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DEVELOPMENT OF A UNIVERSAL ANALYTICAL-STATISTICAL MODEL FOR CALCULATION OF RELIABILITY INDICATORS AND INTEGRATED ASSESSMENT OF COMPLEX TECHNICAL SYSTEMS OF VARIABLE STRUCTURE

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The article deals with a complex technical system of variable structure (CTS VS), which has: complexity, multicomponent, many quantitative and qualitative parameters; the complexity of experimental studies, the risks of hazardous situations and the catastrophic nature of their consequences; the uniqueness of the modes and conditions of the systems functioning. The peculiarities of such systems determine the specifics of their analysis and modeling: the impossibility of creating and using general analytical models; the complexity of ensuring the reliability of modeling due to the uniqueness, insufficient data on hazardous and emergency modes of operation of the CTS VS substation. These features make it possible to substantiate the advisability of combining various approaches and methods for constructing and composing a unified model of the system from the models of its individual components. The proposed principle of constructing systems significantly expands the possibilities of managing the process of functioning of the CTS VS due to the flexible use of the useful properties of each of the structures, depending on the internal state of the system and changing external conditions. A typical example of CTS VS is the air supply system of coal mines. The configuration of this system must constantly change, adapting both to a change in the structure and volumes of the faces themselves, and in connection with a possible change in the parameters of technical devices for pumping air into mines (up to their complete failure).
The aim of the work is to develop a universal analytical and statistical model for calculating reliability indicators and a comprehensive assessment of complex technical systems of variable structure.
The novelty lies in the fact that a universal analytical and statistical model has been developed for determining the boundary values of reliability indicators and calculating a pessimistic and optimistic assessment, which differs in that it takes into account the features of the functioning of non-recoverable and recoverable, redundant and non-redundant technical systems in case of failures and restorations of elements during the influence of various random parameters, which makes it possible to calculate the reliability of the functioning of the CTS VS of the substation and evaluate the effectiveness of the application of measures of structural redundancy.

Keywords: analytical and statistical model, complex technical system of variable structure, reliability indicators, pessimistic and optimistic assessment, structural redundancy, reliability.

REFERENCES

1. Buslenko N.P. *Modelirovanie slozhnyh sistem* [Modeling of complex systems]. Moscow, Nauka, 1978. 400 p.

2. Samarsky A.A., Mikhailov A.P. *Matematicheskoe modelirovanie. Idei. Metody. Primery* [Mathematical modeling. Ideas. Methods. Examples. 2nd ed.] Moscow, Fizmatlit, 2001. 320 p.

3. Altunin A.A. *Teoreticheskoe i prakticheskoe primenenie metodov prinyatiya resheniy v usloviyah neopredelennosti.* Tom 1. *Obshchie principy prinyatiya reshenij v usloviyah razlichnyh vidov neopredelennosti* [Theoretical and practical application of decision-making methods in conditions of uncertainty. Volume 1. General principles of decision-making in conditions of various types of uncertainty]. M.: Izdatel'skie resheniya, 2019. 484 p.

4. Tarasik V.P. *Matematicheskoe modelirovanie tekhnicheskih sistem* [Mathematical modeling of technical systems]. Minsk, Dizajn PRO, 2004. 640 p.

5. Borisov V.V., Misnik A.E. *Kombinirovannyj nejrosetevoj sposob modelirovaniya dlya operativnogo upravleniya slozhnymi sistemami* [Combined neural network modeling method for operational management of complex systems]. Information Technologies, 2012. No. 7. Pp. 69–72.

6. Pospelov D.A. *Bol'shie sistemy. Situacionnoe upravlenie* [Big systems. Situational management]. Moscow: Znanie, 1975. 64 p.

7. Pospelov D.A. *Situacionnoe upravlenie: teoriya i praktika* [Situational control: theory and practice]. Moscow: Nauka, 1986. 288 p.

8. Klyuev R.V., Bosikov I.I. Research of water-power parameters of small hydropower plants in conditions of mountain territories. In the collection: 2016 2nd International Conference on Industrial Engineering, Applications and Manufacturing, ICIEAM 2016 – Proceedings 2. 2016. P. 7911420.

9. Bosikov I.I., Klyuev R.V., Gavrina O.A. *Razrabotka integrirovannoy sistemy, vklyuchayushchey algoritmy i metody analiza nadezhnosti promyshlenno-tekhnicheskoy sistemy. Materialy vtoroy Mezhdunarodnoy nauchnoy konferentsii, posvyashchonnoy 25-letnemu yubileyu Kabardino-Balkarskogo nauchnogo tsentra Rossiyskoy akademii nauk* [Development of an integrated system that includes algorithms and methods for analyzing the reliability of an industrial and technical system. Materials of the second International Scientific Conference dedicated to the 25th anniversary of the Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences]. 2018. Pp. 160–166.

10. Klyuev R.V., Bosikov I.I., Gavrina O.A., Revazov V.C. System analysis of power consumption by nonferrous metallurgy enterprises on the basis of rank modeling of individual techno enosis castes. In the collection: MATEC Web of Conferences. 2018. P. 04018.

11. Bosikov I.I., Alikov A.Yu., Bosikov V.I., Smelkov Z.A. *Issledovaniye zakonomernostey funktsionirovaniya prirodno-promyshlennoy sistemy gorno-pererabatyvayushchego kompleksa s pomoshch'yu matematicheskikh modeley* [Investigation of the regularities of the functioning of the natural and industrial system of the mining and processing complex using mathematical models] // Science perspectives. 2012. No. 1 (28). Pp. 70–72.

12. Jones M., Viola P. Robust Real-Time Face Detection // International Journal of Computer Vision. 2004. 57(2). Pp. 137-154.

13. Fleuret F. and Geman D. Coarse-to-fine face detection // International Journal of Computer Vision. 2001. 41:85–107.

14. Weinzman C. Distributed Micro / Minicomputer Systems. New Jersey: Prentice Hall Inc. 1982. 403 p.

15. Mashintsov E.A., Kotlerevskaya L.V., Krinichnaya N.A. *Upravleniye ventilyatsiyey v ugol'noy shakhte* [Ventilation control in a coal mine] // *Izvestiya Tul'skogo gosudarstvennogo universiteta. Tekhnicheskiye nauki* [News Tula State University. Technical science]. 2014. No. 7. Pp. 188-195.

16. Skopintseva O.V., Balovtsev S.V. *K voprosu otsenki aerologicheskogo riska pri razlichnykh skhemakh ventilyatsii vyyemochnykh uchastkov ugol'nykh shakht* [On the issue of assessing the aerological risk for various ventilation schemes of coal mine excavation areas] // *Nauchnyy vestnik Moskovskogo gosudarstvennogo gornogo universiteta* [Scientific Bulletin of the Moscow State Mining University]. 2013. No. 1. Pp. 87–100.

17. Kaledina N.O. *Obosnovaniye parametrov sistem ventilyatsii vysokoproizvoditel'nykh ugol'nykh shakht* [Justification of the parameters of ventilation systems of high-performance coal mines] // MIAB. Mining Inf. Anal. Bull. 2011. No. 7. Pp. 261-271.

18. Bahvalov L.A., Barannikova I.V., Agabubayev A.T. *Analiz sovremennykh sistem avtomaticheskogo upravleniya provetrivaniyem* [Review of the modern systems of automated ventilation control] // MIAB. Mining Inf. Anal. Bull. 2017. No. 7. Pp. 22-28.

19. Bosikov I.I., Klyuev R.V., Khetagurov V.N., Azhmukhamedov I.M. *Razrabotka metodov i sredstv upravleniya aerogazodinamicheskimi protsessami na dobychnykh uchastkakh* [Development of methods and management tools aerogasdynamics processes at mining sites] // *Ustoychivoye razvitiye gornykh territoriy* [Sustainable development of mountain territories]. 2021. No. 1. Pp. 77–83. DOI: 10.21177/1998-4502-2021- 13-1-77-83.

20. Vasenin I.M., Shrager E.R., Krainov A.Yu., Paleev D.Yu., Lukashov O.Yu., Kosterenko V.N. *Matematicheskoye modelirovaniye nestatsionarnykh protsessov ventilyatsii seti vyrabotok ugol'noy shakhty* [Mathematical modeling of non-stationary ventilation processes of the coal mine workings network] // *Komp'yuternyye issledovaniya i modelirovaniye* [Computer Research and Modeling]. 2011. V. 3. No. 2. Pp. 155–163.

21. Mashintsov E.A., Kotlerevskaya L.V. Krinichnaya N.A. *Upravleniye ventilyatsiyey v ugol'noy shakhte* [Management of ventilation in the coal mine as difficult system] // *Izvestiya Tul'skogo gosudarstvennogo universiteta. Tekhnicheskiye nauki* [News Tula State University. Technical science]. 2014. No. 7. Pp. 188–195.

22. Kharik E.K., Astanin A.V. *Chislennoye issledovaniye ventilyatsii gornoy vyrabotki ugol'noy shakhty v trekhmernoy postanovke* [Numerical study of ventilation of a coal mine in a three-dimensional setting] // Vestnik Nizhegorodskogo universiteta im. N.I. Lobachevskogo [Bulletin of the Nizhny Novgorod University. N.I. Lobachevsky]. 2011. No. 4–5. Pp. 2567–2569.

23. Rychkovsky V.M., Sergeev O.A., Tyurin V.P. *Ob upravlenii ventilyatsiyey na ugol'nykh shakhtakh Kuzbassa* [On ventilation control at coal mines of Kuzbass] // *Bezopasnost' truda v promyshlennosti* [Industrial safety]. 2004. No. 11. Pp. 8–9.

24. Sjöström S., Klintenäs E., Johansson P., Nyqvist J. Optimized model-based control of main mine ventilation air flows with minimized energy consumption // International Journal of Mining Science and Technology. 2020. V. 30. Issue 4. Pp. 533–539. DOI: 10.1016/j.ijmst.2020.05.016.

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