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Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН»

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TO THE ISSUE OF EFFICIENCY OF APPLICATION OF THE SAFETY CONTROL PROGRAM AT NUCLEAR FACILITIES

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Abstract. Nuclear power plays a crucial role in the energy supply structure of modern society, offering significant potential to meet increasing energy demands. However, its application comes with stringent safety requirements due to the associated risks of radiation. This paper presents a thorough analysis of safety control programs at nuclear power facilities, considering technological, environmental, and social factors. The study aims to evaluate the effectiveness of current programs and propose recommendations for their optimization. The research involved a detailed examination of existing safety control programs, including both government and corporate initiatives. Based on the findings, a prototype Python-based monitoring program was developed to automate the collection and analysis of data from various sensors, and to promptly notify responsible personnel when deviations from regulatory standards are detected. A comparative analysis of different safety monitoring programs was conducted to highlight their respective advantages and limitations. The study revealed that existing programs frequently face challenges related to inadequate process automation and difficulties in integrating data from various sources. The developed prototype program showcased potential improvements in monitoring and notification mechanisms, as well as enhanced integration with real data. Incorporating modern technologies, such as artificial intelligence and the Internet of Things, can substantially enhance the effectiveness of security control systems by enabling more accurate and rapid monitoring of the state of objects. The main conclusions of the work emphasize the need to refine existing programs, expand the notification system and improve error handling. Practical application of the research results is aimed at improving the safety level of nuclear facilities and developing new monitoring and response systems.

Key words: nuclear power, safety, control programs, monitoring, technological innovations, internet of things

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АТОМ ЭНЕРГИЯСЫН ПАЙДАЛАНУ ОБЪЕКТІЛЕРІНДЕ ҚАУІПСІЗДІКТІ БАҚЫЛАУ БАҒДАРЛАМАСЫН ҚОЛДАНУДЫҢ ТИІМДІЛІГІ МӘСЕЛЕСІНЕ

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Аннотация. Атом энергетикасы қазіргі қоғамның энергиямен жабдықтау құрылымының маңызды құрамдас бөлігі болып табылады, өсіп келе жатқан энергия қажеттіліктерін қанағаттандыру үшін айтарлықтай мүмкіндіктер береді. Алайда, оны пайдалану қауіпсіздіктің жоғары талаптарына байланысты, бұл радиациялық қауіптердің әлеуетіне байланысты. Бұл жұмыста технологиялық, экологиялық және әлеуметтік аспектілерді ескере отырып, атом энергиясын пайдалану объектілеріндегі қауіпсіздікті бақылау бағдарламаларына жан-жақты талдау жүргізіледі. Зерттеудің мақсаты - қолданыстағы бағдарламалардың тиімділігін бағалау және оларды оңтайландыру бойынша ұсыныстар әзірлеу. Зерттеу барысында мемлекеттік және корпоративтік бастамаларды қоса алғанда, қауіпсіздікті бақылаудың ағымдағы бағдарламаларына егжей-тегжейлі талдау жүргізілді. Алынған мәліметтер негізінде Python тіліндегі мониторинг бағдарламасының прототипі жасалды, ол әртүрлі Сенсорлардан деректерді автоматты түрде жинауға және талдауға, сондай-ақ нормативтік көрсеткіштерден ауытқулар анықталған жағдайда жауапты адамдарға жедел хабарлауға арналған. Қауіпсіздікті бақылаудың әртүрлі бағдарламаларын салыстырмалы талдау олардың артықшылықтары мен кемшіліктерін анықтады. Зерттеу нәтижелері қолданыстағы бағдарламалар көбінесе процестерді автоматтандырудың жеткіліксіздігінен және әртүрлі көздерден деректерді біріктірудің қиындықтарынан зардап шегетінін көрсетті. Бағдарламаның прототипі мониторинг пен хабарландыру механизмдерін жақсарту, сондай-ақ нақты деректермен интеграциялау мүмкіндіктерін көрсетті. Жасанды интеллект және Заттар интернеті сияқты заманауи технологияларды енгізу объектілердің жай-күйін дәлірек және жедел бақылауды қамтамасыз ете отырып, қауіпсіздікті бақылау жүйелерінің тиімділігін едәуір арттыра алады. Жұмыстың негізгі қорытындылары қолданыстағы бағдарламаларды нақтылау, хабарландыру жүйесін кеңейту және қателерді өңдеуді жақсарту қажеттілігін көрсетеді. Зерттеу нәтижелерін практикалық қолдану атом объектілерінің қауіпсіздік деңгейін арттыруға және мониторинг пен жауап берудің жаңа жүйелерін жасауға бағытталған..

Түйін сөздер: атом энергетикасы, қауіпсіздік, бақылау бағдарламалары, мониторинг, технологиялық инновациялар, заттар Интернеті

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К ВОПРОСУ ЭФФЕКТИВНОСТИ ПРИМЕНЕНИЯ ПРОГРАММЫ КОНТРОЛЯ БЕЗОПАСНОСТИ НА ОБЪЕКТАХ ИСПОЛЬЗОВАНИЯ АТОМНОЙ ЭНЕРГИИ

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Аннотация. Атомная энергетика является важным компонентом в структуре энергоснабжения современного общества, предоставляя значительные возможности для удовлетворения растущих потребностей в энергии. Однако её использование связано с высокими требованиями к безопасности, что обусловлено потенциалом серьезных радиационных рисков. В данной работе проводится всесторонний анализ программ контроля безопасности на объектах использования атомной энергии с учетом технологических, экологических и социальных аспектов. Цель исследования заключается в оценке эффективности существующих программ и разработке рекомендаций по их оптимизации. В ходе исследования был проведен детальный анализ текущих программ контроля безопасности, включая государственные и корпоративные инициативы. На основе полученных данных был создан прототип программы мониторинга на языке Python, предназначенный для автоматического сбора и анализа данных с различных сенсоров, а также для оперативного уведомления ответственных лиц в случае выявления отклонений от нормативных показателей. Сравнительный анализ различных программ контроля безопасности позволил выявить их преимущества и недостатки. Результаты исследования показали, что существующие программы часто страдают от недостаточной автоматизации процессов и сложностей интеграции данных из различных источников. Созданный прототип программы продемонстрировал возможности для улучшения механизмов мониторинга и уведомления, а также для интеграции с реальными данными. Внедрение современных технологий, таких как искусственный интеллект и Интернет вещей, может существенно повысить эффективность систем контроля безопасности, обеспечивая более точный и оперативный мониторинг состояния объектов. Основные выводы работы подчеркивают необходимость доработки существующих программ, расширения системы уведомлений и улучшения обработки ошибок. Практическое применение результатов исследования направлено на повышение уровня безопасности атомных объектов и разработку новых систем мониторинга и реагирования.

Ключевые слова: атомная энергетика, безопасность, программы контроля, мониторинг, технологические инновации, Интернет вещей

Introduction

Modern society, in an effort to meet its energy needs, is inevitably faced with a growing dependence on nuclear power. This energy source has significant potential due to its efficiency and environmental advantages over traditional energy sources. However, the use of nuclear energy is associated with high safety requirements, making the development and effective application of safety control programs at nuclear energy facilities an urgent task for the scientific and engineering community (Wang et al., 2020: 2728–2736; Yuan et al., 2018: 1075–1083; Kim et al., 2020: 3262). Nuclear facilities, such as nuclear reactors, are intricate technological systems that demand a systematic and integrated approach to ensure their safety. Managing issues related to nuclear material handling and radiation risk requires ongoing monitoring, analysis, and enhancement of safety systems. Effective safety control programs are essential not only for minimizing potential threats and risks but also for supporting the long-term sustainability and development of nuclear power as a vital element of the global energy balance.

The objective of this paper is to conduct a thorough analysis and evaluation of the effectiveness of safety control programs at nuclear power facilities, considering technological, environmental, and social aspects. The study identifies problematic aspects of existing programs and offers specific recommendations for their optimization. Special attention is paid to identifying potential vulnerabilities and developing innovative approaches to improve the effectiveness of safety systems (Lee et al., 2018; Mishra et al., 2019: 3825–3841; Hossain et al., 2020: 616–653; Sethu et al., 2022: 1–19).

Materials and basic methods

The following materials and methods were used to achieve the objective of the study:

Materials:

1 Data on the radiation background across the territory of the Russian Federation is collected by the automated radiation situation control system of the Rosatom State Corporation. This system provides real-time monitoring and assessment of radiation levels, facilitating the management and response to radiation-related issues. The data collected is crucial for ensuring safety and compliance with radiation protection standards;

2 Publications and reports on safety control programs developed by various research groups and companies;

3 Safety control programs for nuclear plants, including the latest developments in digital technologies.

Methods:

1 Literature review: A study of scientific publications, reports and regulatory documents dealing with safety control programs at nuclear facilities. This method provided insight into the current status and problems in the field;

As complex technological systems, nuclear power plants represent a significant source of risk, particularly the specific risk of radiation exposure. Obtaining quantitative estimates of radiation risk is crucial for implementing measures to reduce risk and prevent accident consequences. To systematize and centralize data on risk assessments of nuclear power plants, it is necessary to develop a program for the management and control of safety response systems at nuclear power facilities (Berberova et al., 2020: 50–56; Lu et al., 2020; Arutyunyan. 2013. 315). The authors Vorotilina A.A. and Koptelov M.V. examined the current state of the organization of the state automated system of radiation situation control in the Russian Federation (Vorotilina et al., 2018: 156–162). They provided a screenshot of the map showing the radiation situation across Russia, based on sensor readings from the automated radiation situation control system of the State Corporation «Rosatom».

M.A. Berberova, V.V. Chuenko, O.V. Zolotareva, O.L. Trefilova, M.A. Grudeva, V.V. Anichkina, E.V. Razina have developed a program of safety control of nuclear power plants using modern technologies that allow to systematize and group data from safety data sheets of nuclear power plants, as well as to organize operational access to information. The program developed by the authors is a Web application designed to systematize and group safety data sheets of nuclear power plants, as well as to organize quick access to the information, which makes it easy to assess the safety status of each of the nuclear power plants considered in this paper (Panteleev et al., 2018: 40–52).

The authors Panteleeva V.A., Popova E.V.V., Segal M.D., Gavrilova S.L., Sednev V.A. and Lysenko I.A. reviewed the goals, objectives, and general solutions of territorial automated systems for monitoring the radiation situation in the Russian Federation to ensure safety monitoring at nuclear power facilities (Panteleev et al., 2018: 48–61).

In the last decade, territorial radiation monitoring and emergency response systems have been established and actively developed in several constituent entities of the Russian Federation. These systems include complex monitoring systems for population protection (CPM-PP), which have been implemented in radioactively contaminated territories (Berberova et al., 2019: 285–289; Guseva et al., 2018: 251–254; Andreev, 2020: 43–51; Otchyot ob OKR po GK № 331/1059-999, 2015: 44; Panshin et al., 2016: 22; Guseva et al., 2018: 1–5; Andreev et al., 2020: 43–51.

Figure 1 presents the general composition of integrated monitoring systems for the state of public protection (Panteleev et al., 2018: 48–61).

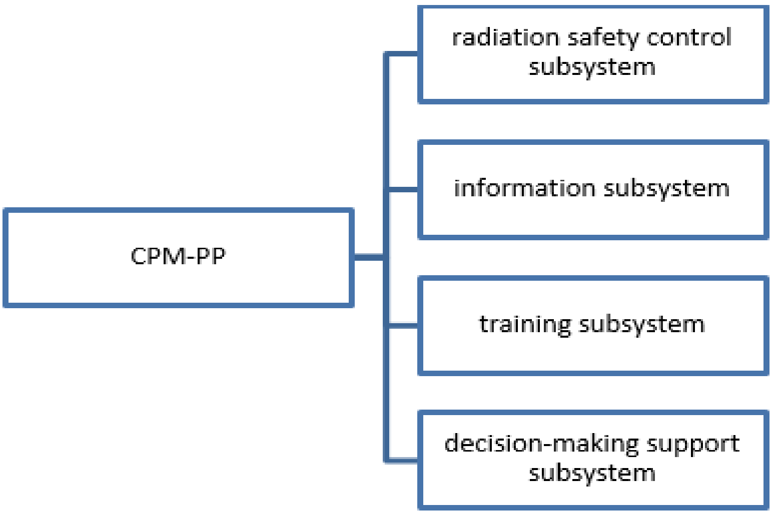

Figure 1. Composition of integrated monitoring systems for the protection of the population (Panteleev et al., 2018: 40–52).

These components work together to provide a robust framework for monitoring, managing, and responding to radiation risks, thereby ensuring the safety and protection of the population.

The subsystem for radiation situation control is a critical component of the regional integrated system for monitoring population protection. Its primary objective is the early detection of changes in radiation levels at measurement sites across the Russian Federation.

This subsystem is designed to achieve the following tasks:

- Continuous Automated Monitoring: Conduct ongoing automated surveillance of the radiation situation, including measuring meteorological parameters;
- Data Processing and Storage: Process, store, and provide operational data on radiation levels in contaminated areas to relevant authorities using GIS technologies;
- Automated Alert System: Automatically signal if monitored radiation parameters exceed established normative levels, triggering alarms or emergency notifications.

The integrated monitoring system for population protection incorporates both stationary and mobile means for radiation situation control.

Stationary facilities include:

- Information Collection and Processing Center: A facility for collecting, processing, transmitting, and storing data on radiation situation;
- Communication Channels: Infrastructure for transmitting data between monitoring stations and central processing centers;
- Stationary Radiation Monitoring Posts: Fixed locations equipped with sensors for continuous radiation monitoring.

Mobile radiation monitoring facilities include:

- Mobile Radiometric Laboratories: Portable units equipped for radiometric analysis;
- Mobile Onboard Gamma Imaging Complexes: Systems based on unmanned aerial vehicles (drones) for gamma imaging and radiation assessment;
- Rapidly Deployable Automated Radiation Monitoring Systems: Mobile systems that can be quickly set up to monitor radiation levels in different locations.

The authors have developed a project focused on creating models, algorithms, and a software package designed to enhance safety measures in the design of new and existing nuclear power plants. The authors presented the structure of the database on the reliability of nuclear power plant equipment (Figure 2).

UNSKE annunciator module solid state general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: operates spourious or false response
FAILURE RATE OR PROBABILITY rec : 1.7E-6/hr
Source: IEEE 500 (1984) pg.40 Ultimate source: operating experience
Comment: Reference : NUREG 2232 (1980)
BTABN battery
Component boundary: battery,container,terminal connections incl.lst breaker connect. Operating mode: all Operating environment: normal
Generic failure mode: degraded Original failure mode: inadequate output
FAILURE RATE OR PROBABILITY rec : 3.2E-6/hr high: 7.5E-6/hr low: 4.9E-7/hr REPAIR TIME: 4-7 hours
Source: NUREG 3831 (1985) (tbl.A6) Ultimate source: operating experience (plant records)
Comment: Operating experience:total pop. 51.Operational time 1.564.315 hrs No.of failures 5.
Repair time is range of medians.
BTAFN battery
Component boundary: battery,container,terminal connections incl.lst breaker connect. Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output
FAILURE RATE OR PROBABILITY rec : 6.4E-7/hr high: 3.0E-6/hr low: 3.0E-8/hr REPAIR TIME: 4-7 hours
Source: NUREG 3831 (1985) (tbl.A6) Ultimate source: operating experience (plant records)
Comment: Operating experience: total pop. 51.Operating time 1.564.315hours No of failures 1. High and low chi-square estimates.
Repair times range of median
BTAFO battery
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: operational failure
FAILURE RATE OR PROBABILITY mean : 8.2E-8/hr 95%: 2.5E-7/hr 5%: 8.E-10/hr REPAIR TIME: 11.2 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500(1977)(pg104),rec=median; max=80% of distribution. Operating experience: 96.426 hours of operation, no failures.
Repair time is mean of updated component maintenance duration.
BTAFT battery
Component boundary: battery only Operating mode: standby Operating environment: normal
Generic failure mode: fail to function Original failure mode: failed effective output
FAILURE RATE OR PROBABILITY mean : 1.3E-2/d 95%: 6.8E-2/d REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.41 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Demand failure rate is based on refueling outage testing interval Operating experience: Total pop.129.No of demands 531.Number of
failures 7. a=0.0346; b=2.59

Figure 2. Structure of the equipment reliability database proposed by the authors (Panteleev et al., 2018: 48–61).

The presented structure of the nuclear power plant equipment reliability database contains the following information:

- equipment category code;
- type of component
- mode of operation;
- type of failure
- failure probability
- recovery time;
- source of information;
- comments.

2 Modeling and software development: Creation of a prototype of a safety control and monitoring program using the Python programming language. The program was designed to incorporate current technology and real-world data integration capabilities.

Development of a program for safety control and monitoring at nuclear power facilities requires a serious approach and attention to detail. Below is an example of a simple program concept in Python, one of the popular programming languages, presented in Figure 3.

```python
python                                                    Copy code

import time
import random

class NuclearSecurityMonitor:
    def __init__(self):
        self.sensors = {
            "radiation": {"threshold": 50.0, "status": "OK"},
            "temperature": {"threshold": 100.0, "status": "OK"},
            "pressure": {"threshold": 200.0, "status": "OK"}
        }
        self.emergency_contacts = ["emergency_email@example.com", "emer

    def monitor_sensors(self):
        while True:
            for sensor, data in self.sensors.items():
                reading = self.get_sensor_reading(sensor)
                if reading > data["threshold"]:
                    data["status"] = "ALERT"
                    self.handle_alert(sensor, reading)
                else:
                    data["status"] = "OK"
            time.sleep(60)  # Проверка каждую минуту

    def get_sensor_reading(self, sensor):
        # Здесь можно использовать реальные данные с датчиков или их моделир
        return random.uniform(0, 300)

    def handle_alert(self, sensor, reading):
        # Здесь реализовать логику обработки сигнала тревоги,
        # например, отправка уведомления на контакты в случае превышения пор
        alert_message = f"ALERT: {sensor} reading exceeded threshold. C
        self.notify_emergency_contacts(alert_message)

    def notify_emergency_contacts(self, message):
        # Здесь реализовать отправку уведомления на заранее заданные контакт
        print(f"Notifying emergency contacts: {message}")

if __name__ == "__main__":
    security_monitor = NuclearSecurityMonitor()
    security_monitor.monitor_sensors()
```

*Figure 3.*View of the program.

Let's analyze the proposed program of safety control and monitoring at nuclear power facilities:

Nuclear Security Monitor class definition:

- The class is created to describe a security monitoring object;
- Has a sensors attribute representing different types of sensors (e.g. radiation, temperature, pressure) with their threshold values and current status;
- Contains a contact list for emergency notifications.

Method monitor_sensors:

- An infinite loop to monitor the status of sensors;
- For each sensor, the current value is checked against a threshold;
- If the threshold is exceeded, the handle_alert method is called.

Get_sensor_reading method:

- A method that simulates getting data from sensors;
- In this case, random data generation is used.

Method handle_alert:

- Called when the sensor value exceeds a threshold;
- An alarm message is generated;
- The notify_emergency_contacts method is called to notify contacts.

The notify_emergency_contacts method:

- Simulates sending a notification to predefined contacts.

Main code block:

- An instance of the NuclearSecurityMonitor class is created;
- The monitor_sensors method is called and infinite monitoring starts.

Analysis:

- The program offers a basic framework for sensor monitoring, yet it currently relies on random data generation rather than real sensor readings;
- The notify_emergency_contacts method only prints a message to the console. In a practical system, a proper notification mechanism should be implemented;
- There is a lack of additional security measures, such as data encryption or authentication;
- The program fails to consider security standards and nuclear facility security requirements, and it does not include event auditing features;
- No error handling, which can lead to unpredictable behavior in a real-world environment;
- This code is a basic example and should be significantly extended and improved to meet real-world nuclear safety requirements and standards. Also, for such critical systems, a more in-depth safety analysis should be performed and possibly safety experts should be involved.

Optimizing existing safety programs and proposing innovative approaches requires in-depth analysis and understanding of specific requirements, standards and unique system features. In this context, let us offer some general recommendations and ideas for improving the effectiveness of the safety system at nuclear power facilities:

Optimization Recommendations:

Integration with Real Data:

- Replace simulated data with real sensor readings for more accurate monitoring.

Improve Notifications:

- Expand the notification mechanism to include different communication channels (email, SMS, emergency calls) and the ability to automatically generate reports.

Logging Implementation:

- Add a logging system for event recording and debugging. This can be useful for later analysis and auditing.

Error Handling:

- Implement error handling to prevent unpredictable program behavior in case of crashes or incorrect data.

Recommendations for improving security:

Data Encryption:

- Implement data encryption mechanisms to protect the confidentiality and integrity of information.

Authentication and Authorization:

- Implement an authentication and authorization system to ensure that only authorized users have access.

Physical Security:

- Consider physical security measures to protect equipment from unauthorized access.

Innovative Approaches:

Use of Artificial Intelligence (AI):

- Integrate machine learning to predict and detect anomalies in data to prevent incidents.

Integration with the Internet of Things (IoT):

- Connect sensors to the IoT network for more extensive monitoring and real-time data collection.

Blockchain Technologies for Auditing:

- Consider the use of blockchain technology to provide transparency and immutability of audit data.

Cyber-Physical Systems:

- Develop cyber-physical systems that combine physical processes and information technology to better manage security.

Staff Training:

Provide staff training on safety and response to different scenarios.

Each of these suggestions requires additional work and adaptation to the specific context and requirements of nuclear power facilities. It is important to involve safety experts and follow all applicable regulations and standards.

3 Benchmarking: Evaluating the effectiveness of various security monitoring programs based on their capabilities, accuracy and responsiveness. Both real data and simulation results were used for this purpose.

Results

The following results were obtained during the study:

1 Analysis of the current state of safety control programs:

- Modern systems for monitoring the radiation situation in Russia, particularly those managed by the automated control system of Rosatom State Corporation, provide high accuracy and promptness in data collection and reporting;

- There are notable problems with the integration of data from various sources. This lack of seamless integration can hinder the overall effectiveness of safety control programs.

2 Development of a prototype of a safety monitoring program:

- A prototype Python program was developed to monitor sensor status and notify emergency services. The program includes functionality for monitoring radiation, temperature, and other sensors, as well as for automatic notification if thresholds are exceeded;

- The prototype demonstrates the potential for integration with real data and improved notification mechanisms to significantly improve the efficiency of safety monitoring systems.

3 Program benchmarking:

- Programs using modern technologies such as IoT (Internet of Things) and Artificial Intelligence (AI) show higher accuracy and responsiveness compared to traditional methods. This confirms the need to incorporate the latest technologies into safety monitoring systems of nuclear facilities;

- Integration with real data and improved notification mechanisms significantly increase the efficiency of safety monitoring systems. This makes it possible to respond promptly to changes in radiation background and other potential threats.

Observation

Comparison of the results obtained with the work of other scientists has shown that the introduction of modern technologies, such as artificial intelligence and the Internet of

Things, can significantly improve the efficiency of security control systems. The main advantages of the proposed program include high accuracy and responsiveness, the ability to integrate with various data sources, and automation of notification processes.

Despite the promising potential of the proposed safety monitoring program, several shortcomings need to be addressed:

1 Need for Further Refinement:

- Meeting Safety Requirements: The program requires additional refinements to fully comply with all safety requirements and nuclear power standards.
- Sophisticated Data Processing and Cybersecurity: More advanced data processing mechanisms and enhanced cybersecurity measures are necessary to ensure the program's effectiveness and security.

2 Error and Exception Handling:

- Robust Mechanisms: The current program lacks comprehensive error and exception handling, which could result in unpredictable behavior in real-world environments.
- System Resilience: Developing more robust error handling mechanisms is crucial to improving the system's resilience and reliability.

3 Notification System:

- Expansion and Improvement: While the program includes a mechanism for notifying emergency services, this feature requires further expansion and improvement.
- Multiple Communication Channels: In a real-world scenario, different communication channels such as email, SMS, and emergency calls should be utilized.
- Automatic Reporting: The possibility of automatic reporting should be incorporated to ensure timely and efficient communication during emergencies.

To address these shortcomings, the following steps should be taken:

- Refinement of Safety Compliance: Continue refining the program to meet all nuclear power safety requirements and standards. This includes integrating more sophisticated data processing and cybersecurity measures.
- Enhanced Error Handling: Develop and implement more robust error and exception handling mechanisms to ensure system stability and resilience.
- Advanced Notification System: Expand and enhance the notification system to include multiple communication channels and automatic reporting capabilities for effective emergency response.

By addressing these areas, the proposed safety monitoring program can be significantly improved, ensuring greater reliability and compliance with stringent nuclear power safety standards.

Conclusion

The research findings highlight several key conclusions and recommendations for enhancing safety monitoring programs at nuclear power facilities:

- Continuous Improvement and Integration: Modern safety monitoring programs need ongoing advancements and the integration of new technologies to enhance their effectiveness;
- Artificial Intelligence (AI) and Internet of Things (IoT): The implementation of AI and IoT technologies can substantially improve the accuracy and efficiency of monitoring nuclear facility conditions;
- Compliance and Data Protection: Developed programs must comply with all safety standards and requirements, ensuring robust data protection and an efficient notification

system;

- Regular Updates and Training: It is crucial to regularly update and test software, as well as to train personnel in safety and emergency response protocols.

The practical application of these conclusions and recommendations involves:

- Integration into Existing Systems: Incorporating the proposed programs and recommendations into current safety control systems at nuclear plants;

- Development of New Systems: Creating new monitoring and response systems leveraging advanced technologies.

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