**Introduction.** In conditions of uncertainty and risk, the task of saving energy production or consumption costs in the aspect of safety is relevant. An effective tool for solving the problem is the use of information and measurement systems. **Aim.** Building safety models for energy saving using information and measurement systems based on a systematic approach. **Materials and methods.** Traditional approaches to solving problems using information and measurement systems do not take into account the systematic approach to risk accounting. New models and methods based on a systematic approach to risk accounting are proposed. The model of the security system includes a set of necessary energy-saving measures. The model for assessing the effectiveness of a security system for energy-saving measures takes into account the interests of all information and measurement systems participating in the implementation process. The method for creating a security system takes into account the interconnections of energy-saving measures. **Results.** The developed models and the plan for creating a security system make it possible to minimize economic, informational, psychological, environmental and didactic risks when implementing energy-saving measures using information and measurement systems. **Conclusion.** The implementation of the developed models and the plan for creating a security system at the Chelyabinsk thermal power station-2 ensured a reduction in risks when performing energy-saving measures using an automated system of integrated energy metering.

**Keywords:** information-measuring systems; energy saving; safety; automation; modeling.
To ensure energy saving, the task of step-by-step introduction of automated information and measuring systems. Reliability, cost, volume of automated work, measurement errors, number of measuring channels, skill level and number of staff, as well as the impact on the performance indicators of an automated control system and heat power equipment determine the economic efficiency of the implementation of automated systems [9].

Effective tools for risk management in the conditions of introduction of new information technologies is the use of management models and methods of efficiency assessment [10, 11].

**Terms of reference**

An important task of industrial and energy enterprises is to reduce the cost of production or consumption of energy resources. Automated information and measurement systems (AIMS) are used to solve the problem. The most widespread in Russia was hardware-software system “Energy” [12].

When introducing new information technologies, the experience of enterprises is used and mathematical modeling is applied. For example, the experience of implementing information systems in FSUE “Russian Post” and Chelyabinsk thermal power station-2 is known [13, 14]. Theoretical laws or experimental data underlie mathematical modeling [15, 16]. The presence of AIMS makes it possible to minimize the costs for the collection and analysis of big data [17].

The Department of Applied Mathematics of the South Ural State University has developed a method for searching for unacceptable energy losses based on a network mathematical model that takes into account the interaction between input and output energy flows. The implementation of the method allowed to reduce the time and labor of works in the zone of possible damage to the energy carrier, and also effectively plan measures for further troubleshooting [18].

An important task is to monitor compliance with the safe operation of equipment. The method [19] allows improving the efficiency of energy-saving measures related to the safe operation of equipment and the objectivity of working with personnel.

The application of the method of planning personal development trajectories on the basis of the competence model makes it possible to minimize economic and didactic risks in the training of personnel for working with information and measuring systems [20].

The maximum effect in the implementation of any project is achieved by taking into account the impact of all potential risks [21].

The use of information-measuring systems allows you to save the cost of generating or consuming energy in the face of uncertainty and risk. The aim of the study is to build safety models in the implementation of information-measuring systems.

1. Building models for creating and evaluating the efficiency of systems providing energy saving safety

As an object of research for energy conservation, an automated integrated energy accounting system was chosen at Chelyabinsk thermal power station-2. The object of the study includes an automated workplace and a complex of technical means “Energy”, which unites a local computer network (Fig. 1).
Краткие сообщения

As a result of automation of data collection, unbalance of electricity decreased by 10 times, the entries in the meter reading log, the calculation of unbalance and the filling of output forms became unnecessary.

The introduction of the Energy technical equipment complex at Chelyabinsk thermal power station-2 allowed reducing the claimed peak power by 10%.

Security model for energy conservation includes risks, steps and actions to minimize the impact of risks.

For the selected object, a model of the security system is formed (Table 1).

| Stage | Event |
|-------|-------|
| **Economic risks** | |
| 1.1. A large number of levels of automation of measuring channels for energy accounting | The choice of the automation level of the measuring channels for energy accounting according to the economic criterion |
| 1.2. Inadmissible energy losses | The use of effective methods of searching for unacceptable energy losses |
| 1.3. Loss and distortion of data as a result of untimely detection of invalid measuring channels | Organization of a site of on-duty engineers for operative search of unreliable measuring channels |
| **Information risks** | |
| 2.1. Errors of operational and repair personnel | Organization of emergency response training for operational and maintenance personnel |
| 2.2. Loss of data at the time of elimination of invalid measuring channels | Switching to duplicate measuring channels |
| **Psychological risks** | |
| 3.1. The psychological barrier to mastering new methods | Organization of effective personnel policy |
| **Environmental risks** | |
| 4.1. The effect of electric current and energy on the health of staff | Search Methods for Unacceptable Energy Losses |
| **Didactic risks** | |
| 5.1. Insufficient competence to apply new methods | Organization and conduct of refresher courses |

Evaluation of the effectiveness of the energy saving system is carried out on the basis of quantitative assessments of the impact of risks (“1” is a minor effect, “2” is average, and “3” is strong).

The methodology for assessing the energy saving safety system was implemented at the Chelyabinsk thermal power station-2 (Table 2).

2. Designing the safety system for energy saving

The algorithm for designing a security system for energy saving is presented below:

1. An expert group is developing a safety model for energy conservation. The model includes risks and measures to minimize them. An example of a safety system model for the technical diagnostics of measuring Channels is given in Table 1.

2. Based on knowledge and experience, each expert creates a safety assessment model for energy saving. The model includes possible risks and their weight (“1” – the influence of an insignificant, “2” – an average, “3” – a strong one). An example of a safety assessment model for the technical diagnosis of measurement channels is given in Table 2.

3. The final safety assessment model is based on the models of all experts. In this model, the weight of each risk is defined as the sum of the risk weights from the expert models.

4. A preliminary plan of measures for creating a security system is being developed on the basis of the final model for assessing the security system. In this plan, the procedure for implementing measures is determined by the scales of the corresponding risks of the final model.

5. Based on the interaction of activities, the action plan is adjusted to create a security system. The described algorithm is implemented at Chelyabinsk thermal power station-2.

The expert group included all participants in the energy conservation process: heads of departments, representatives of maintenance and repair personnel.
Model of safety system presentation for energy saving at Chelyabinsk thermal power station-2

| Stage | Weight of risk |
|-------|----------------|
| 1.1. A large number of levels of automation of measuring channels for energy accounting | 3 |
| 1.2. Inadmissible energy losses | 3 |
| 1.3. Loss and distortion of data as a result of untimely detection of invalid measuring channels | 3 |

Information risks

| Stage | Weight of risk |
|-------|----------------|
| 2.1. Errors of operational and repair personnel | 3 |
| 2.2. Loss of data at the time of elimination of invalid measuring channels | 3 |

Psychological risks

| Stage | Weight of risk |
|-------|----------------|
| 3.1. The psychological barrier to mastering new methods | 2 |

Environmental risks

| Stage | Weight of risk |
|-------|----------------|
| 4.1. The effect of electric current and energy on the health of staff | 2 |

Didactic risks

| Stage | Weight of risk |
|-------|----------------|
| 5.1. Insufficient competence to apply new methods | 2 |

The final model for evaluating the energy-saving safety system was implemented at Chelyabinsk thermal power station-2 (Table 3).

Table 3

The final model for assessing of the energy-saving safety system at Chelyabinsk thermal power station-2

| Stage | Weight of risk |
|-------|----------------|
| 1.1. A large number of levels of automation of measuring channels for energy accounting | 3 |
| 1.2. Inadmissible energy losses | 3 |
| 1.3. Loss and distortion of data as a result of untimely detection of invalid measuring channels | 3 |
| 2.1. Errors of operational and repair personnel | 3 |
| 2.2. Loss of data at the time of elimination of invalid measuring channels | 3 |
| 3.1. The psychological barrier to mastering new methods | 2 |
| 4.1. The effect of electric current and energy on the health of staff | 2 |
| 5.1. Insufficient competence to apply new methods | 2 |

A preliminary plan of measures for creating a security system is developed on the basis of the final model for evaluating a security system for energy conservation. In this regard, the procedure for implementing measures is determined by the scales of the corresponding risks of the final model (Fig. 2).
Based on the interaction of activities, this plan has been adjusted (Fig. 3):

– After choosing the automation level of the measuring channels for energy accounting, it seems advisable to organize a site of duty engineers at the second stage (activity 1.3);

After implementation of organizational changes in the structure of enterprises at the third stage, it is recommended to carry out activities related to personnel training for work in new conditions (activities 2.1, 3.1 and 5.1);

– At the fourth stage, measures 1.2, 2.2 and 4.1 are implemented, related to the implementation of professional duties of trained personnel.

As a result of the development of a security system for energy conservation, measures to ensure security were determined based on the interests of all participants in the energy saving process and an effective plan for creating a security system was developed taking into account the interconnection of activities.

**Conclusion**

The task of providing integrated safety of energy saving with the help of information and measuring systems based on the developed models was solved.

A new model of the security system includes a set of necessary energy-saving measures.

The new model for evaluating the effectiveness of the security system for energy-saving measures takes into account the interests of all participants in the implementation of information-measuring systems involved in the implementation process.

The plan for creating a security system takes into account the interrelationships of energy-saving measures.

The developed models and the plan for creating a security system allow minimizing economic, informational, psychological, ecological and didactic risks when performing energy-saving measures with the help of information-measuring systems.

The implementation of the developed models and the plan for creating a security system at the Chelyabinsk thermal power station-2 ensured a reduction in risks when performing energy-saving measures using an automated system of integrated energy metering.

**References**

1. Loginov E.L., Raykov A.N. [Network information attack on the control systems of critical infrastructure energy facilities]. *Thermal Engineering*, 2015, no. 4, pp. 3–9.

2. Rakhmanov M.I. Avarii energosistem paralizuyut mir [Power System Failures Paralyze the World]. Available at: http://www.Cnews.ru. (Date of Access 01.08.2018)

3. Bogatenkov S.A., Gelrud Ya.D. *Proektirovanie sistemy obespecheniya bezopasnosti professional'noy deyatelnosti v informatsionnom obshchestve: monografiya* [Designing a System for Ensuring the Safety of Professional Activities in the Information Society: Monograph]. South Ural St. Univ. Publ. Center, 2018. 128 p.
4. Tolmachev V.D. [On the Staffing of Modern Energy]. *Energy Security and Energy Conservation*, 2011, no 1, pp. 37–38. (in Russ.)

5. Ivanov T.V., Ivanov S.N., Loginov E.L., Naumov E.B. *Intellectualnaya elektroenergetika: strategicheskiy trend mezhdunarodnoy konkurentosposobnosti Rossii v XXI veke* [Intellectual Electric Power: Strategic Trend of Russia's International Competitiveness in the 21st Century]. Moscow, Sputnik + Publ., 2012, 303 p.

6. Gubanov D., Korgin N., Novikov D., Raikov A. Modern Collective Intelligence. E-Expertise. Series: Studies in Computational Intelligence. *Springer*, 2014, 558 p. DOI: 10.1007/978-3-319-06770-4_1

7. *Gosudarstvennaya programma energosberezheniya i povysheniya energeticheskoy efektivnosti na period do 2020 goda* [State Program of Energy Saving and Energy Efficiency Improvement for the Period until 2020]. Available at: http://www.ceskom.ru/files/normativ/energosafe/energosafeprogram.pdf

8. Bogatenkov S.A. *Modeling of Safety System for Technical Diagnostics of Measuring Channels under Conditions of Information Introduction and Measuring Systems*. 2017 2nd International Ural Conference on Measurements (UralCon), pp. 323–329. DOI: 10.1109/URALCON.2017.8120731

9. Koretskiy A.S., Rincus E.K., Oster-Miller. *Efektivnost ASU teploenergeticheskimi processami* [The Effectiveness of Automated Control Systems of Heat Power Processes]. Moscow, Energoatomizdat Publ., 1984, 316 p.

10. Bogatenkov S.A. [Training of Personnel to Work with Information and Measurement Systems in the Security Aspect]. *Energy Security and Energy Conservation*, 2017, no 1, pp. 34–39. (in Russ.) DOI: 10.18635/2071-2219-2017-1-34-39

11. *Upravlenie initiativami akademicheskogo prevoskhodstva – nastoyashchyi intellektual'nyy vyzov* [Managing the Initiatives of Academic Excellence is a Real Intellectual Challenge]. Available at: http://stop100.ru/news/39143

12. *Sayt firmy OOO NTP “Energokontrol’”* [Site of Company “Energy Control”]. Available at: http://www.energocontrol.ru (Access Date 01/02/2017)

13. Morgunov A.F. [The Introduction of a Distributed Information System in a Multi-branch Organization: the Experience of FSUE Russian Post]. *Business Informatics*, 2014, no. 1, pp. 34–41. (in Russ.)

14. Bogatenkov S.A. [Questions of the Organization of Personnel in the Implementation of Information and Measurement Systems]. *Energy Security and Energy Conservation*, 2017, No 4, pp. 58–60. (in Russ.) DOI: 10.18635/2071-2219-2017-4-58-60

15. Mokeyev V.V., Vorobiev D.A. Analysis of Socio-economic System Processes Performance with the Help of Eigenstate Models. *Bulletin of the South Ural state University. Series: Mathematical modeling and programming*, 2015, vol. 8, no. 1, pp. 66–75. DOI: 10.14529/mmp150105

16. Kolechev K.K., Mezin S.V. [Construction of Mathematical Models of Processes of Heat and Power Equipment on the Basis of Statistical Methods of Approximation]. *Thermal Engineering*, 2015, No 7, pp. 44–51. (in Russ.)

17. Pazderin A.V., Sofin V.V., Samoylenko V.O. [The Mathematical Method of Monitoring the Reliability of the Measurement Data on the Flows of Energy Resources on the Basis of the Theory of Estimation State]. *Thermal Engineering*, 2015, No 11, pp. 26–31. (in Russ.)

18. Bogatenkov S.A., Trubina E.N., Bogatenkov D.S. [Automating the Search for Unacceptable Energy Losses Using Automated Energy Meters]. *Electrical safety*, 1998, no 3–4, pp. 39–44. (in Russ.)

19. Bogatenkov S. A., Malovechko S. N., Kosterin V. V. Secure State Power System Models Building. *2016 2nd International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, pp. 1–5. DOI: 10.1109/ICIEAM.2016.7911642

20. Bogatenkov S.A. [Implementation of Information and Measuring Systems planning of Personal Development Trajectories]. *Energy Security and Energy Conservation*, 2018, no. 1, pp. 39–42. (in Russ.) DOI: 10.18635/2071-2219-2018-1-39-42

21. Gelrud Ya.D., Loginovskiy O.V. *Upravlenie proektami: metody, modeli, sistemy: monografiya* [Project Management: Methods, Models, Systems: Monograph]. South Ural St. Univ. Publ., 2015, 330 p.

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ЭНЕРГОСБЕРЕЖЕНИЕ С ПОМОЩЬЮ ИНФОРМАЦИОНАЛЬНО-ИЗМЕРИТЕЛЬНЫХ СИСТЕМ: МОДЕЛИРОВАНИЕ СИСТЕМЫ БЕЗОПАСНОСТИ

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Введение. В условиях неопределенности и риска актуальной является задача экономии затрат на выработку или потребление энергии в аспекте безопасности. Эффективным инструментом для решения задачи является применение информационно-измерительных систем.

Цель исследования. Построение моделей безопасности для энергосбережения с помощью информационно-измерительных систем на основе системного подхода к учету влияния рисков.

Материалы и методы. Традиционные подходы к решению задач с помощью информационно-измерительных систем не учитывают системного подхода к учету рисков. Предлагаются новые модели и метод на основе системного подхода к учету рисков. Модель состава системы безопасности включает комплекс необходимых энергосберегающих мероприятий. Модель оценки эффективности системы безопасности для энергосберегающих мероприятий учитывает интересы всех участников в процессе внедрения информационно-измерительных систем. Метод создания системы безопасности учитывает взаимосвязи энергосберегающих мероприятий.

Результаты. Разработанные модели и метод создания системы безопасности позволяют свести к минимуму экономические, информационные, психологические, экологические и дидактические риски при выполнении энергосберегающих мероприятий с помощью информационно-измерительных систем.

Заключение. Реализация разработанных моделей и метода создания системы безопасности на Челябинской ТЭЦ-2 обеспечила уменьшение рисков при выполнении энергосберегающих мероприятий с помощью автоматизированной системы комплексного учета энергии.

Ключевые слова: информационно-измерительные системы, энергосбережение, безопасность, автоматизация, моделирование.

Литература
1. Логинов, Е.Л. Сетевые информационные атаки на системы управления энергетическими объектами критической инфраструктуры / Е.Л. Логинов, А.Н. Райков // Телезэнергетика. – 2015. – № 4. – С. 3–9.
2. Рахманов, М.И. Аварии энергосистем парализуют мир. [Электронный ресурс] / М.И. Рахманов. – Режим доступа: http://www.Cnews.ru (дата обращения: 01.08.2018)
3. Богатенков, С.А. Проектирование системы обеспечения безопасности профессиональной деятельности в информационном обществе: моногр. / С.А. Богатенков, Я.Д. Гельруд.– Челябинск: Издат. центр ЮУрГУ, 2018. – 128 с.
4. Толмачев, В.Д. О кадровом обеспечении современной энергетики / В.Д. Толмачев // Энергобезопасность и энергосбережение. – 2011. – № 1. – С. 37–38.
5. Интеллектуальная электроэнергетика: стратегический тренд международной конкурентоспособности России в XXI веке / Т.В. Иванов, С.Н. Иванов, Е.Л. Логинов, Э.Б. Наумов. – М.: Спутник+., 2012.
6. Modern Collective Intelligence / D. Gubanov, N. Korgin, D. Novikov, A. Raikov // E-Expertise. Series: Studies in Computational Intelligence. – Springer, 2014. – V558.
7. Государственная программа энергосбережения и повышения энергетической эффективности на период до 2020 года. [Электронный ресурс]. – Режим доступа: http://www.ceskom.ru/files/normativ/energosafe/energosafe_program.pdf (дата обращения: 01.08.2018)
8. Bogatenkov, S.A. Modeling of safety system for technical diagnostics of measuring channels under conditions of information introduction and measuring systems / S.A. Bogatenkov // 2nd International Ural Conference on Measurements (UralCon). – 2017. – P. 323–329. DOI: 10.1109/URALCON.2017.8120731
9. Эффективность АСУ теплознергетическими процессами / А.С. Корецкий, Э.К. Ринкус, Ю.Р. Остерт-Миллер и др.; под ред. А.С. Корецкого и Э.К. Ринкуса. – М.: Энергоатомиздат, 1984.
10. Богатенков, С.А. Подготовка персонала к работе с информационно-измерительными системами в аспекте энергобезопасности / С.А. Богатенков // Энергобезопасность и энергосбережение. – 2017. – №1. – С. 34–39. DOI: 10.18635/2071-2219-2017-1-34-39
11. Управление инициативами академического превосходства – настоящий интеллектуальный вызов [Электронный ресурс]. – Режим доступа: http://Stop100.ru/news/39143/ (дата обращения: 01.08.2018)
12. Сайт фирмы ООО НТП «Энергоконтроль» [Электронный ресурс]. – Режим доступа: http://www.energocontrol.ru (дата обращения: 01.08.2018)
13. Моргунов, А.Ф. Внедрение распределенной информационной системы в многофилиальной организации: опыт ФГУП «Почта России» / А.Ф. Моргунов // Бизнес-информатика. – 2014. – № 1. – С. 34–41.
14. Богатенков, С.А. Вопросы организации персонала при внедрении информационно-измерительных систем / С.А. Богатенков // Энергобезопасность и энергосбережение. – 2017. – № 4. – С. 58–60. DOI: 10.18635/2071-2219-2017-4-58-60
15. Mokeev V.V., Vorobiev D.A. Analysis of socio-economic system processes performance with the help of eigenstate models. Bulletin of the South Ural State University. Ser. Mathematical modeling and programming, 2015, vol. 8, no. 1, pp. 66–75.
16. Колчев, К.К. Построение математических моделей технологических процессов теплозnergетического оборудования на основе статистических методов аппроксимации / К.К. Колчев, С.В. Мезин // Теплоэнергетика. – 2015. – №7. – С. 44–51.
17. Паздерин А.В. Математический метод контроля достоверности измерительной информации о потоках энергетических ресурсов на основе теории оценивания состояния / А.В. Паздерин, В.В. Софьин, В.О. Самойленко // Теплоэнергетика. – 2015. – №11. – С. 26–31.
18. Богатенков, С.А. Автоматизация поиска недопустимых потерь энергии с помощью автоматизированных средств учета энергии / С.А. Богатенков, Е.Н. Трубина, С.А. Богатенков // Электробезопасность. – 1998. – № 3–4. – С. 39–44.
19. Bogatenkov S.A. Secure state power system models building / S.A. Bogatenkov, S.N. Malovechko, V.V. Kosterin // 2nd International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM), 2016. – Р. 1–5. DOI: 10.1109/ICIEAM.2016.7911642
20. Bogatenkov, S.A. Informatization of Information and Measuring Systems: planning of personnel development / S.A. Bogatenkov // Energy Saving and Energy Conservation. – 2018. – № 1. – С. 39–42. DOI: 10.18635/2071-2219-2018-1-39-42
21. Гельвуд, Я.Д. Управление проектами: методы, модели, системы: моногр. / Я.Д. Гельвуд, О.В. Логиновский. – Издат. центр ЮУрГУ, 2015. – 330 с.

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