

Probabilistic Criterion for Evaluation of the Dependability of Critical Electrotechnical Systems

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Abstract. *In the paper, a probabilistic methodology for the quantitative evaluation of the dependability of critical electrotechnical systems operating under destructive impacts is proposed. It is shown that traditional reliability and availability indicators are insufficient for describing system conduct under partial degradation, complete loss of operability, and subsequent recovery processes.*

Dependability is interpreted as an integral probabilistic property reflecting a system's ability to retain and restore critical functions under adverse conditions. A state-based Markov model is applied to describe the evolution of the functional state through a finite set of functional states and probabilistic transitions. Within this framework, dependability is characterized by three complementary probabilistic components: retention of full operability under destructive impact, recovery after partial loss of functionality, and recovery after complete loss of operability.

On this basis, a normalized integral dependability criterion bounded within the interval [0;1] is proposed using weighted aggregation of the probability components. The proposed approach provides a rigorous and flexible tool for comparative analysis and evaluation of critical electrotechnical systems with respect to resilience and recoverability.

Keywords: *dependability, dependability indicators, critical electrotechnical systems, Markov processes, state-based modeling, recovery of operability.*

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Introduction

Critical-purpose electrotechnical systems in the twenty-first century have become one of the key foundations of the functioning of modern society. Power supply systems, communication systems, data centers, water and gas supply facilities, transport infrastructure, and medical institutions form an interconnected network, the failure of individual elements of which is capable of causing cascading disruptions in adjacent sectors and leading to severe socio-economic consequences [1], [2]. Under conditions of digitalization and increasing interdependence of infrastructures, even a short-term loss of power supply can result in disproportionately large losses.

Modern electrotechnical systems operate under conditions of a growing number of destructive impacts of various natures. These include natural disasters (hurricanes, floods and earthquakes), technological accidents, as well as anthropogenic factors associated with operational errors and equipment ageing

[3]. In recent decades, targeted destructive impacts characteristic of armed conflicts have acquired particular significance, within which critical infrastructure becomes the object of systematic attacks. The practice of recent years demonstrates that power supply and communications are often regarded as priority targets, since their disruption leads to paralysis of medical, food, municipal, and governance systems.

Traditional approaches to the analysis of electrotechnical systems predominantly rely on the concepts of reliability and fault tolerance, oriented towards random component failures and statistically stationary operating conditions [4]. However, under conditions of targeted and large-scale destructive impacts, such models prove to be insufficient, since they generally do not take into account degradation dynamics, the possibility of partial loss of functionality, and the processes of system recovery after severe damage. In response to these challenges, the scientific literature has actively developed the con-

cepts of robustness and resilience, aimed at analyzing the ability of infrastructures to withstand extreme events and recover after them [5], [6].

Despite significant progress in the field of analyzing the robustness and protection of critical infrastructures, the term “dependability” is increasingly used in engineering and scientific practice, intuitively reflecting the ability of a system to ensure the performance of critically important functions under destructive impacts. At the same time, this term does not have a generally accepted rigorous definition and is not accompanied by a unified set of quantitative indicators that would allow an objective evaluation of the level of dependability of electrotechnical systems. The absence of a formalized and measurable criterion significantly limits the possibilities for analysis, design, and management of such systems, especially in the context of critical infrastructure.

It should be noted that in the absence of a quantitatively defined indicator it is impossible to correctly compare different system architectures, substantiate design decisions, and develop strategies for increasing their resistance to destructive impacts. Thus, the problem of dependability acquires not only theoretical but also applied significance, being directly related to ensuring energy security and the resilience of vital societal functions.

In this regard, the aim of this study is, first, to formalize the concept of dependability with respect to critical electrotechnical systems and, second, to develop a clear, interpretable, and quantitatively measurable criterion that makes it possible to evaluate the ability of a system to retain and restore the performance of its functions under destructive impacts. Achieving this aim requires an analysis of existing approaches to the evaluation of operability and the identification of their methodological limitations, which determines the content of the subsequent sections of the work.

1 State of the Art

In contemporary scientific literature, the concept of “dependability” reflects the ability of a system to provide the required level of service with a predefined degree of confidence, encompassing aspects of reliability, availability, maintainability, safety, and security, as well as mechanisms of failure prevention, fault tolerance, recovery, and disturbance prediction [7]. An important methodological consequence of this approach is that dependability is not reduced to the “probability of failure-free operation” or to a single reliability indicator: it presupposes a multicomponent description of system conduct over time, including functional degradation

and subsequent recovery, as well as consideration of organizational and technological operational loops. For critical electrotechnical systems, this is of particular importance, since their systemic operability is determined not only by equipment failures, but also by the availability of control and communication, the operation of automation, and the capabilities for rapid recovery.

The contemporary literature on power engineering has traditionally developed a set of reliability indicators (SAIDI/SAIFI, ENS/EENS, LOLP/LOLE, etc.) and adequacy and security models, which make it possible to formally evaluate the probability of power supply shortages and the expected duration or frequency of outages. At the same time, when transitioning to the analysis of the dependability of critical systems, two persistent limitations become evident. First, a significant proportion of reliability indicators describe the averaged quality of power supply and do not distinguish levels of functional degradation (complete or partial loss of operability), nor do they consider recovery dynamics as an independent component of dependability. Second, classical metrics prove to be insufficiently sensitive to scenarios of rare but high-impact events (HILF), in which the rate of degradation, the depth of functional loss, and the speed and probability of recovery become decisive [9–12]. For this reason, in recent years, alongside “reliability” approaches, the direction of resilience has been actively developing as a characteristic of a system’s ability to withstand destructive impacts, adapt to them, and recover [9–12], [18], [20], [21]. For the dependability of critical electrotechnical systems, what is fundamental is not the terminological distinction, but the fact that resilience approaches effectively bring back into focus the phase structure of an event: the pre-disturbance state, degradation, the minimum level of functioning, and recovery to normal operation [9], [10], [21].

A significant contribution to the formalization of this phase logic has been made in works proposing temporal metrics of degradation and recovery and emphasizing the need to distinguish between the “infrastructural” and “operational” components of power system response [9]. An important methodological advantage of such approaches is that they facilitate the interpretation of dependability as a probabilistic process of transitions between functional states. At the same time, even advanced resilience metrics often remain oriented towards aggregated integral indicators of losses or recovery time, rather than towards a probabilistic decomposition of dependability by key events of “retention of full functionality / recovery after partial degradation / recovery after complete loss”, that is, they do not

provide a direct measurable criterion that naturally supports a Markov (state-space) interpretation required for further formal analysis.

In review works devoted to resilience metrics, the problem of the absence of a standardized framework is emphasized: there are many metrics, but they are often incomparable, and the choice of an indicator is determined by modeling convenience rather than by the completeness of the description of dependability [11], [12], [21]. This is directly manifested in the fact that a significant proportion of publications focuses on a single dominant axis—for example, expected energy not supplied or recovery time – and thereby lose the distinction between scenarios in which the same “integral damage” is achieved through fundamentally different trajectories of degradation and recovery. For critical infrastructure, where threshold effects and cascading consequences are important, this constitutes a substantial limitation. Thus, even in the presence of a wide spectrum of resilience metrics, there remains a methodological demand for a dependability criterion that would be simultaneously meaningfully interpretable for critical infrastructure and formally measurable through state probabilities and transition probabilities.

An additional dimension of the dependability of modern power systems is associated with their transformation into cyber-physical systems, in which fault tolerance is determined not only by the physical network, but also by monitoring, communication, and control loops. In works devoted to the impact of digitalization, it is emphasized that the integration of information and communication technologies (ICT) increases observability and controllability, but at the same time creates new classes of vulnerabilities and failures capable of reducing systemic dependability [12], [13]. Accordingly, operability criteria that do not take into account failures of measurement, data transmission, and control become methodologically incomplete for critical systems. Review studies on the reliability of cyber-physical layers show that traditional component reliability must be complemented by models of data failures, routing errors, and disruptions in the operation of control centers, since it is precisely these mechanisms that are capable of transferring a system into degraded states without “classical” damage to power equipment [12]. The systematization of policies and models of cyber-physical power systems further fixes the gap between engineering reliability models and the task of comprehensive dependability as a property of a “system of systems” [13].

At the applied level, this is manifested in the development of reliability models of cyber-physical

power systems that take into account random failures of measurement and remote control, which directly leads to the need to describe the system through a set of functional states and probabilistic transitions between them [14]. Similarly, in distribution network problems, schemes are considered in which the reliability of the power component becomes dependent on the characteristics of the communication channel (including modern wireless technologies), and dependability must be evaluated as a result of the joint dynamics of “power engineering + communication” [22]. These works confirm a general conclusion: for critical electrotechnical systems, functional resilience under destructive impacts is determined not by a single indicator, but by a combination of probabilities of transition into different functional states and probabilities of recovery.

In parallel, literature on micro-energy systems and microgrids is developing, where the presence of distributed generation, storage, and islanded modes creates a natural formulation of “full/partial operability” and “recovery/reconfiguration”. It is indicative that in studies where a state-space apparatus is directly applied and cyber failures are taken into account, the formulation almost inevitably shifts to a probabilistic description of degradation and recovery, although the final metrics are often again collapsed into traditional indices [24], [15]. Some works explicitly position the analysis in terms of the dependability of microgrids and use Markov constructions (including extensions such as fuzzy-Markov), which demonstrates the compatibility of Markov logic with the dependability problem [23]. At the same time, the question remains open as to which specific comprehensive measurable dependability indicator should be considered adequate for a critical electrotechnical system – such that it 1) preserves the interpretation of “retention of full functionality” and “recovery from degradation”, 2) can be parameterized through state and transition probabilities, and 3) allows comparison of different strategies for enhancing resilience and recovery.

A number of works attempt to eliminate this gap by extending traditional reliability towards operations and maintenance management, emphasizing that system “availability” is determined not only by design decisions, but also by the life cycle, maintenance policies, risk management, and recovery resources [16]. Such reviews are important for the analysis of dependability, as they reintroduce the temporal component of recovery and organizational constraints into the model. However, they generally do not provide an explicit formal dependability criterion that would be “embedded” in a probabilistic model of the functional states of a critical system.

Similarly, frameworks for measuring the resilience of critical infrastructure in general fix the diversity of existing measurement approaches and the need for comparable metrics, but do not propose a specialized dependability criterion specifically for electrotechnical systems, where the key issue is the preservation of power supply and critical functions under targeted destruction [17].

Contemporary reviews on power system resilience and strategic measures for enhancing resilience directly use the term dependability as one of the target characteristics of resilient infrastructure and emphasize that metrics are needed which support comparison of solutions both in terms of the ability to “withstand” and the ability to “rapidly and with a defined probability recover” [20]. In a similar vein, works aimed at achieving conceptual consensus on resilience emphasize that metrics should reflect not only final damage, but also the process properties of degradation and recovery, since it is precisely these that determine the real dependability of critical systems under HILF events and combined threats [18]. Finally, reviews on the cybersecurity of microgrids directly link resilience and dependability with the need to jointly account for attacks/failures and recovery scenarios, since control resilience becomes a factor in preserving the power supply function for critical loads [25]. For critical energy infrastructure based on renewable energy sources, it is also emphasized that the growing role of such facilities requires a comprehensive view of resilience, network integration, and cyber protection as elements of dependability, rather than as separate “add-ons” to classical reliability [26].

Taken together, the cited sources make it possible to draw a key conclusion for the formulation of the problem addressed in this study: the literature has established a general framework of dependability as a multicomponent system property [7], developed approaches to resilience metrics that introduce degradation and recovery as central elements of evaluation [9–12], [18], [20], [21], and relies on results concerning the cyber-physical nature of power systems and the need to account for failures of measurement, communication, and control [12–15], [22], [25]. At the same time, a methodological gap remains: there is no single, easily interpretable, and measurable comprehensive dependability criterion for a critical electrotechnical system that would be directly expressed through probabilities of functional states and transitions between them (including retention of full operability under impact and probabilities of recovery from partial and complete loss of operability) and would thereby naturally support Markov analysis. Eliminating this gap constitutes the

substantive basis of the research objective and the subsequent development of a formal apparatus for the evaluation of dependability.

Thus, the conducted analysis of contemporary scientific approaches to the evaluation of operability, reliability, robustness, and resilience of critical electrotechnical systems indicates the presence of a substantial methodological gap between the large number of existing indicators and the absence of a single, clearly formalized, and quantitatively measurable dependability criterion that would adequately reflect system behavior under destructive impacts. Existing metrics either focus on averaged indicators of failures and service losses or describe degradation and recovery through integral temporal characteristics that largely depend on the choice of service function and threshold values [9–12], [18], [21]. At the same time, the literature insufficiently represents approaches that would make it possible to directly link dependability with the probabilistic structure of the system’s functional states and the processes of transition between them, in particular taking into account the distinction between retention of full operability under impact and recovery after partial or complete loss of functionality.

In this regard, the further development of the theory of dependability of critical electrotechnical systems requires a clear formalization of the very concept of dependability in terms compatible with the contemporary dependability framework, as well as the definition of requirements for a quantitative indicator capable of reflecting both the states of system functioning and the dynamics of its degradation and recovery under destructive impacts. Such an indicator should be interpretable from an engineering point of view, suitable for comparative analysis of alternative architectures and protection strategies, and formally linked to the probabilistic characteristics of the system, which opens the possibility for the application of rigorous methods of stochastic analysis.

2 Formalization and Justification of the Dependability Criterion for Critical Electrotechnical System

Based on the analysis of contemporary approaches to the evaluation of operability and dependability of critical electrotechnical systems, dependability is appropriately considered as an integral probabilistic characteristic that reflects a system’s ability to retain and restore the performance of its functions in the presence of destructive impacts. Such an interpretation is consistent with the generally accepted dependability framework and makes it possible to move from qualitative descriptions to

quantitative evaluation, which is necessary for comparative analysis of architectures, justification of design decisions, and support of critical infrastructure management [27], [28].

A key modeling assumption of this study is the assumption of the Markovian nature of processes in the system, according to which the evolution of the functional state of an electrotechnical system is described by a Markov process. Within this assumption, it is considered that the probabilities of transitions between states depend only on the current state of the system and do not depend on the prior history of degradation or recovery. This makes it possible to represent system behavior in the form of a finite set of functional states corresponding to different levels of operability, and a matrix of transition probabilities between them, conditioned both by destructive impacts and by recovery processes. The Markov formulation is well established in problems of reliability and dependability analysis of complex technical systems and provides a formally rigorous and at the same time engineering-interpretable description [27], [29].

Within this formulation, dependability cannot be adequately characterized by a single scalar indicator such as the probability of failure-free operation or the availability factor. The behavior of critical electrotechnical systems fundamentally depends on the depth of degradation and the recovery scenario, which necessitates the identification of several complementary components. For this purpose, dependability is proposed to be characterized by three probabilistic components, each of which has a clear physical and engineering interpretation.

The first component reflects the probability of retaining full operability of the system under the action of a destructive impact. For electrotechnical systems, this quantity characterizes the ability of the infrastructure to withstand the impact without transitioning into a degraded state, that is, without losing the ability to provide nominal power supply to critical loads. High values of this probability indicate the effectiveness of structural redundancy, physical and cyber protection, circuit redundancy, and damage localization, which is key to preventing cascading disruptions in interconnected infrastructures [30], [31].

The second component characterizes the probability of restoring full operability after a partial loss of functionality. Partial degradation for electrotechnical systems implies operation in a limited mode, for example with the disconnection of non-critical loads, transition to islanded operation, or the use of backup power sources. This component reflects system adaptability, its reconfiguration capabilities, and

the effectiveness of recovery procedures. For modern distributed power supply systems, it is precisely the ability to return quickly and with high probability to the nominal operating mode after partial disturbances that determines the practical level of dependability [32].

The third component corresponds to the probability of restoring full operability after a complete loss of system functionality, which occurs in cases of large-scale accidents, destruction of key network elements, or loss of centralized control. For critical electrotechnical systems, this property is fundamentally important in view of the need to ensure the long-term provision of vital societal functions even in the event of repeated or combined destructive impacts. It reflects maintainability, resource availability, the effectiveness of emergency recovery strategies, and organizational aspects of operation [33], [34].

All three components are probabilities and, accordingly, take values in the range $[0;1]$. To form an integral dependability indicator, it is proposed to combine them using weighted aggregation. The composite dependability criterion G is defined as a weighted sum of the corresponding probabilities with non-negative weighting coefficients that satisfy the normalization condition:

$$G = w_1 \cdot P_{Ret} + w_2 \cdot P_{RPL} + w_3 \cdot P_{RFL},$$

where w_1, w_2, w_3 – are weighting coefficients;

P_{Ret} – probability of retention of full operational capability;

P_{RPL} – probability of recovery after partial loss of operational capability;

P_{RFL} – probability of recovery after complete loss of operational capability.

With the imposition of the additional normalization condition:

$$w_1 + w_2 + w_3 = 1$$

the criterion G is a convex combination of probabilities and strictly belongs to the interval $[0;1]$.

The value $G = 0$ corresponds to a system that is incapable of either withstanding destructive impacts or restoring operability after degradation, whereas the value $G=1$ corresponds to an idealized system that retains or fully restores operability in all considered scenarios. In practice, high values of the criterion are characteristic of specially protected systems or distributed power supply systems in which the failure of individual elements does not lead to a loss of operability of the system as a whole [35], [36].

The weighting coefficients in this criterion have a clear physical meaning and reflect the relative importance of different aspects of dependability for

a specific object or operating conditions. Their selection makes it possible to adapt the criterion to the system type, permissible levels of degradation, and recovery priorities without changing the overall structure of the indicator.

Thus, the proposed criterion combines formal rigour, engineering interpretability, and configurationally flexibility, which makes it suitable for further use in stochastic analysis and optimization of critical electrotechnical systems. At the same time, the linear form of aggregation and the Markov assumption define the limits of applicability of the criterion, which should be taken into account when analyzing systems with pronounced memory effects or nonlinear interaction of degradation and recovery processes; these limitations are considered as directions for further development of the proposed approach.

3 Discussion

The proposed composite dependability criterion should be considered in the context of existing metrics that are traditionally used for the evaluation of operability, reliability, and robustness of electrotechnical systems. Such a comparison makes it possible to clearly delineate both the advantages of the proposed approach and its place among existing engineering tools for the analysis of critical infrastructure. Classical reliability indicators, in particular the probability of failure-free operation, mean time to failure, and the availability factor, are widely used for the evaluation of power systems under stationary operating conditions [37]. These metrics are well formalized and have a clear statistical interpretation; however, they are generally based on a binary division of system states into “operable” and “inoperable”. As a result, they reflect neither intermediate levels of degradation nor the distinction between partial and complete loss of functionality, which is fundamentally important for critical electrotechnical systems under destructive impacts.

Power supply quality indices commonly used in power engineering practice, such as SAIDI and SAIFI, are oriented towards evaluating the consequences of failures for consumers and characterize the average duration and frequency of power supply interruptions [38]. Although these indices are useful for regulatory and operational analysis, they are not dependability indicators in the strict sense, since they are not directly linked to the internal structure of the system, do not reflect its ability to recover after large-scale destruction, and do not allow assessment of the impact of alternative architectural solutions.

Resilience metrics proposed in contemporary literature represent a significant step towards accounting for the dynamics of system degradation and recovery [39]. Many of them are based on integral characteristics of the service function over time, in particular on the area under the recovery curve or on the speed of return to the nominal level of functioning. Despite their conceptual attractiveness, such metrics often depend on the choice of threshold values, time horizons, and the form of the service function, which complicates their comparative use and engineering interpretation. In addition, they usually do not distinguish between scenarios of partial and complete loss of operability, combining them into a single degradation indicator.

In contrast to the approaches mentioned above, the proposed dependability criterion is based on an explicit state-based representation of system conduct and on a Markov model of transitions between functional states. This makes it possible to directly link the value of the criterion to physically and engineering-interpretable scenarios of retention of operability and recovery. An important distinction is also that the criterion is not reduced to an averaged indicator of losses or recovery time, but is formed as a weighted combination of probabilities of fundamentally different events, each of which has independent significance for the analysis of dependability.

Compared with multidimensional approaches to the evaluation of dependability, the proposed criterion maintains a balance between completeness of description and practical applicability. On the one hand, it aggregates several aspects of system conduct into a single normalized indicator, which simplifies comparative analysis and optimization. On the other hand, the presence of weighting coefficients makes it possible to adapt the criterion to specific operating conditions, the type of electrotechnical system, and permissible levels of degradation, without losing the transparency of the indicator’s structure.

At the same time, the proposed criterion does not claim to be a universal replacement for all existing metrics and should be regarded as a complement to classical reliability indicators and power supply quality indices for the analysis of dependability under destructive impacts and complex degradation scenarios.

Conclusion

In this paper, the scientific problem of formalization and quantitative evaluation of the dependability of critical electrotechnical systems under destructive impacts is solved. In contrast to traditional

approaches predominantly focused on reliability and availability indicators or average recovery characteristics, the paper proposes a coherent probabilistic concept of dependability that is directly linked to the functional states of the system.

The key scientific novelty of the study lies in the introduction and justification of a composite state-based dependability criterion, which fundamentally differs from existing metrics in that it explicitly distinguishes different levels of system degradation and the corresponding recovery scenarios. The proposed approach does not reduce system behavior to a binary “operable/inoperable” model, but formalizes dependability as a set of probabilistic characteristics reflecting retention of full operability, recovery after partial loss, and recovery after complete loss of functionality. Such a decomposition makes it possible to adequately describe the conduct of critical electrotechnical systems under complex and combined scenarios of destructive impacts.

Another significant element of scientific novelty is the use of a Markov model of functional states as the formal basis for constructing the dependability criterion. Unlike many works in which Markov models are applied only for calculating individual reliability indicators, in this study they are used for the direct determination of the components of the integral criterion. This ensures a rigorous link between the physical interpretation of degradation and recovery processes and the quantitative evaluation of dependability.

The proposed aggregation rule in the form of a weighted normalized combination of probabilities also has methodological novelty. It makes it possible to obtain an integral indicator bounded within the interval $[0;1]$, with a clear interpretation of its limiting values, while simultaneously providing flexibility in adapting the criterion to different classes of electrotechnical systems and operating conditions. The introduction of weighting coefficients transforms the criterion from an abstract theoretical measure into an engineering tool suitable for practical analysis, comparison of architectures, and justification of design decisions.

Comparative analysis with existing reliability metrics, power supply quality indices, and resilience measures has shown that the proposed criterion occupies a distinct niche within the system of indica-

tors used for the evaluation of electrotechnical systems. It complements classical approaches by eliminating their methodological limitations in describing multilevel degradation and recovery, while at the same time avoiding dependence on the subjective choice of time horizons and threshold values inherent in many resilience metrics.

The obtained results form a new conceptual and methodological basis for the quantitative analysis of the dependability of critical electrotechnical systems. The proposed criterion can be used for systematic comparison of alternative architectures, evaluation of the effectiveness of protection and recovery measures, as well as a basic element of stochastic models and optimization problems aimed at enhancing the resilience and recoverability of critical infrastructure. This determines the practical significance and scientific promise of further development of the proposed approach.

Conflicts of interest

The author of this paper declares that there is no conflict of interest regarding this study, including financial, personal, authorial, or any other that could influence the research, as well as the results presented in this paper.

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Data availability

All data are available in numerical or graphical form in the main text of the research.

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The author confirms that he used artificial intelligence technologies only to translate the text of the article into English.

Author's contribution

Dmytro Stetsiuk: The research, data processing, creation of visualization of results and text, conceptualization and other activities are entirely the work of the author.

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Ймовірнісний критерій оцінювання гарантоздатності критичних електротехнічних систем

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Анотація. В статті розглядається проблема формалізації та кількісного оцінювання гарантоздатності критичних електротехнічних систем, що функціонують в умовах деструктивних впливів. З огляду на зростаючу вразливість сучасної енергетичної інфраструктури до природних, техногенних і цілеспрямованих руйнівних подій показано, що традиційні показники, засновані на надійності та готовності, є недостатніми для адекватного опису поведінки системи за умов часткової деградації, повної втрати функціональності та подальших процесів відновлення.

Гарантоздатність запропоновано інтерпретувати як інтегральну ймовірнісну властивість, що відображає здатність системи зберігати та відновлювати виконання своїх критично важливих функцій у несприятливих умовах. Застосовано state-based підхід, у межах якого еволюція функціонального стану системи моделюється Марковським процесом на скінченній множині функціональних станів. У цій постановці гарантоздатність характеризується трьома ймовірнісними складовими: ймовірністю збереження повної працездатності за дії деструктивного впливу, ймовірністю відновлення після часткової втрати працездатності та ймовірністю відновлення після повної втрати працездатності.

Інтегральний критерій гарантоздатності запропоновано шляхом агрегування зазначених складових за допомогою зваженої нормованої лінійної комбінації, що забезпечує обмеженість отриманого показника інтервалом $[0;1]$ і чітку інженерну інтерпретацію його граничних значень. Уведення вагових коефіцієнтів забезпечує гнучкість критерію, дозволяючи адаптувати його до різних класів електротехнічних систем, експлуатаційних пріоритетів і допустимих рівнів деградації без зміни формальної структури показника.

Ключові слова: гарантоздатність, показники гарантоздатності, критичні електротехнічні системи, Марковські процеси, state-based моделювання, відновлення працездатності.

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