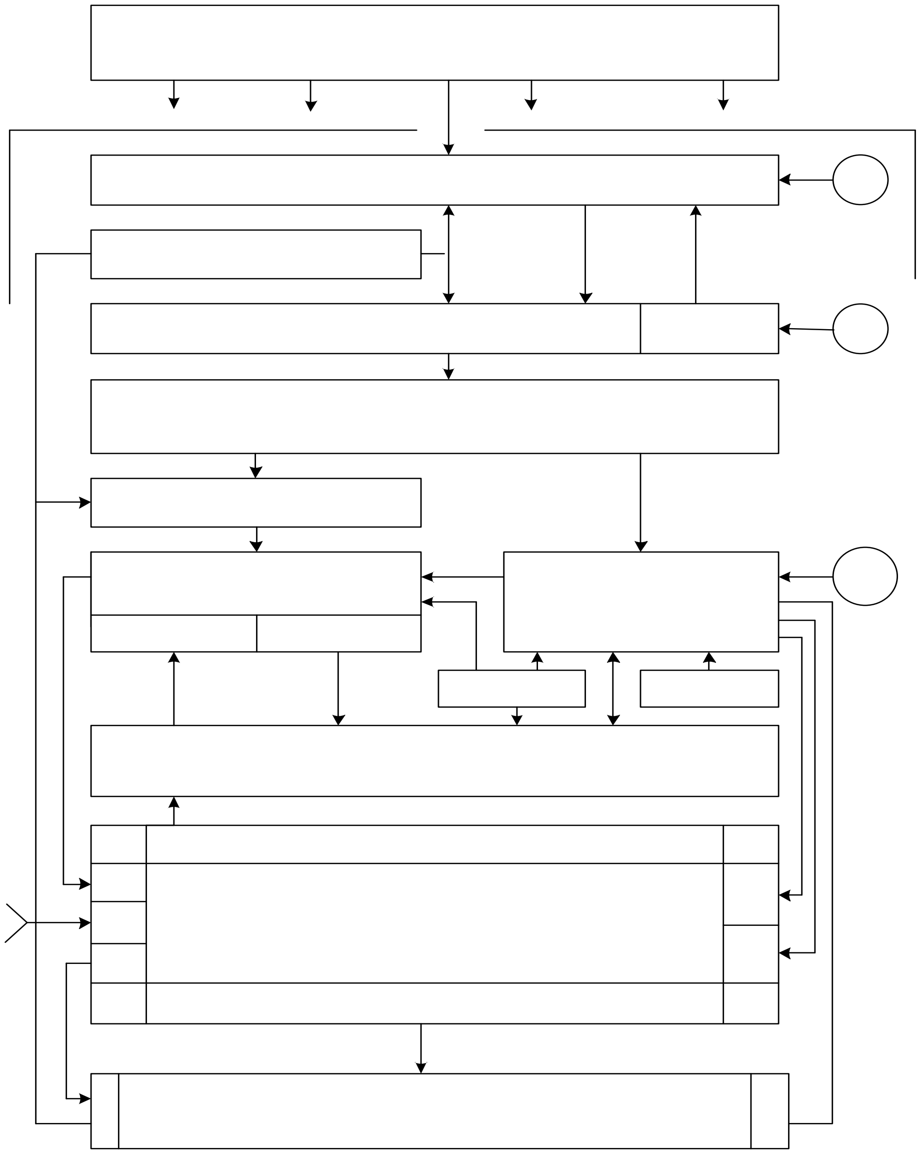

Figure 1. Technogenic complex management system hierarchical structure

According to figure 2 balance in the system is achieved through control actions that coordinate the dynamics of the production mode (productivity) with the input resources flows at a given blocks state, which are reflected in the target space taking into account the perturbation factors [2, 9].

The target problem and situational tasks can be effectively solved if the level of staff and their cognitive and professional abilities and skills are taken into account when overcoming difficult mode situations by coordinating the management system that is affected by information and system disturbances [8, 21].

Problem statement. For industrial and technogenic complexes, which are characterized by a set of different types of physic-chemical, energy and thermodynamic transformations, an important problem is the construction of a number of models of structure and dynamics of objects, that can be described on the systems analysis methods basis, logical-linguistic and algebraic description approaches and structural connections and dynamics of resources transformation and processes management in the course of technological processes in energy-active objects and their influence on ecological environment [4, 16, 20].

Solving the above type problems on the basis of system information technologies and algebra-logic models would provide a unified approach to the identification of the structure and operation and management mode in existing systems and to create new ones based on information technologies.

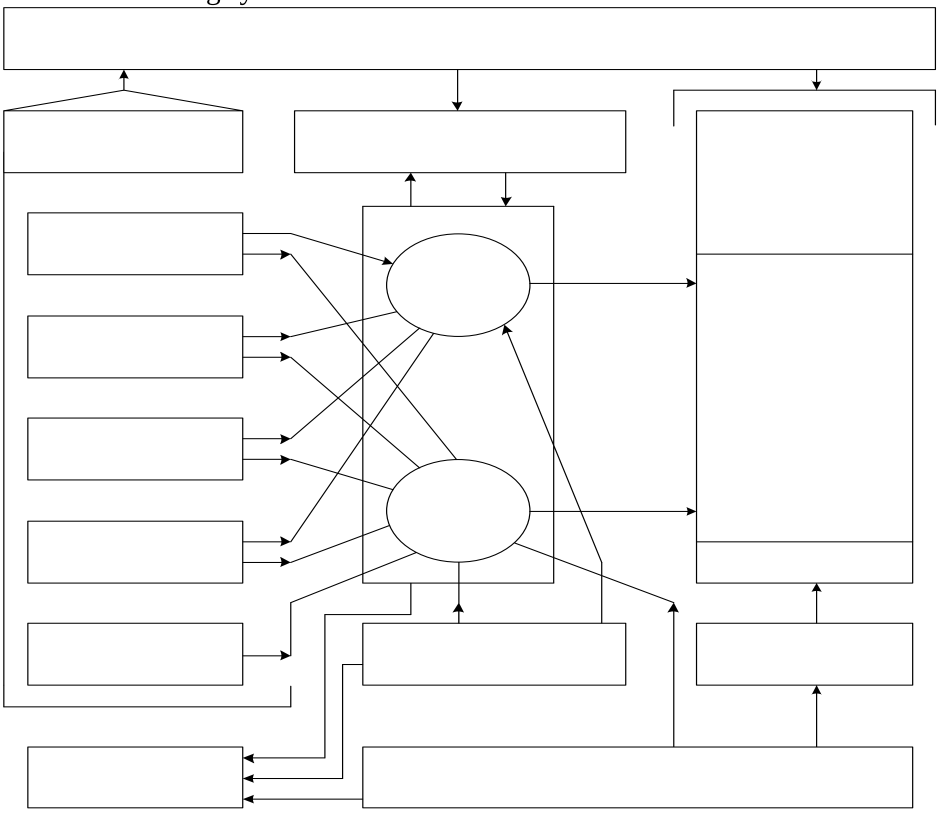

Figure 2. Block diagram of the balance components between threats and management in the system

3. System and information structure of the problem of whole-oriented management in the conditions of threats and risks

At the present stage of infrastructure development for socio-administrative and technogenic spatially-distributed systems, the management problem in the face of threats, information attacks and resource risks is distinguished, among others, by the great difficulty of constructing methods for solving them. To effectively find methods for solving these complex and urgent problems, it is necessary to comprehensively use system models, methods for identifying the structure and modes, assessment of dynamic situations, which would allow to develop ways for solving management problems in the face of threats and risks of technogenic accidents and environmental disasters on the system-information basis and resource balance for effective functioning and achievement of strategic stability of technogenic system [22, 29].

Technogenic systems, as objects of study, include the following components of the production structural organization:

1. Nodes, units, measuring devices of the processor, actuators;
2. Blocks, technological lines, control and data selection systems;
3. Functionally complete technological structures (power units, resource preparation) production processes, resource flows supplying means;
4. Production complexes with a certain infrastructure for the manufacture of certain products, waste storage systems;
5. Socio-technogenic cluster structures and management structure regional systems;
6. Cognitive models of the person-manager.

Production technogenic systems are characterized by: a structure that describes the organization scheme of its functional purpose (energy-active, energy-passive) structural parameters according to which the technological process is realized (geometry, reliability, strength) and technological process dynamics (state, mode, functioning purpose) parameters [14].

Purpose. On the basis of system analysis and algebra of categories there is a need to analyse structural organization features of aggregate systems with a hierarchy to describe technogenic, ecological and social environments. Consider the situations descriptions that develop on the management object and displays through all the basic parameters and relationships necessary for its classification and decision-making in terms of cognitive impairment and interference.

4. Analysis of the dynamics and situation in complex systems with a hierarchy

In the process of development of the technological process in time (in units, blocks, technological lines, systems) the state of each component is determined by the parameters: Z_S – state, Z_R – mode, Z_C – position in the target space according to the time reference according to figures 1-2 [27];

In space $\left(R_Z^n \times R_T\right)$ – (parameters – time); $Z_{Si} \in \Pi S_i$; then the corresponding representation of state spaces (ΠS), mode spaces (ΠS), goal space (ΠC):

$$Z_{ri} \in \Pi R_i \ \left(Z_{Ci}, Z_{ri}, Z_C\right) \subset \left\langle \Pi S_i \otimes \Pi R_i \otimes \Pi C_i \right\rangle;$$

$$Z_{Ci} \in \Pi C_i \ \text{where} \quad \Pi S_i = \left\{I_Z^i \times T\right\}, \quad \Pi R_i = \left\{I_r^i \times T\right\}.$$

According to the problem, the goal space is defined, by definition, for each functional component:

$$\Pi S_i = \left\{I_Z = \left\{\max Z_{Si}, \min Z_{Sij}\right\} \forall Z_i \in I_Z, \forall t \in T_m\right\};$$

$$\Pi R_i = \left\{\mathrm{E}\left[Z_{ri}, t_i\right] \subset \left(I_R \times T_m\right), I_R = \left\{\max Z_{ri}, \min Z_{ro}\right\}\right\};$$

$$\Pi C_i = \left\{R_\theta \times T_m, \left| \ L_A^+ L_A^- \ \right|, \left|L_g^+, L_n^+\right|, L_{\min}\right\}.$$

As part of the system analysis, the situation is determined by a set of parameters $\left(t_S, Z_V, Z_C \middle| t_i\right)$, at a time t_i, in the interval $\left(t_i + \Delta_i\right) = T_m$ of observation T_m and is formed according to the diagram by the relationship between resource and structural components in the thermodynamic substructure (TDS) and product-forming (PS) (Figure 3).

The situation in the system, the control object is determined by a set of parameters that represent the way of describing the spaces at a given time t_i, in the observation interval τ_i of the term T_m:

$\forall_{ti} \in T_m \vdots Sit \prod S\left(t_i, x \middle| T_m\right) \equiv \left\{x\left(t_i, \tau\right) \middle| T_m\right\} \Rightarrow \left\{trakX\left(t_i\right), t_i \in T_m\right\}$ – determines the trajectory graph $x(t)$ on the interval T_m.

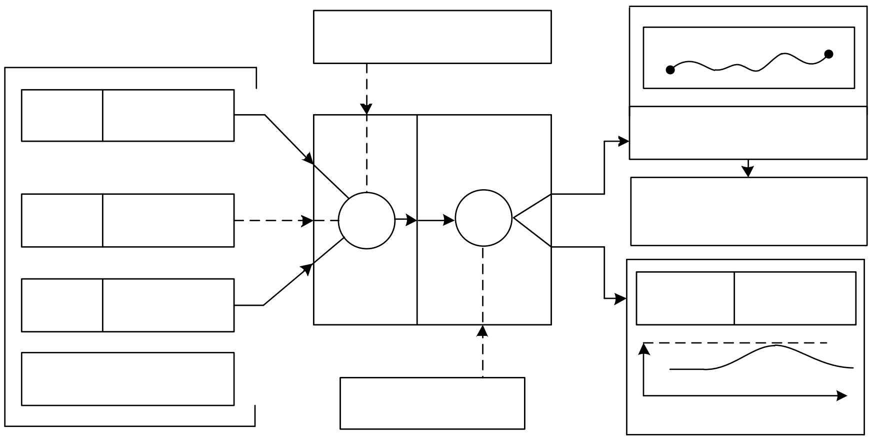

Figure 3. Block diagram of the structural connections between the units and production line control units

Accordingly, the concentration of harmful emissions depends on the parameters values:

$$C_K(t_i / T_m) = f(Z_r^t, Z_S^t, F_u, F_r | C_i \in \Pi C_i)$$

where $Z_r^t = Z_r(t_i, \forall t_i \in T_{\mathrm{m}})$ – mode, $Z_S^t = Z_S(t_i, \forall t_i \in T_m)$ – state.

According to the given structural connections block diagram and the system approach, lets allocate definitions of situations in states, modes and target spaces. Lets introduce the definitions, which are necessary to highlight the concepts of the situational approach. [7, 24].

Definition 1.1. The current situation on the control object will be a description of all information about the control object structure and its operation at a given time in the system target space $Sit_P(Z_C^+ \subset \Pi C_i, \forall t \in T_m) \Rightarrow Z_C(t) \subset V_C(\Omega)$ where $V_C(\Omega_i) \subset V_{Ci}$, $V_{CS} = \bigcup_{i=1}^{n} V_{CI}(\Omega_i)$ – division of the target space into alternative areas.

Definition 1.2. The complete situation on the control object will be a set of current situations on a time interval T_m, taking into account knowledge about the state, mode, position in the system target space $(\forall t \in T_m, Z_i \in \Pi C_Z)$:

$$SitDS_P \cong \left\{ \forall t_i \in T_m, Z_C(t), Z_r(t), Z_S(t) \right\}, \; sipDS_p \cong \{T_m \times R_Z / \{L_i\}, t\}$$

where R_Z – parameter, $\Pi C_Z \cong (R_Z \times T_m)$, T_m – time interval, $sitDS_p$ – situation in a dynamic situation.

Statistical estimates of changes in their trajectories during control actions:

$$U_i : \forall t : U_i^C : Z_C(t_i) \to Z_C(t_{i+1}), \forall t_i \in T_m; U_i^r : Z_r(t_i) \to Z_{\mathrm{r}}(t_{i+1});$$

$$U_S : Z_S(t_i) \to Z_S(t_{i+1}) \text{ when } Z_C(t_i) \in V_C(\Omega_i), \{U_i\} \in strat(U/C),$$

where $Z_r(t_i) \in V_{nr}, Z_S(t_i) \in V_{ns}$ – normalized state area and object mode: $V_{nr} \in (I_r \times T_m)$ – the space area.

Definition 3. Relationship, as a mathematical structural element, forms connections between concepts, objects, functional groups of objects components of the system description language, logic, facts.

Based on a system analysis of the identification problem according to the definition, the following relations classes can be distinguished in the structure [19, 25]:

1. Classification ratio – determines the classification system elements into groups and classes with similar properties and structure;
2. Characteristic ratio – attribute different qualitative features to concepts and objects and are decisive for the selection of elements class with the same properties;
3. Quantitative ratio – determine the quantitative concepts characteristics and are based on the definition of measure;
4. Comparison relations – compare the characteristic and quantitative relations of the two characteristics of concepts, which represents objects or situations.
5. The relations of belonging – connects two elements that are related situationally and are a component of the classification procedure.
6. Time relations – determine time characteristics: simultaneity, to be earlier, later, now, time of action.
7. Space relations – fix the object place and its connections with others in the spatial structure of the real world.
8. Causal relations – reflect the cause-effect relationships that determine the purpose, motivation, preferences in decision-making, link their consequences under the management action and perturbations factors.
9. Information relations – describe the processes of reception, transmission of data, their content and interpretation in the situation classification in the system.
10. Ordinal relations – describe the relationship between the elements of the real world and their order in the course of events and spatial structures.

The systems dynamics is described by the actions and processes that occur in it and are accordingly classified into:

- Imperatives – direct instructions on the actions of a certain class to change the state of the unit, object (management directives);
- Processes – describe changes in object state, the logic of decisions, data processing and can occur in the managed object;
- States – record a certain situation in the control object according to the description of its parameters and structure.
- Positions – fix control objects position in the terminal time and spatial basis of the system.

Based on the above analysis, it is possible to form a method of presenting a scheme (diagram) of active management interaction with the object and the influence of factors in a terminal diagram form of active influences on the structure and the technological process course [26].

Accordingly, management actions and threats also lead to a change in the state and mode of management object – that is, to a situation in the system that must be assessed, analysed and made corrective decisions to counter threats.

Lets introduce the definition of system-information components of management implementation.

Definition. Action – targeted action of the active element on the influence object.

Definition. $Di(Fj/t_к)$ – the effect of the influence factor on the management object state.

Event. $ПD_iF(t/Zc)$ – a purposeful action was performed under the influence of a factor (active), which led to a change in the object state.

Situation. $SitПi\ (t,\tau_i)$ – position and parameters of the control object (system) in the goals and state space at time *t*, on the interval τ_i.

The state of the control object – $StnOY\langle StruktX, Y, T\rangle$ – a set of parameters that determine the object position in the space of states in $ПS = ((X \times Y)\times T)t_i$ – according to the specified structure and dynamics of parameters change.

5. Models of situational diagrams to represent the state of the system

Based on the concept of balance and cause-effect relationships, a diagram of chains change in the state of the energy-active object due to the targeted action of threats and attacks on the control object was developed (figure 4) (resource and information components) [6, 22]:

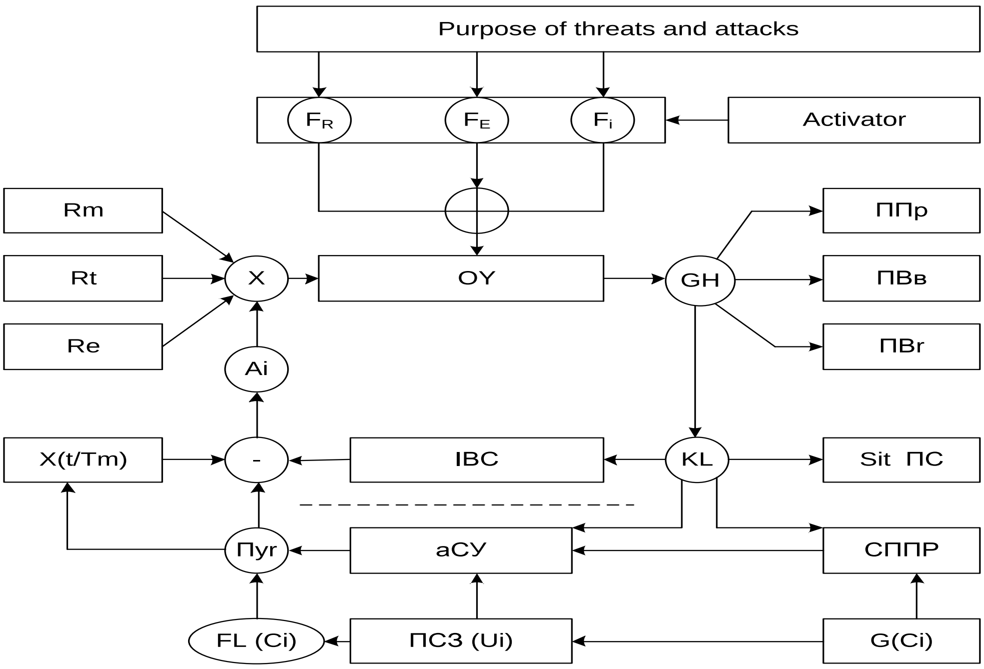

Figure 4. Diagrams of changes in the state of an energy-active object under the threads influence to the control process, functions and modes

Accordingly, lets select the structural components of the diagram according to their functional purpose [11, 13]:

1. resource (Str DR (Rm, Rt, Re) – material, energy, thermodynamic resources;
2. management object (OY, ПR, ППr, ПBv, ПBr) – the process of product formation, solid and gaseous waste;
3. management structure:

- KL – situation classifier;
- IMS – information – measuring system;
- ACS – automated control system;
- DSS – management decision support system;
- G (Ci) – target generator;
- PTT (u) – processor target management tasks;
- ПУr – object mode control processor;
- FL (Ci) – sequential generation of targets to compensate for perturbations factors;
- (FR, Fi, FE) – factors influencing the information, resource and energy structure of the technogenic system object.

The state change diagram is the basis for building terminal cause-effect relationships in the threats assessment and the emergencies occurrence if the management system cannot form a response [8, 15, 18].

The system component of the control counteraction can be formed in the form of a diagram, which is the basis for constructing situational relations diagrams (figure 5).

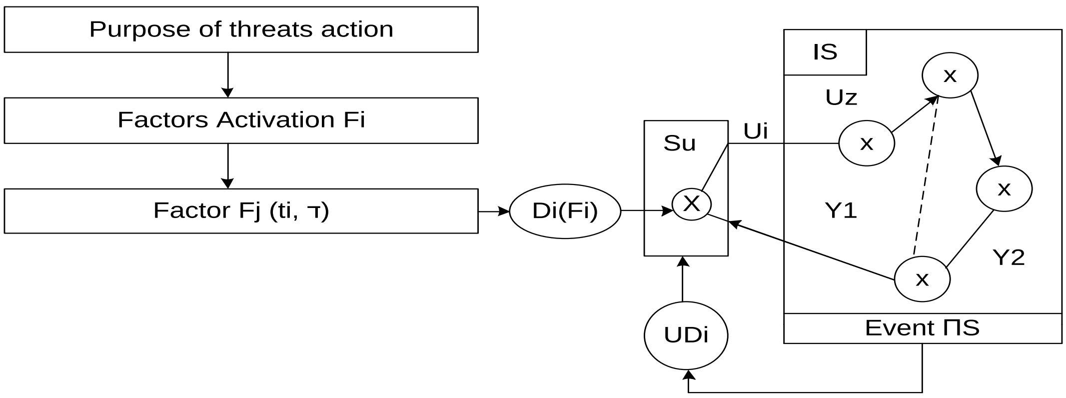

Figure 5. Situational relationships diagram in the object management system

5.1. Model 1. Situational diagram with parallel – sequential structure

This diagram describes the thermodynamic transformations in the energy-active blocks of the technogenic system (Figure 6). Accordingly, the components (R_m, R_{ca}) – energy-active in (A_{r1}) – the unit turn into an energy-active form (thermodynamic processes of energy generation as in (A_{r2}) – is converted into a kinetic of given power level [24, 26].

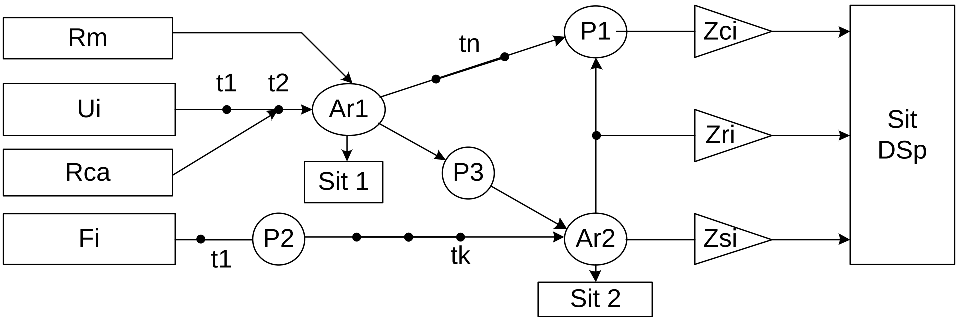

Figure 6. Situational diagram with parallel – sequential structure

Symbols: (Ui, Fi) – active actions, (Ar_1, Ar_2) – active transformations, Sit – situation model in Ari units, $\{t_i\}$ – traffic time counts.

According to the above, lets construct state change diagrams under the action of *Ui* control and successive over time influence factors $\{Fi\}$, which leads to a consistent situation change, respectively:

- $UDi(t_1, t_2) \rightarrow Agv_1 \rightarrow Sit(t_1)$ – management actions;
- $D(Fi|I|t \; .....t_k) \rightarrow \{P_2(Fi)\} \rightarrow Ar_2(F_i|t_1...t_k) \rightarrow Z_{Ci}$ – formation of an active factor over time $\{F_i|t_1....t_k\}$ diagram, which led to a change in the object's state.

5.2. Model 2. Situational diagram

Situational diagram of situation change under the action of factors $\{F_i\}$ in the interval of terminal time for each moment $t_i \in T_m$ and unfolds a events chain, which are respectively linked in cause-effect diagrams of the object's state (trajectory in the state and target space) and is the basis for identifying causes of control failure. Based on the decomposition of the diagram, the reverse transition is performed (change of the state trajectory – to the cause, the active action factor), which provides the choice of control (action mode) (Figure 6) [25, 27].

Accordingly, the diagram shows the influence of a set of factors with a stochastic structure, which act on the control object unit and, accordingly, lead to a change in the system state and unit mode (set power) $\{F_1....F_n|\tau_i \in Tm\} \rightarrow Sit(t_1) \rightarrow \{Sit(t_{mi})\}$.

Figure 5 shows the influence accumulation on the object under the action of a influence factors system, which is superimposed on the management action and when the intensity of the factors leads to the failure in the object management:

$$H_1 \vdots I\left(\bigcup_{t=1}^{n} Fi\right) \leq I_d \Rightarrow D(\{F_r\}) \rightarrow \min_u T_m \rightarrow ALARM \rightarrow STOP$$

$$H_2 \vdots I\left(\bigcup_{i=1}^{n} F_j\right) \geq I_d \Rightarrow D\left(\left\{\bigcup_{i=1}^{1} F_i\right\}\right) \rightarrow \max_u T_m \rightarrow ALARM \rightarrow AVAR,$$

where $I(\;)$ – the intensity of the influence of the factor on the management process.

5.3. Model 3. Diagrams of factors influences on the aggregate structure of energy-active management object with active and passive resources transformation

An energy-aggregated object with a complex resources transformation due to thermodynamic transformations, has different types of functional blocks in its structure that are influenced by control and perturbing factors through the appropriate transmission channels of their actions to the mode [9]. Accordingly, lets allocate resource units, energy-active, productive (Figure 7).

The influence factors on the mode and state of the aggregate object diagram, with the specified set of input parameters $\{Z_{ri}|_{i=1}^{n}\}$ – state, $\{U_j|_{j=1}^{m}\}$ – control actions and influence factors $\{F_{uij}, F_{ur}\}$ on the mode and unit control, the technological energy transformations dynamics is presented through the operator $A_{TS} = A_{TS}(t_i, U, F, Z_r, Z_S, Z_C)$. The diagram is the basis for assessing the situation and changing the events scenario in the target system space and state spaces and dynamic energy-active mode of technological system object operation under the action of factors and control actions.

The given diagrams according to the models represent the change of the object's state according to the time positions $\{t_1 \ldots t_\kappa\} \subset T_m$, on the terminal interval when the way of influence of the perturbation factors changes.

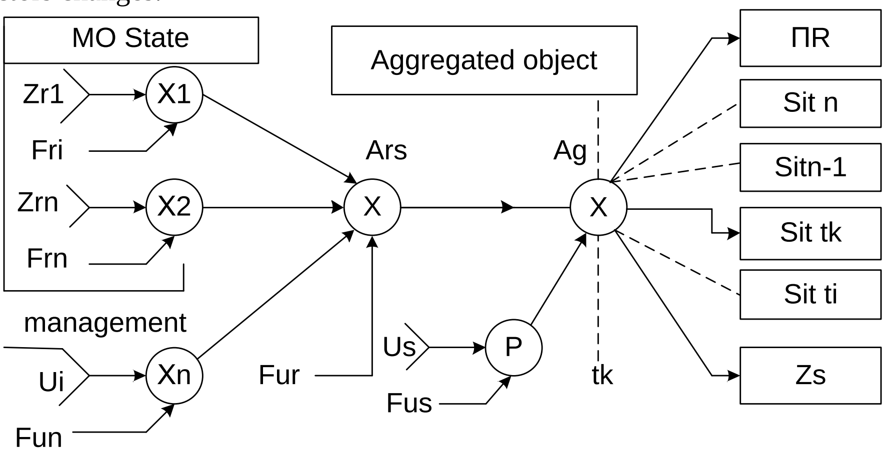

Figure 7. Situational diagram of action factors categorical representation on active and passive units

5.4. Model 4. Terminal diagram of influence factors

The action mode on the time interval τ of factors and the multiplicative structure is reflected through the event development scenario and on the terminal diagram of cause-and-effect relationships of changes in situations in the control object (Figure 8). The diagram shows the structure of situation changing process at time intervals $\{t_i, t_{i+m}\}$under the action of active influence set of factors on aggregated object $\{A_i\}$ state and mode [26].

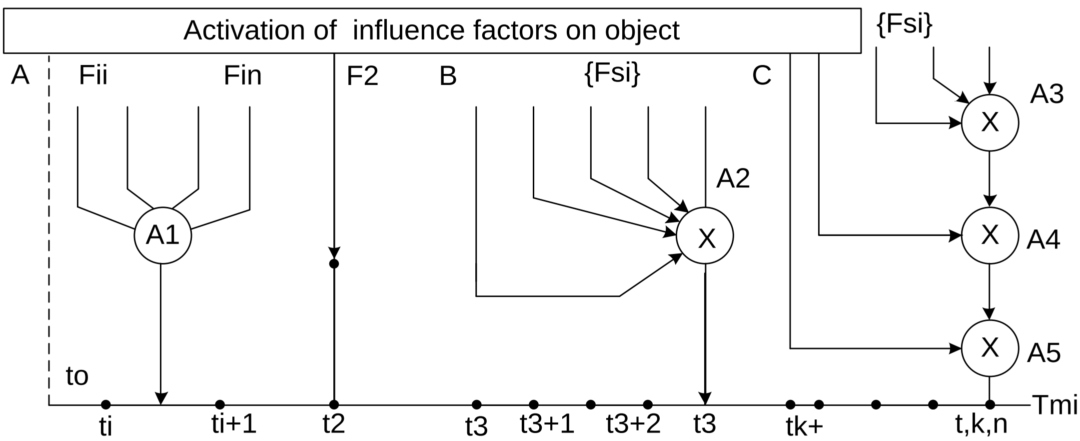

Figure 8. Factors influence terminal diagram on the object's mode

5.5. Model 5. The factors influence degree on the control actions and object's modes with an aggregated structure at intervals {T_i}

Under the influence of influencing factors $D(Fj|VarI)$ – with a change in the intensity of the control mode becomes non-stationary (Figure 9).

In the time of exposure and therefore the diagrams structure is complicated in the control actions performing process.

To assess units operations reliability (Model 4) and systems of energy-intensive units, it is necessary to create methods for presenting procedures for the accumulation of influencing factors on the basis of additive-multiplicative (threshold actions) models [26].

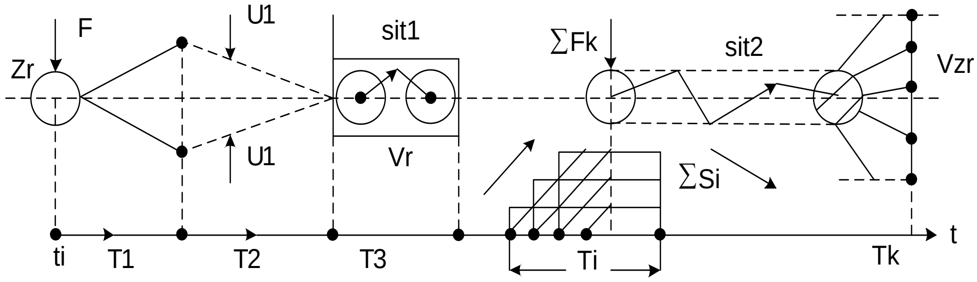

Figure 9. Diagrams of change in the influencing factors intensity

5.6. Model 6. Accumulation of action factors activity on the time axis

With the complex action of control strategies and influence factors (mode, state, information), which have a negative character with varying degrees of intensity, the object mode depends on the transition probability through the risk level mode parameters of the control object [26] – according to the hypothesis:

$$\left[H_I : \left(I\left(\sum F_i^t \Big|_{i=1}^{n} \Big| t \in T_m \right) \geq \alpha_{risk} \right) \begin{matrix} \to Sit1(ALARM) \\ \to Sit2(AVAR) \end{matrix} \right].$$

That is: If $\left(P_{rob}\left(\sum F_i^I \Big|_{i=1}^{n}\right) \geq \alpha_{risk}\right) \Rightarrow (sit_1)(AVAR)$ and the diagram is in accordance (Figure 10).

Risk occurrence components due to factors influencing on management are divided into:

- DF_{risk1} – passive factors with the accumulation of influence level;
- DF_{risk2} – additive threshold model of factors influence;
- $DFrisk3$ – multiplicative model of factors influence;
- DF_{risk4} – chain model of attack generation;
- $\{Sit_{itn}\}$ – the sequence of situations that lead to an emergency situation in an energy-active object.

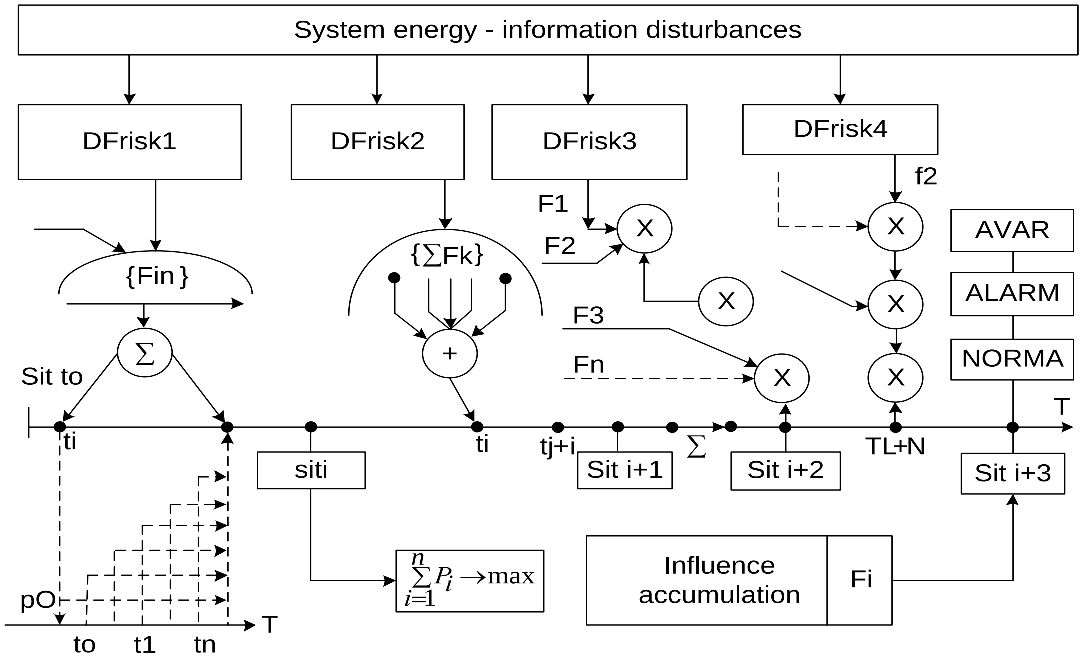

Figure 10. Risk intensity factors terminal accumulation diagram of emergency situation occurrence in the technogenic system unit

Influence factors components by their action are composed according to the conditions: the action in time and the intensity level:

$$\forall t_i \in T_m : \bigcup^{m} F_{Ki} - \text{[or any } F_K \text{]};$$

$$\exists (t_i, \tau_i) \in T_m : \bigcap_{i=1}^{m} \mathrm{F}_{\mathrm{Kj}} - \text{[or all together } F_K \text{]};$$

$$\exists Rang\{t_i \in T_m\}\,\{F_{n-1} \ldots F_{nk}\} - \text{[or each successively]}.$$

6. Risk assessments under the influence of active type perturbations

The risk level assessment is based on the analysis of modes in the space of the modes state, the target breakdown of their target state area – normal operating, maximum and minimum power on the basis of matching scales, a risk distribution function is built [14, 23].

The structure of the risk function, depending on technological type $\delta(Pn)$ goes to functions set of parabolic and rectangular type, reflecting the change in the risks level from the load and the type of threats that lead to an accident or shutdown of the unit (Figure 11).

$$\varphi(\alpha risk) = P_n^1(a, F_i, t) \to \alpha ri$$

At δ – function of risks distribution

$$(\alpha_r = 1{,}0) \text{ if } P_n^1(U, F_i, t) = 1{,}2 Shp$$

$$(\alpha_r = 0 \pm \varepsilon) \text{ if } P_n(U, F_i, t) = 0{,}5 Shp$$

$$(\alpha_r = 1{,}0) \text{ if } P_n(U, F_i, t) \in [0 \div 0{,}2] Shp \,.$$

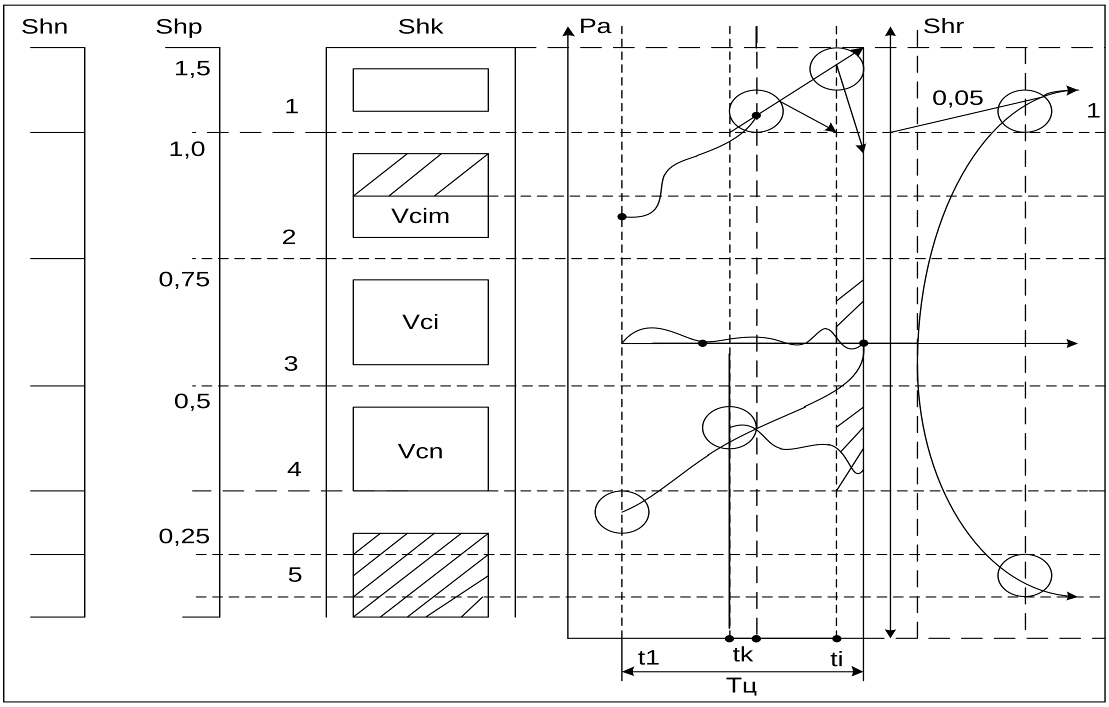

Figure 11. Load and risk scales *Shkr, Shp* coordination in assessing the dynamic situation

Designation: Shp – load assessment normative scale:

- Shn – normative stages of the scale;
- Shk – cognitive load scale;
- Shr – risk allocation function;
- R – is the active power of the unit.

In other cases, under the influence of intensive factors (resource, system, information), the magnitude of the load level risk function is a component of the family (Figure 12):

$$\varphi\left(\alpha_{ri}, P_i, F_i \middle| Shp\right) \in \left\{ \bigcup_{i=1}^{u} \varphi_i \left(\alpha_r, P_j \middle| \bigotimes_{R=1}^{u} F_A \right) \middle| Sh \right\};$$

$$\text{where } \varphi_j\left(\alpha_r, P_K\right) \Rightarrow \left[\exp\left(-\left(K_1 P_{Ki}\right)\right) = \alpha_r\right], \forall_R \in Shp.$$

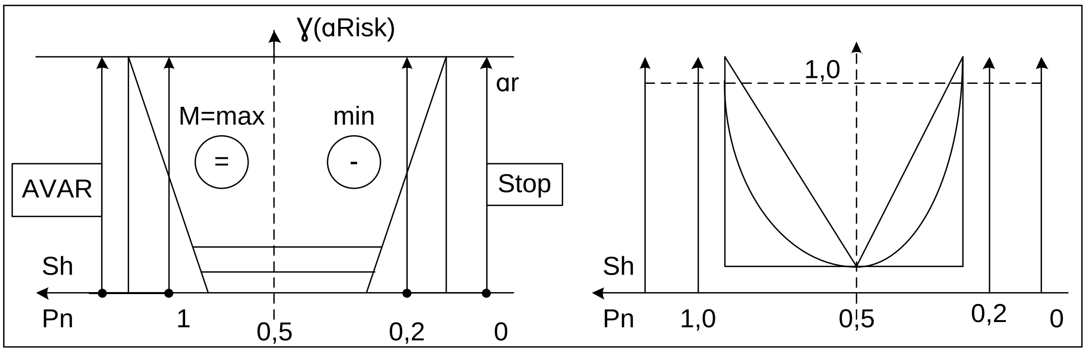

Figure 12. The structure of the risk function

According to the above influence factors cause-and-effect analysis with the intensity accumulation that exceeds the threshold α_P according to the rule: If $\left[\sum_{i=1}^{m} P_i(F_i) > \alpha_P\right]$ than $\left[\bigcup_{i=1}^{m} F_i : \mathrm{Sit}(\mathrm{t_i}) \rightarrow Sit(t_{i+1})\right]$ there is a change in the situation in the control object on energy-active object functioning terminal time interval.

Consider the formation model of cause-and-effect relations diagram, which lead to chains of situations successive change in the management object with energy-active structure and active control actions and factors influencing on its state and mode. The change in the situation occurs on the terminal cycles $\{T_i\} = \{t_i, t_{i+n}\}_{i=1}^{m}$, under the influence of factors with their actions intensity accumulation on the control (Figure 13) and is reflected in the signals classifier (KL).

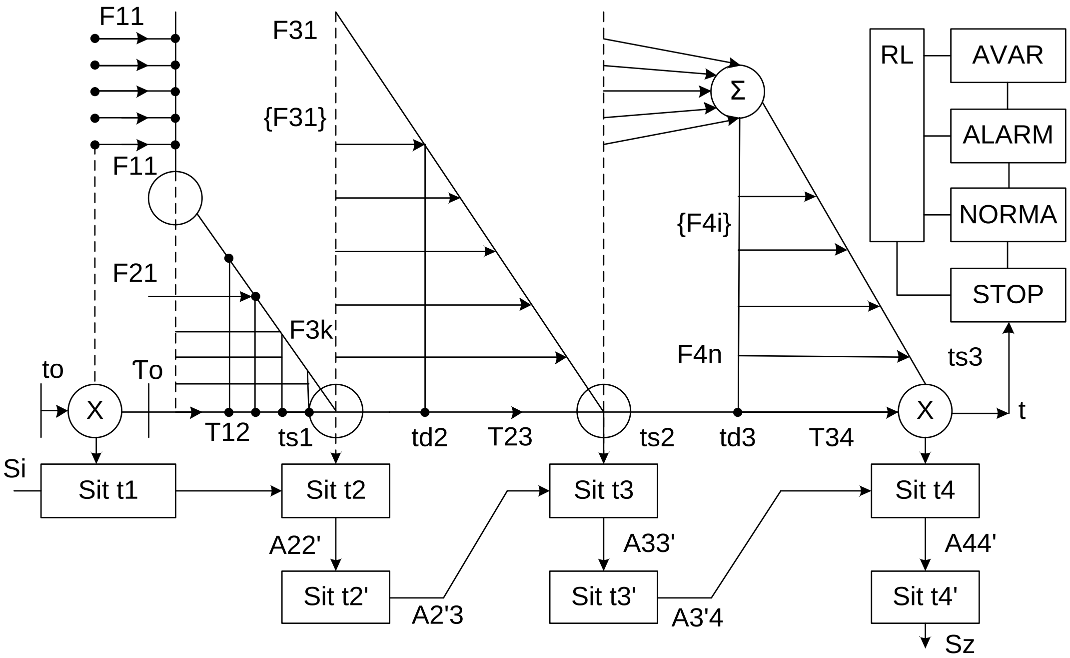

Figure 13. Situational changes diagram in the state under the influence of factors influencing the energy-active object with a controlled structure

Designation on (Figure 13) of the object condition change diagram:

- $\{Sitt_i\}$ – the mode situation of object at the time t_i;
- $\{A_{ij}\}$ – transition operators (when the state changes);
- $\{T_{ij}\}$ – terminal time cycles;
- $\{t_{Si}\}$ – the beginning of the time of factors accumulation;
- $\{F_{Si}\}$ – additive structure of factors action;
- $\{F_{Ri}\}$ – consistent flow structure of factors.

Integration (Figure 8) of Ishikawa, cause-effect and categorical diagrams on terminal time cycles is the basis for the development of identification diagnostic procedures for the units detection with high levels of harmful emissions into the ecological environment, when changing the object operation mode of under resource influence, thermodynamic and information impact factors and the corresponding level of emergencies risk according to (Figures 1-13).

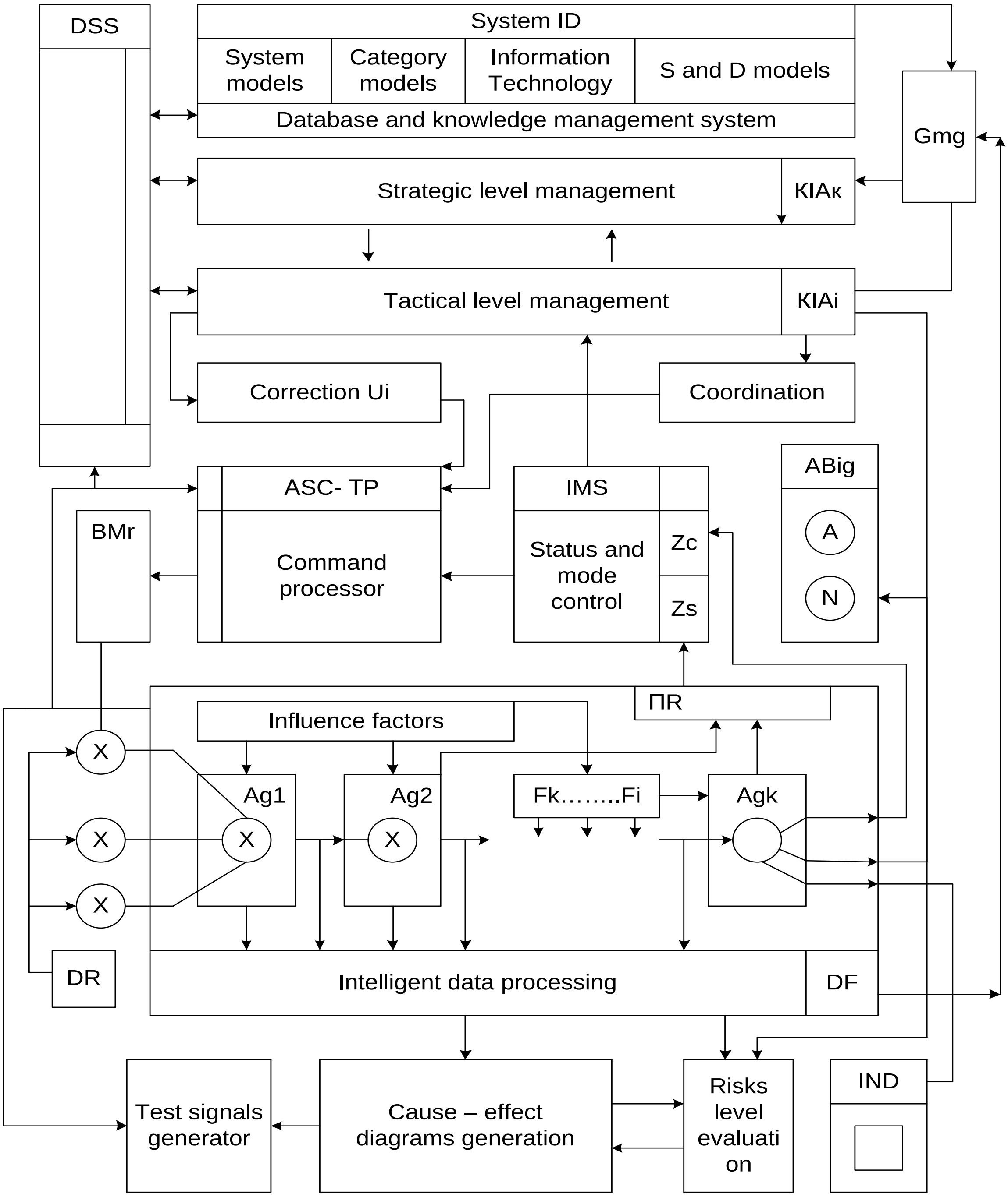

Figure 14. Identification of technogenic system condition and mode information – resource scheme

Notation for Figure 14: S and D models – Structure and Dynamics models, DSS – decision support system; DF – data flows; Gmg – models of situations images generator; KIAi – a team of managers based on the concept of an intellectual agent; ACS-TP – technological process automatic control system; IMS – information – measuring system (data selection, rationing, evaluation of parameters and situational data on the state of control objects); Agi – aggregate structure of technological process or other type; IND – mode indication; (Zs, Zc) – parameters of the state of the units; (Fk, Fi) – factors of active physical impact and reliability; BMr – executive mechanism for managing the flow of resources from the source (DR); (ABig) – emergency visualization of the state of the units.

According to the information-resource concept of condition identification and technogenic system functioning mode, the scheme (Figure 14) reflects structural and information communications and the formation scheme of administrative decisions was developed [1, 28, 30].

Based on the scheme (Figure 14) the following monitoring stages of the system state can be identified:

1. Stage of managerial actions formation in the conditions of the minimum influence of external and internal states;
2. Managerial actions formation, based on the strategy of compensation, which is performed by operational personnel (model of the person – PMD, the person who makes decisions as a cognitive intellectual agent);
3. For resource and information attacks on the management process, requires the use of coordination strategy at the level of strategic management, for which it is necessary to perform intelligent operations using information technologies:

- Diagnostics mode of all units and components management means condition, the analysis of deviations from the purpose;
- Structural nodes identification mode through which the action of influencing factors on the basis of testing is possible;
- Construction of cause-effect diagrams to identify factors of influence and assess the risks of their action;
- Development and implementation of strategies for coordinating the modes and condition of all units and control means to counter threats with maximum efficiency and minimum risk of accidents;

4. Operational and technical personnel ability assessment, to take measures to counteract the factors threats of physical type and information attacks on the basis of the person-cognitive intellectual agent model;
5. Implemented solutions control and evaluation of their effectiveness in relation to the accident risk level in the terminal cycle of technogenic system management.

Based on the conducted analysis and figures 1-14 diagrams of impacts and risk assessment tables for different management situations of technogenic system with energy-active units are formed (on the example of studies of Burshtyn TPP and glass industry enterprises) (Table 1-5), which take into account the ability of operational personnel to make decisions in risky situations.

Table 1

The management failure risk level due to information – cognitive operations incorrect performance

№	Operation type	Kid	αr
1	Goal-orientation function	FCi	0,5-0,8
2	Ability to generate currents	FAGstrat	0,7-0,9
3	Logical thinking in conditions of risk	FLgm	0,5-1,0
4	Ability to assess the system situation	Fc(Sit)	0,6-1,0
5	Ability to plan whole-oriented actions	Fc(Di)	0,7-1,0
6	Ability to make decisions in the face of threats	Fc(Rz)	0,75-1,0
7	Ability to goal-oriented thinking	Fzm(Ci)	0,8-1,0
8	Cognitive analysis of the threats nature	Fka(Zi)	0,4-1,0
9	Cognitive ability to form problem-solving programs	Fkz(Rz)	0,7-1,0
10	Level of intellectual activity	RID	0,5-1,0

Table 2

Accident risk function assessment when changing the power unit load due to personnel coordination

№	Modes	Shp	$\alpha risk$
1	Mode correction	0,4-1,0	0,1-0,3
2	Changing the mode of the power unit	0,6-0,9	0,1-0,5
3	Optimizing the external load response	Opt 0,6-1,0	0,1-0,75
4	Adaptation to changes in load pulses	Adap. 0,4-1,1	0,25-1,0
5	Target coordination of power units group	$\sum_{i=1}^{n} P_E(Uk)$	0,5-1,0

Table 3
Estimation of risk functions at change of I (F) factors action intensity on management object modes

№	modes	Pn	I(Fr)	$\alpha risk$
1	Start mode	0-0,25	< 0,5	0,5-1,0
2	Norma *(P<* $\frac{1}{2}Pn)$	0,25-0,5	0,5-0,95	0,05-1,0
3	Norma *(P>* $\frac{1}{2}Pn)$	0,5-1,0	0,5-0,95	0,15-0,25
4	ALARM	0,9-1,15	0,6-1,0	0,8-1,0
5	AVAR	>1,2	0,5-1,0	> 0,95

Table 4
Risk functions estimation at resource change components quality (fuel) and various loading modes

№	Load modes	$\alpha risk$	Indicator αr
1	Minimum load power	0,45-0,60	ALARM $\alpha_r > 0{,}5$
2	Normal mode	0,5-0,95	NORMA 0,05-0,1
3	Limit mode	0,9-1,05	ALARM1 0,05-0,1
4	Pre-emergency mode	0,95-1,1	ALARM 2 0,5-0,9
5	Emergency situation	1,1-1,3	$\tau r \le \tau d$ 0,9-1,0

Table 5
Risk level change when changing the information attacks factors intensity

№	Informational attacks on ASC	Shp	$\alpha risk$
1	Information – measuring system	0,2-1,2	0,5-1,0
2	Intelligent data processing	0,2-1,2	0,5-1,0
3	Situation assessment processor in the object	0,2-1,2	0,75-1,0
4	Management and decision making processor	0,2-1,2	0,75-1,0
5	Command processor	0,2-1,2	0,8-1,0

According to the tables (Table 1-5) obtained in the process of testing professional and cognitive characteristics, professional suitability assessments are formed [7, 23, 26].

$$\alpha_{1risk} = \bigcap_{i=}^{u} Kid, Kid \in [0{,}5 \div 1];$$

$$\alpha_{2risk} = \bigcap_{i=1}^{n} Shp_j, Shp_j \in [0{,}1 \div 1];$$

$$\alpha_{3risk} = \bigcap_{s=1}^{n} \alpha_{risk}, \alpha_{risk} \in [0{,}1 \div 1{,}0];$$

$$\text{then } \alpha_{4risk} = \max \alpha_{risk_i}, i \in [1 \div 4];$$

$$\alpha_{5risk} = \max \alpha_{Riski}, \alpha_{Risk} [0{,}5 \div 1{,}0];$$

$$\alpha^{/}_{5Risk} - \bigcap_{\kappa=1}^{n} Shp_i, Shp \in [0{,}2 - 1{,}2] -$$

are indicators of the limit mode and transition to the power unit operation emergency area.

Novelty

According to logical-cognitive and categorical concepts the information technology for integration of system and categorical models and identification methods of structural components of system and nodes, on which actions of threats are possible, leading to emergencies and influences on ecosystem, a method of an estimation of mode and cognitive risks in the process of object management and threat actions and appropriate means to counter attacks on resources and management modes is developed.

7. Conclusion

To ensure the anti-accident safety of technogenic energy-active systems and possible environmental pollution, on the basis of system and information technology, information-resource concept, the scheme of interpretation of terminal diagrams, categorical and Ishikawa diagrams for analysis of physicochemical stages of processes in the technological unit is substantiated. This makes it possible to counteract the threat of accidents, which can lead to pollution of the aquatic environment, atmosphere and soil, the ecological environment of energy-intensive facilities.

The developed method of analysis is an information and system basis for creating the structure of the monitoring system of the surrounding ecosystem, which should take into account the peculiarities of technological processes, chemistry of reagents, facilities operation modes, the basis for developing methods of emergency measures by counteracting threats, the effectiveness of which depends on the knowledge level and cognitive characteristics of operational personnel.

8. References

[1] A. Bol'shakov Intelligent management system of organizational and technical systems, Moscow, Hotline, Telecom, 2016.

[2] N. Viner Cybernetics / management and connection in animal and in machine, Science, 1983

[3] B. Herasymov, V. Lokazyuk O. Oksiyuk, O. Pomorova, Intelligent decision support systems, Yevr, 1983, 335 p.

[4] M. Holubets, Ecosystemologia, Lviv, Polli, 2000

[5] L. Sikora, N. Lysa, R. Martsyshyn, Y. Miyushkovych, R. Tkachuk, Information processing system for detection impurity in technical oil based on laser: Data stream mining & processing (DSMP), in: Proceedings of the IEEE Third international conference, Lviv, Ukraine. 2020, pp. 378–381. doi: 10.1109/DSMP47368.2020.9204018

[6] D. Pospelov, Logical-linguistic models in control systems, Moscow, Science, 1981

[7] L. Sikora, Cognitive models and logic of operational management in hierarchical integrated systems in conditions of risk, Lviv, CSD «EBTES», 2009 p.

[8] G. Pospelov, Situational management, Moscow, Science, 2016

[9] A. Melikhov, L. Bernshteyn, S. Korovin, Situation counseling system with fuzzy logic, Moscow, Science, 1990

[10] E. Petrov, M. Novozhylova, I. Trebnyk Methods and means of decision making in socio-economic systems, Kyiv, Technic, 2004

[11] A. Loskuto, A. Mikhaylov, Fundamentals of the theory of complex systems, Moscow-Izhevsk, Compter investigation insitute, 2007

[12] O. Larichev, Theory and methods of decision making, Moscow, Logos, 2008

[13] V. Romanov Intelligent information system in economics, Moscow, Test Publishing, 2007

[14] N. Mashina, Ecological risk and method of its measurement, Kyiv, TSNL, 2003

[15] E. Khenly, K. Kumamoto, Reliable design of technical systems and risk assessment, Kyiv, High School, 1987

[16] T. Hovorushchenko Methodology of Evaluating the Sufficiency of Information for Software Quality Assessment According to ISO 25010. Journal of Information and Organizational Sciences, 42 1 (2018) 63-85. doi: https://doi.org/10.31341/jios.42.1.4

[17] T. Hovorushchenko, Information Technology for Assurance of Veracity of Quality Information in the Software Requirements Specification. Advances in Intelligent Systems and Computing. 689 (2018) 166–185. doi: 10.1007/978-3-319-70581-1_12
[18] V. Prisnyakov Mathematical modeling of information processing by the operator of human-machine systems, Moscow, Machinebuilding, 1990
[19] V. Lyamets, A. Tevyashev, System analysis, Kharkiv, KHNURE, 2004
[20] D. Novykov, People factor in management: a collection of scientific works, Moscow, ComBook, 2006
[21] V. Petrov, Theory of solving inventive problems, Moscow, Solon-press, 2019
[22] A. Guts, L. Pautova, Y. Frolova, Mathematical methods in sociology, Moscow, Librocom, 2014
[23] G. Salvendi, Humans factor, Moscow, World, Ch.3, Part 3, 1991
[24] L. Sikora, R. Tkachuk, N. Lysa, I. Dronyuk, O. Fedevych, Information and Logic Cognitive Technologies of Decision-making in Risk Conditions, CEUR WS, 2623 (2020) 340–356.
[25] L. Sikora, N. Lysa, R. Tkachuk, V. Kunchenko-Kharchenko, Y. Kryvenchuk, Strategic terminal integration of game system and information resource consepts as a basis of analysis of energy active interaction of technogenic and ecological systems, in: Proceedings of the International Workshop on Cyber Hygieneco-located with 1st International Conference on Cyber Hygiene and Conflict Management in Global Information Networks, CybHyg-2019, Kyiv, 2019, pp. 665–679.
[26] L. Sikora, N. Lysa, O. Fedevych, M. Navytka, R. Tkachuk, I. Dronyuk, Information technologies of formation of intellectual decision-making strategies under conditions of cognitive failures, in: Proceedings of Computational & Information Technologies for Risk-Informed Systems, CITRisk-2020, Kherson, Ukraine, 2020, pp. 233-254.
[27] L. Sikora, N. Lysa, Information and laser technologies for creating systems for environmental monitoring of energy-intensive man-made production structures, Lviv, Ukraine Academy of printing, 2019
[28] Y. Alpanadze Warranty supervision of complex technical systems, Moscow, Machinebuilding, 1988
[29] A. Tompson, D. Striklend, Strategic management, Vil'yams, Moscow, 2006
[30] M. Zgurovskiy M., Dobronogov A., Pomerantseva T. (1997). Study of social processes based on the methodology of systems analysis, Kyiv, Science thought