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EVENT RISKS FROM THE STANDPOINT OF ENTROPY SYSTEMS

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Annotation. It is proposed to consider risk as an event category in the aspect of time, event and entropy scales in understanding their direction in relation to time, events and changes in the energy-entropics of the event system in the paper. A similar model for studying risks in any systems, not related to their probabilistic characteristics, is based on the concepts of catastrophe theory in the application at times on the time scale preceding the present time T_P. Such a model can be easily represented in the form of a directed multilevel graph, the root directory of which displays one of the known bifurcations, at the moment of time $\Delta\tau$, which turns into an accomplished event. The energy component of such an event in the form of its entropy gives an idea of the degree of reliability of the transition from uncertainty to a verified event. It is it that in the time interval $\Delta\tau \rightarrow T_P$ illustrates the magnitude and direction of event risk that can lead to accidents and other undesirable events. It can be argued that the *multiple uncertainty that precedes the accomplished certainty in time is the key to understanding event risk as an analytical category.*
Some examples show the methodology of using the theory of catastrophes in comparison with the time scales, events and entropy to study marketing risks associated with events that may occur.

Keywords: risk, theory of catastrophes, accomplished certainty**,** event certainty, probabilistic characteristics.

INTRODUTION

The discussion of understanding risks as a category of hazards in any engineering systems is most often associated with understanding the phenomenon of time, its past, present and future. The authors studying this problem, one way or another, are looking for a solution to the phenomenon of the thermodynamic or, in another way, the psychological "arrow of time" at the level of philosophy, quantum mechanics, thermodynamics, knowledge of uncertain events, etc. Most often, risks are determined through the probability of events that are the reason for their appearance against the background of many other equivalent events. And, the most typical variant, which one has to face, claims that a reliable study of this phenomenon, as a probabilistic category, is not possible by calculation.

Most often, risks are determined through the likelihood of events that cause their manifestation against the background of many other equivalent events. And, the most typical option, which one has to face, claims that a reliable study of this phenomenon is difficult by calculation.

THEORETICAL BACKGROUND

SOME ASPECTS OF EVENT RISKS PHILOSOPHY

For ease of understanding the processes of risk formation, we will present the well-known unidirectional "arrow of time" in the following interpretation: the entire time scale "ST" is easily divided into several irregular intervals [1], this is past, present, future. Geometric representation of the relativity of the time scale and the scale of events from the standpoint of risk formation shown in the Figure 1.

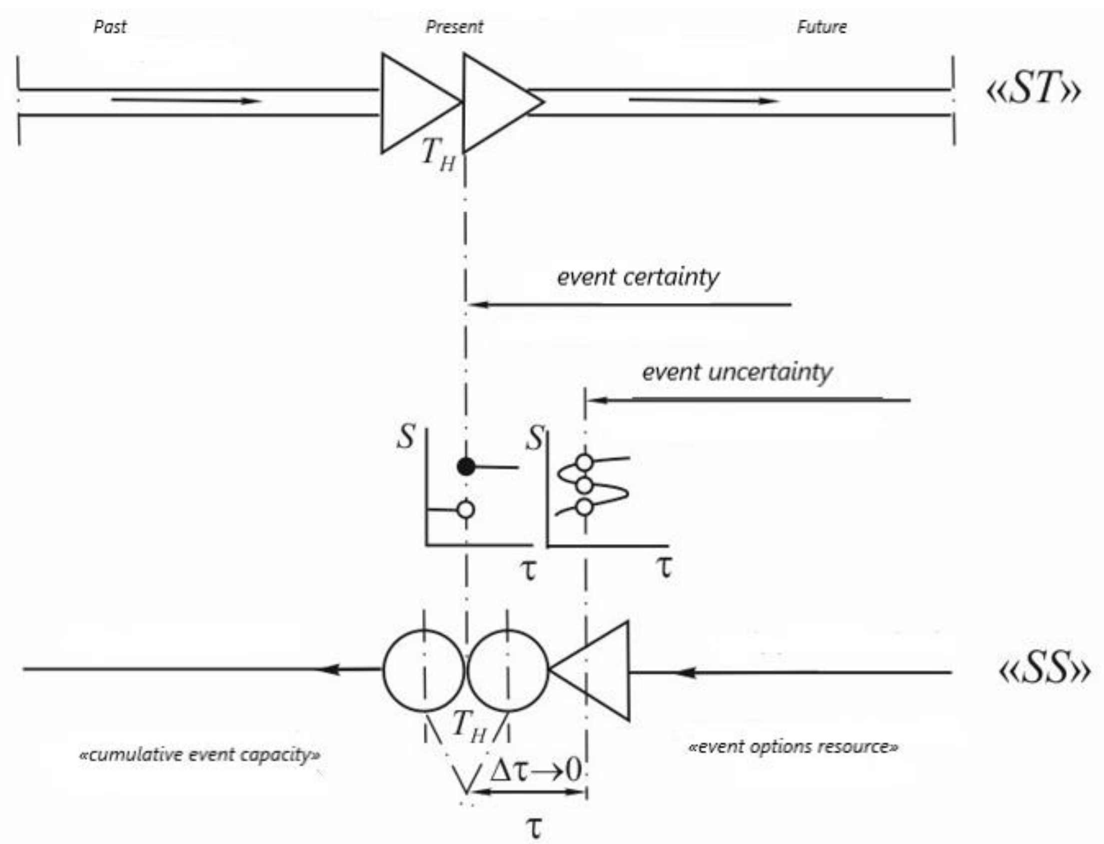

Figure 1. Geometric representation of the relativity of the time scale and the scale of events from the standpoint of risk formation

The past gives an idea of what has happened, the future is associated with the assumed, and the present is associated with the coming.

There is another unidirectional scale speculatively. It can be called the "SS" event scale. In work [2], it is shown that the series of events in chronology is a multi-layer spatial structure, consisting of events that have already taken place and remained in the past, events that occur now, in the present, and events that can be predicted from the future. *Moreover, all events, in one way or another, are associated with energy consumption*, which is important for this work. The vector of such events is always directed in the direction opposite to the “arrow of time” as it shown at Figure 1.

This simple scheme does not take into account one conditional event interval: between potential and onset events. In time, this interval ($\Delta\tau$), like the present time ($T_{н}$), tends to zero. This is an event interval of uncertainty before the present time, which is almost always zero, but its meaning in the time series is extremely large. The zero interval ($\Delta\tau$) instantly separates one single of several potential events from the essence of the event that has occurred. One could argue about the existence of this condition in the form $\lim_{\Delta\tau\to 0}(T_{н} + \Delta\tau) = T_{н}$, if not for the convincingness of the theory of catastrophes [3], in particular, the concept of bifurcation, which is the essence of the transition from time uncertainty of an event with a zero interval to an event that has happened, it is quite unambiguous.

Unlike traditional bifurcations aimed at the transition of the system from stability to an unstable state, in our case we are dealing with a system that, under the influence of many smallest increments in the form of individual events, tends to stability in the form of one single event that occurs in the present time. In the theory of catastrophes, this process is called out-of-bifurcation self-organization of the system, that is, actions to order elements of one level at the expense of internal factors of the system, which, in this case, is the event resource base as illustrated in Figure 1.

The above model can be easily represented in the form of a sequential digraph (Fig. 2), where the vertices (*ij*) are a reflection of some supposed events (*j*) or the happened event "00" at each *i*-th level of the predicted time interval in the future, in relation to the present, and the edges of the graph are cause-and-effect relationships that sequentially transform one *j*-th reason into another. There are four consecutive levels (*i* = 4) of supposed events, each of which at its own level is independent from other equal levels. And only when moving to the next level, its own inter-level connection is manifested.

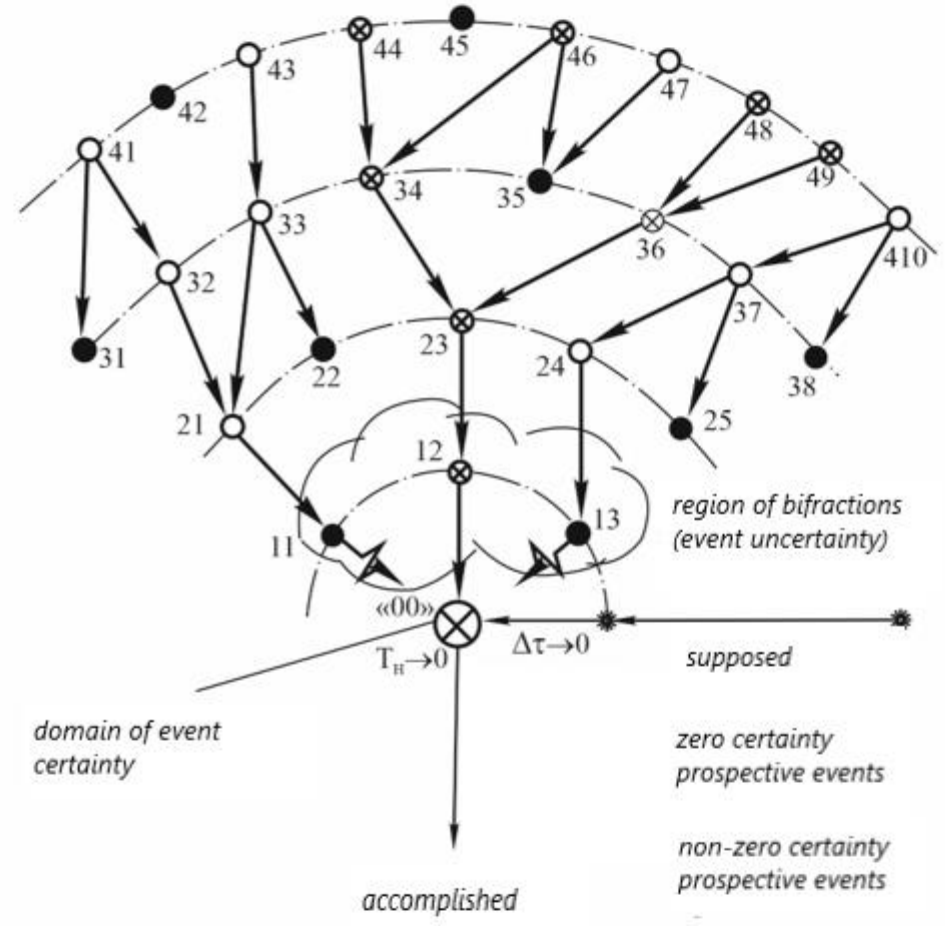

Figure 2. An oriented graph of mappings of the assumed eventfulness and causal relationships between the events that are in the assumption

Let us single out three components: supposed events (four levels in the time interval of the future), the event interval between potential and onset events ($\Delta\tau \to 0$), the present time $T_н \to 0$ and the area of already accomplished events. The lowest, first, level of events shows us exactly the bifurcation, for example, in the form of a Whitney assembly, when in the time period $\Delta\tau$ there are only three variants of events: 11, 12, 13, and only one of them, namely 12, has already become reality after a moment in the present time (see Fig. 2). The chain of alleged events that led to the accomplished "00" looks like:

$$00 \to \overbrace{(23)}^{I} \to \overbrace{(34)}^{II} \to \overbrace{(34 \to 36)}^{III} \to \overbrace{(44 \to 46 \to 48 \to 49)}^{IV}$$

All other possible events did not lead to a real result, event "00".

In nature, there is another parameter, the one-pointedness of which is not questioned. This is entropy. Entropy, as a measure of energy dissipation, is an indicator of the dynamism of a system. The smaller the measure of energy dissipation established and fixed in time, the more the system is oriented towards sequential structuring, the manifestation of new systemic qualities that prevent the emergence of uncertainty. And vice versa, the more significant is the dissipation of energy, the more the system tends to stability, balance, stability.

In a simplified version, the increase in the entropy ΔS of the system is a quantitative measure of the disorder, which is determined by the number of admissible events N related to the system. That is, $\Delta S \sim \ln N$. The entropy of the system is the greater, the more there are admissible options for its states from the future, and related events that determine these states in the antecedent to the present. This means that for the future time the number of undefined states is $N_F \gg 1$, and for the present time there is only one, quite definite state $N_{\mathrm{H}} = 1$, which is now happening. The transition from $N_F \gg 1$ to a well-defined $N_{\mathrm{H}} = 1$ is carried out at the desired time $\Delta\tau \to 0$, which precedes the present. Therefore, the condition $\Delta S_F \gg \Delta S_{\mathrm{H}}$ is always satisfied as shown in Figure 3. And the risk of getting a well-defined event from the future is always equal to $R \cong (S_F - S_{\mathrm{H}})/\Delta S_F = 1$ in the transition from risk uncertainty to a certain event of the present.

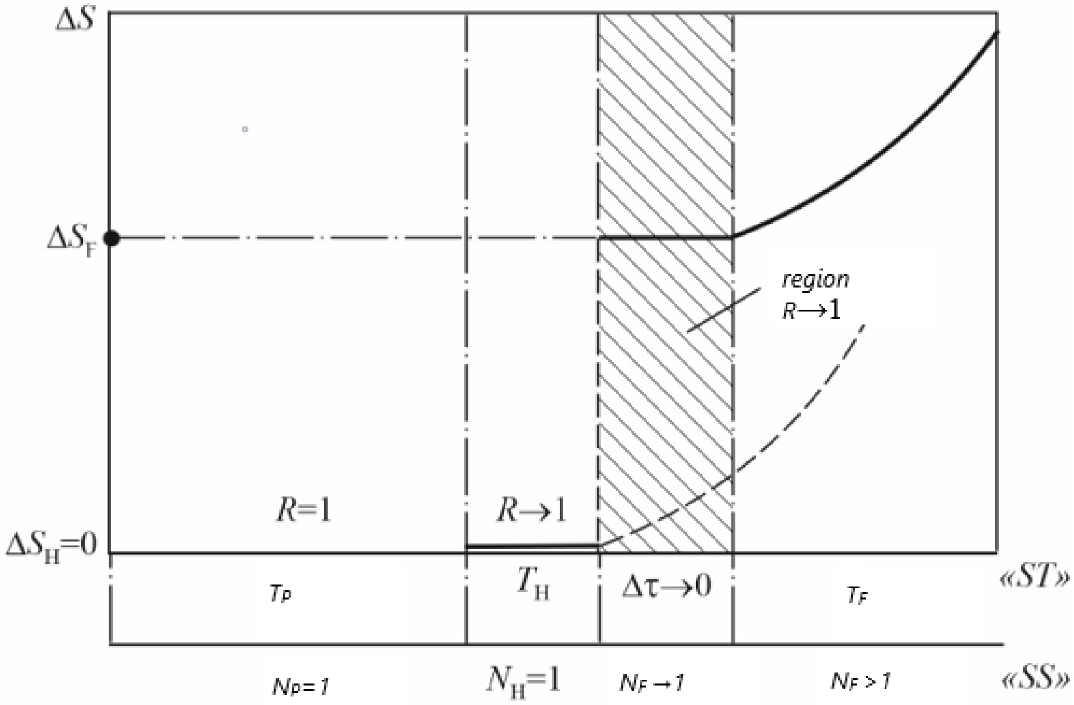

Figure 3. Entropy of risk in the ratio of time "ST" and event "SS" measurements

The opposite of the unidirectional arrow of time and entropy, on the one hand, and the scale of events, on the other, is emphasized by their main properties. For the arrow of time and entropy, this is the sequence and inevitability of the onset of the subsequent time, the subsequent dissipation of energy or information, etc. For the scale of events, this is the uncertainty and palliativeness of the states that have not yet arrived.

The same applies to such an indicator of the system as the risk associated with its existence and operation. Formally, in the coordinates $R = \Phi(\Delta S)$, for the first time, there are interdependent probabilistic characteristics: risk and entropy.

METHODOLOGY

We may be interested in the risks associated with production activities and production systems. As a rule, such systems are structured, fully manageable and predictable. Information about the state of the production system is, of course, related and refers to the technical system by which the production is carried out and to the technological process, that is, the sequence of programmed actions, physical, chemical, mechanical and other effects, material and energy flows involved in production, It also applies to a person, an employee, an operator, his actions, mistakes. The variety of all these indicators gives the normative, including the related information, state of the production process. At the same time, for a variety of reasons, these standard indicators change their initial values depending on external conditions, changes in related industries, wear and tear of the technical system, the influence of the human factor. All this leads to a certain informational distortion of the state of a large production system. Distortions in information lead to distortions, adjustments to the conditions of the technological process, changes in the operation of a technical system and its elements, to a change in the conditions of a person's work.

All this is the reason that when the system enters an abnormal mode of operation, they, under certain circumstances, will lead to an emergency. Therefore, it should be taken for granted that the conditions of emergency operation and the associated risks are determined, first of all, by the state of information about the state of the production system, its insufficiency or redundancy, loss of orderliness of information, its distortion and, most importantly, lack of response to this information. That is, to changes in entropy in the system.

Information about the normative state of the system can be known in advance and remain in the past, that is, be available, for example, in the "cumulative capacity of events" as shown in Figure 1. In the process of work, it can change, be distorted, deviate from what is laid down in the normative documentation and become known at the last moment and only with a certain degree of probability. So, we come to understand that we are dealing with information uncertainty. Moreover, the degree of uncertainty depends on the number of possible (assumed) states of the system, including dangerous or, conversely, safe.

Making a decision under risk conditions is, in essence, either avoiding danger (state "0"), or the onset of a dangerous event - "1". It becomes clear that in the first case the system has an organized character, in the second case we are dealing with a destructive system and with high entropy. This means that the calculation of the uncertainty is possible. The latter statements allow us to create a model of interaction of the main parameters, which, in our opinion, should be taken into account in risk management, namely, the change in non-entropy ΔN_s), entropy (ΔS) and risks (R) in the coordinate space. Formation of risk uncertainty in one of the coordinate grids in conditions of bifurcation along the coordinates $R(\Delta N_s)$ shown in Figure 4.

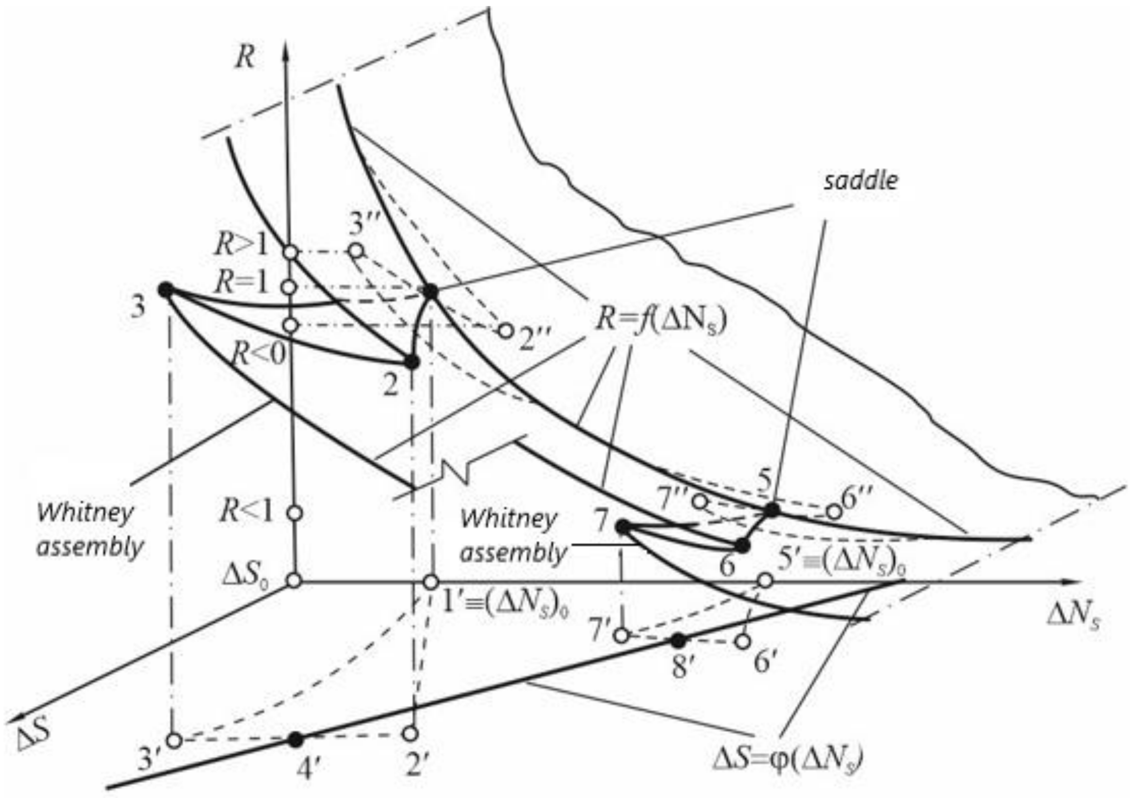

Figure 4. Formation of risk uncertainty in one of the coordinate grids in conditions of bifurcation along the coordinates $\boldsymbol{R}(\Delta \boldsymbol{N_s})$

On the graph, the saddle of the Whitney assembly (point 1) is located on the coordinate plane $R(\Delta N_s)$ and corresponds to the coordinates $\Delta N_s = (\Delta N_s)_0$and $R \sim 1{,}0$. Moreover, the saddle of the assembly, point 1 (and 5, respectively) is always located on the curve $R = f(\Delta N_s)$. This is the limiting point after which the system enters the real time interval with a bifurcation, for example, in the form of a Whitney assembly (points: 1-2-3 and 5-6-7). The loop of the

Whitney assembly in the coordinate space $R, \Delta S, \Delta N_s$ follows the shape of the curve $R = f(\Delta N_s)$ on the corresponding coordinate plane. And the projection of the current saddle point (4') of the Whitney assembly is always tied to the coordinate dependence $\Delta S + \Delta N_s = S_{max}$.

Thus, a smooth and unambiguous dependence of the type $R = f(\Delta N_s)$ receives uncertainty, in this case, the Whitney assembly (or other catastrophe), which occurs in the form of a risk event with an increase in entropy from ΔS_0 and above $\Delta S \geq \Delta S_0$) in the period before the present time, and which will instantly grow into a real event, one of two or three reflected in the Whitney assembly illustrated in Figure 2, either it will be point (2) for which $R < 1{,}0$, or it there will be point (1) for which a risk event $R = 1{,}0$ will take place, or for point (3) we get a hypothetical event with R> 1.0. There may be more than three possible variants of alternative events, but in this case, more complex dependencies of bifurcations such as dovetail, umbilic, etc. should be used [3].

The problem of finding one single option from a set of uncertain events can have a solution according to the theory of catastrophes. Calculated dependencies for determining a unique variant of an event from the area of bifurcation uncertainty for some disasters shown in Table 1.

Table 1. Calculated dependencies for determining a unique variant of an event from the area of bifurcation uncertainty for some disasters. (here $M = x^2 + \Delta\tau,\ N = y^2 + \Delta\tau$)

№	Disaster name	The equation Disasters	Equation solution	Disaster risk
1	Fold	$E = Mx$	x_1, x_2, x_3	0,333
2	Build Whitney	$E = x[Mx + a]$	x_1, x_2, x_3, x_4	0,25
3	Dovetail	$E = x\{x[Mx + a] + b\}$	x_1, x_2, x_3, x_4, x_5	0,20
4	Butterfly	$E = x(x\{x[Mx + a] + b\} + c)$	$x_1, x_2, x_3, x_4, x_5, x_6$	0,16
5	Ombilica hyperbolic	1.$E = x(M + 0{,}5y) +$ $+y(N + 0{,}5x)$ 2. $3x^2 + ay + c = 0$ 3. $3y^2 + ax + c = 0$	$x_1, x_2, x_3, y_1, y_2, y_3$ x_1, x_2, y_1, y_2	0.333 0,25
6	An endless sequence of forms for one variable	$E = x^{\alpha+1} + x^{\alpha} + \cdots . \beta$	$x_i,\ \ i = 1{,}1, \alpha$	0,9(9)

RESULTS AND DISCUSSIONS

We will show how some risks from the occurrence of systemic accidents in power systems and approaches to their management are determined. The main challenge is to ensure a safe energy supply and reliable supply management. Equipment: high-voltage main and distribution power lines, transformers, electrical generating capacities of all types. Each node has its own vulnerability due to the onset of risk events [6-8].

These events include:

- natural events (floods, storms, bad weather, rains, earthquakes, tornadoes, mudstorms, extreme changes in air temperature, meteorological disasters);

- equipment malfunctions caused by wear, material fatigue, changes in operating conditions;

-human errors during operation;

- offenses related to artificial interference by special people, cybercrime;

- terrorism artificial destruction of the power supply system.

In electrical safety, there are three standard types of failures in electrical equipment. These are: a standard accident, which refers to the failure of one element of the system; non-standard accident associated with the simultaneous failure of two or more elements at the same time; critical accident associated with a failure due to improbable events.

The most typical events associated with the risk of disruption in the operation of linear electrical equipment:

-high wind speed (1);

- extremely high (2) or extremely low (3) temperature;

- heavy precipitation in the form of rain (4) or snow (5);

- adhesion of snow (6) icing of wires (7);

- snow storms (8);

- flood (9);

- landslides initiated by extreme precipitation (10);

- thunderstorms (11);

- snow avalanches (12);

- earthquakes (13);

- tsunami (14);

- forest and other fires (15);

- storms and hurricanes (16).

The occurrence of such events can be classified according to the seasons: winter (W), winter-spring (W-Sp), spring (Sp), spring-summer (Sp-Su), summer (Su), summer-autumn (Su-Ot) , autumn (Ot), autumn-winter (Ot-W) depending on meteorological, average climatic and

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other natural conditions. The matrix of cascading events, when each subsequent event is the cause of the previous one and, in turn, becomes the cause of the subsequent event, is presented in Table. 2.

Table 2. Matrix of possible events associated with risks for the linear power supply system due to natural causes

Period of the year	Developments															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
W	«1»	«1»	«1»	0	«1»	«1»	«1»	«1»	0	0	0	0	0	0	0	«1»
W-Sp	«1»	«1»	«1»	«1»	«1»	«1»	«1»	«1»	«1»	«1»	0	0	0	0	0	«1»
Sp	«1»	«1»	«1»	0	«1»	0	0	0	0	0	«1»	0	0	0	0	«1»
Sp-Su	«1»	«1»	«1»	«1»	0	0	0	0	0	2	«1»	0	0	0	0	0
Su	0	«1»	«1»	«1»	0	0	0	0	0	0	«1»	0	0	0	0	0
Su-Ot	«1»	«1»	«1»	«1»	0	0	0	0	0	«1»	«1»	0	0	0	0	«1»
Ot	«1»	«1»	«1»	«1»	«1»	0	0	0	0	0	0	0	0	0	0	«1»
Ot-W	«1»	0	«1»	«1»	«1»	«1»	0	0	0	0	0	0	0	0	0	«1»

As investigated, for example, consider the group of events "5" - "8", which occur in the winter-spring period of the year. As a matrix of cause-and-effect relationships, we will take the time period of interest to us, February 20-March 10 (Table 3).

Table 3. Incident matrix for selected events that can disrupt the operation of the electricity transmission system

Days of the period	Developments					
	«5»	**«6»**	**«7»**	**«8»**	**«9»**	**«10»**
20.02.	6	4	3	0	0	1
21.02.	12	6	8	0	0	1
22.02.	0	0	0	0	1	0
23.02.	5	0	0	0	0	0
24.02.	8	5	5	1	0	0
25.02.	22	11	3	1	0	0
26.02.	11	5	4	1	0	1
27.02.	14	0	7	0	0	0
28.02	16	0	4	0	0	0
01.03.	0	0	0	1	1	1
02.03.	0	0	0	1	0	0
03.03.	0	0	0	0	0	0
04.03.	4	0	0	0	0	1
05.03	7	1	3	0	0	0
06.03.	2	0	0	1	1	0
07.03.	0	0	0	0	0	0
08.03.	3	0	0	0	0	0
09.03.	5	1	0	0	0	0
10.03.	0	0	0	0	0	0

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In particular, the projected time period on March 27 includes increased risks associated with precipitation in the form of snow (14 cases during the study period) and glaciation of conductive wires (7 cases). Bifurcation uncertainty in this case has the character of a fold catastrophe and has three solutions to the equation $\Delta E = x(x^2 + \Delta\tau)$. With a constant potential of the system, the calculated values of the risks are here $x_{1,2} = \sqrt{-\Delta\tau}$, $x_3 = 0$, the solution of which, taking into account expression (2), represents the result of a choice of two options: heavy precipitation in the form of snow, or icing of wires.

The check is carried out using the regression equation between the energy potential and the significant indicators of the system. The regression equation obtained on the basis and calculation of the number of events associated with the influence of climatic conditions on the state of emergency power transmission lines (see Tables 3 and Tables 4) has the form

$$\Delta E = 7{,}1 \cdot 10^{-6}x^4 - 1{,}3 \cdot 10^3 x^2 + 0{,}37x$$

and

$$d(\Delta E)/dx = 28{,}4 \cdot 10^{-6}x^3 - 2{,}6 \cdot 10^3 x + 0{,}37 = 0.$$

Empirical dependences have their analogues in the theory of catastrophes, as it shown in Table 2, in the form of the Whitney assembly, where the parameter $\Delta\tau = 1{,}3 \cdot 10^3$, or 0.36 of hours. According to the regression equation, the parameter $a = 0{,}37$. Let's first assume that $x \leq 1{,}0$. Then, omitting the first polynomial of the equation, its solution will become $x = 0{,}14 \cdot 10^{-3} \ll 1{,}0$.

The actual level of risk associated with the two parameters shown will be equal to one, if we assume that in the present time two indicated events will occur at once and one should prepare for them in combination. This prevents the possibility of a risk event and emergency. For a time interval of 0.36 hours, such a forecast gives more accurate statistics on the obtained climatic precipitation in the form of snow and glaciation of wires, and therefore requires appropriate preparations for work related to snow removal. Even if, due to other random events, the corresponding risks are not justified, and such natural phenomena do not occur on this particular day, the measures may have a preventive value, the meaning of a training session, etc. But at the same time, preparedness for their implementation will cause the prevention of their consequences for a large engineering system.

CONCLUSION

Probabilistic methods for assessing the risks of events have their drawbacks, which are difficult for an objective assessment of the risk itself at the time of its occurrence. The reason lies in the uncertainty inherent in the concept of the probability of an event, as a function of a possible state, but far from reality. It is proposed to use one of the bifurcation states to assess the risk of an event in the present time, as a function of certain energy indicators of the system (entropy), which can accumulate in some future as the most reliable forecast and transit at the present time in the form of a well-defined value through a buffer transition from an indefinite state to certainty in the time period $\Delta\tau \rightarrow 0$ preceding the present. This approach, as a first approximation, allows you to avoid probabilistic uncertainty in the calculations of the risk parameters of the system.

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