Analysis of Accidents and Incidents What Happened at Nuclear Power Plants in Russia from 1992 to 2019

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Abstract. The article discusses emergencies that occurred at nuclear power plants in the Russian Federation for the period from 1992 to 2019. In the work, a systematic and statistical analysis was carried out, the number of emergency events was counted, the nuclear power plants at which accidents and incidents occurred, the year of occurrence of the emergency event was indicated, the main objects, the causes of emergencies were identified, the types of reactors at which accidents often occurred were identified, conclusions are drawn.

1. Introduction

The nuclear power industry of the Russian Federation ranks second among European countries in terms of nuclear power generation capacity. Today, 10 nuclear power plants (NPP) are actively operating in Russia, 38 power units are in commercial operation, with a total capacity of 31 GW, which generate about 15% of all electricity produced in the country. Despite the fact that the generation of electricity at nuclear power plants is considered an environmentally friendly way, the consequences of failures are felt all over the world [1-17].

Various emergencies are possible at NPP: accidents and incidents. Accident - destruction of structures or technical devices used at a hazardous production facility, uncontrolled explosion or release of hazardous substances. Incident - failure or damage to technical devices used at a hazardous production facility, deviation from the established mode of the technological process [18].

2. The applied methods

The work considers and analyzes the emergencies that occurred at nuclear power plants in Russia from 1992 to 2019, and carried out a systematic and statistical analysis. The materials were taken from sources [1,17, 20]. When analyzing statistical data, the following programs were used: Microsoft Excel, Microsoft Word. To carry out a systematic and statistical analysis, the main factors were identified: the number of accidents and incidents; year of origin; the name of nuclear power plants in which accidents and incidents occurred: Beloyarsk NPP, Balakovskaya NPP, Leningrad NPP, Novovoronezh NPP, Kursk NPP, Kalinin NPP; the main objects of occurrence of emergency events: transformers and cable ducts, control systems and automation failures, steam generators and steam pipe systems, pumps and pumping systems, sensors and mechanisms of the pressure system, a technological channel; causes of emergencies: technical malfunctions, short circuits, personnel fault, automation failure and unknown reasons; types (name) of reactors: BN, RBMK, VVER. Earlier, an
analysis of emergencies that occurred at nuclear power plants from 1952-1972 in the world was carried out [19].

In Russia, over the period from 1992 to 2019, fourteen emergencies at nuclear power plants were registered, of which one was an accident and thirteen incidents (Table 1). One accident happened on March 24, 1992 at the Leningrad nuclear power plant. Due to erroneous actions of the personnel, a depressurization of the technological channel of the RBMK reactor occurred, which led to an emergency shutdown of the reactor and the release of radioactivity into the atmosphere [1, 17]. The first incident occurred on December 22, 1992 at the Beloyarsk NPP. When pumping radioactive waste, due to the negligence of the plant personnel, the pump maintenance room was flooded with radioactive waste at Unit 3 of the fast neutron reactor (BN). The consequences of the incident are the release of radioactivity into the atmosphere [1, 20]. The second happened on May 20, 2004 at the Leningrad NPP. Due to the unauthorized pressing of the station personnel on the emergency button in the operating room, an emergency shutdown of the fourth power unit of the RBMK reactor occurred. The third one took place on November 4, 2004 at the Balakavo NPP. This incident was associated with a malfunction in the steam pipeline system at Unit 2, which led to an emergency shutdown of the 2nd power unit of the VVER reactor. The fourth appeared on February 10, 2008 at the Kursk NPP. Due to a technical malfunction, a fire occurred on the brush-contact apparatus of the generator No. 1 of the RBMK reactor. The consequences of the incident are large fire [1]. The fifth happened on February 12, 2008 at the Leningrad NPP. Due to the ingress of water into the stator winding of the electric motor, a short circuit and an emergency decrease in power occurred at power unit No. 4 of the RBMK reactor, where an alarm was triggered. The sixth incident took place on February 18, 2008 at the Novovoronezh NPP. A short circuit occurred here due to the ingress of water on the sensors of the control and measuring equipment, which led to an emergency decrease in power at Unit 4 of the VVER reactor. The seventh occurred on September 19, 2008 at the Balakovo NPP. Due to a technical malfunction of the generator shaft sealing system and lowering the level in the damper oil tank, power unit No. 2 of the VVER reactor was shut down. The eighth was on November 12, 2008 at the Balakovo NPP. Also, due to a technical malfunction of the main circulation pump, unit No. 2 of the VVER reactor was shut down [1]. The ninth appeared on August 31, 2008 at the Balakovo NPP. During operation, an emergency shutdown occurred, which was associated with a malfunction of the control system at Unit 2 of the VVER reactor. The tenth happened on November 12, 2008 at the Novovoronezh NPP. This incident was associated with a malfunction of the emergency protection system of power unit No. 4 of the VVER-type reactor. The eleventh took place on December 18, 2015 at the Leningrad NPP. During operation, due to a technical malfunction in the low-pressure steam line, a breakthrough occurred with the release of steam at the deaerator unit of the 2nd power unit of the RBMK reactor. Consequences - shutdown of the reactor [1]. The twelfth happened on February 18, 2018 at the Kursk NPP. For unknown reasons, a transformer for the station's own needs caught fire, which led to the shutdown of the fourth power unit of the RBMK reactor. The thirteenth incident occurred on July 18, 2019 at the Kalinin nuclear power plant. Due to a short circuit, power unit No. 4 of the VVER reactor was shut down. The consequences of the incident are the ignition of the transformer for the station's own needs [1].

Table 1. Accident events in Russia for the period from 1992 to 2019.

| №  | Date           | Name of NPP          | Emergency event | Reason                  | Type of reactor |
|----|----------------|----------------------|-----------------|-------------------------|-----------------|
| 1  | March 24, 1992 | Beloyarsk NPP        | Accident        | Staff fault             | RBMK            |
| 2  | December 22, 1992 | Beloyarsk NPP    | Incident       | Staff fault             | BN              |
| 3  | May 20, 2004   | Leningrad NPP       | Incident        | Staff fault             | RBMK            |
| 4  | November 4, 2004 | Balakovo NPP  | Incident        | Technical malfunction   | VVER            |
| 5  | February 10, 2008 | Kursk NPP        | Incident        | Technical malfunction   | RBMK            |
| 6  | February 12, 2008 | Leningrad NPP    | Incident        | Short circuit           | RBMK            |
| 7  | February 18, 2008 | Novovoronezh NPP | Incident        | Short circuit           | VVER            |
3. Results and discussions

For the period from 1992 to 2019, 13 incidents and 1 accident. The largest number of incidents was recorded at the Balakovo NPP - 29%: in 2004, 2008, 2008, 2008; at the Leningrad NPP - 22%: 2004, 2008, 2015; at the Kursk NPP - 14%: 2008, 2018; at Novovoronezh NPP - 14%: in 2008, 2008 and at Beloyarsk NPP - 14% in 1992 there was one incident and one accident; at the Kalinin NPP - 7%, this incident happened in 2019. (Table 2).

| № | Name of NPP       | Number of emergency situations | Percentage ratio |
|---|------------------|--------------------------------|------------------|
| 1 | Balakovo NPP     | 4                              | 29%              |
| 2 | Leningrad NPP    | 3                              | 22%              |
| 3 | Kursk NPP        | 2                              | 14%              |
| 4 | Novovoronezh NPP | 2                              | 14%              |
| 5 | Beloyarsk NPP    | 2                              | 14%              |
| 6 | Kalinin NPP      | 1                              | 7%               |

Emergency situations most often occurred in transformers and cable ducts: 4 times at the Leningrad NPP in 2008, at the Kursk NPP in 2008, 2018 and at the Kalinin NPP in 2019; in control systems and automation failures: 3 times at the Leningrad NPP in 2004, at the Balakovo NPP in 2008 and at the Novovoronezh NPP in 2008; in steam generators and steam pipeline systems: 2 times at Balakovo NPP in 2004, at Leningrad NPP in 2015; in pumps and pumping systems: 2 times at the Beloyarsk NPP in 1992, at the Balakovo NPP in 2008; in sensors and mechanisms of the pressure system: 2 times at the Novovoronezh NPP in 2008, at the Balakovo NPP in 2008; in the technological channel: once at the Leningrad NPP in 1992 (Table 3).

| №  | Objects of occurrence                      | Number of emergency situations | Percentage ratio |
|----|-------------------------------------------|--------------------------------|------------------|
| 1  | Transformers and cable ducts               | 4                              | 29%              |
| 2  | Control systems and automation failures    | 3                              | 22%              |
| 3  | Steam generators and steam piping systems  | 2                              | 14%              |
| 4  | Pumps and pumping systems                  | 2                              | 14%              |
| 5  | Sensors and mechanisms pressure systems    | 2                              | 14%              |
| 6  | Technological channel                      | 1                              | 7%               |

During this period, emergency events most often occurred due to technical malfunctions. The number of accidents that occurred due to technical failures – 35%, due to short circuits-22%, due to the fault of personnel-22%, due to automation failures-14% and for unknown reasons-7% (Table 4).
Table 4. Main causes of emergency events at NPP in Russia.

| №   | Objects of occurrence | Number of emergency situations | Percentage ratio |
|-----|-----------------------|-------------------------------|------------------|
| 1   | Technical faults      | 5                             | 35%              |
| 2   | Short circuit         | 3                             | 22%              |
| 3   | Personnel fault       | 3                             | 22%              |
| 4   | Automation failures   | 2                             | 14%              |
| 5   | Unknown reasons       | 1                             | 7%               |

The largest number of emergency situations was registered at «VVER» – 7, «RBMK» – 6, «BN» – 1 reactors (Table 5).

Table 5. Number of emergency events at various reactors.

| №   | Type of reactor | Number of emergency situations | Percentage ratio |
|-----|-----------------|-------------------------------|------------------|
| 1   | VVER            | 7                             | 49%              |
| 2   | RBMK            | 6                             | 44%              |
| 3   | BN              | 1                             | 7%               |

After analyzing the emergency situations at nuclear power plants in Russia from 1992-2019, we come to the conclusion that the largest number of emergency events occurred at the Balakovo and Leningrad nuclear power plants (51% of all accidents). The objects of emergency situations were transformers and cable channels, control systems and automation failures (51% of all accidents). The main reasons for the occurrence of emergency events were technical failures (35% of all accidents). The largest number of accidents occurred at VVER-type reactors (49% of all accidents). To ensure the safe operation of the NPP, it is necessary to take into account all the factors that contribute to the occurrence of an emergency situation from the design stage to the stage of decommissioning of the plant [21-25].

4. References
[1] State Atomic Energy Corporation "Rosatom": official website Access mode: http://www.rosatom.ru/
[2] U.S. Nuclear Regulatory Commission RG 1.174 An approach for using probabilistic risk assessment in risk-informed decisions on plant-specific changes to the licensing basis Revision 2 2011 p 16
[3] Mikeev A K 1990 Fire protection of the NPP Moscow energoatomizdat p 432
[4] ASME/ANS RA-Sa-2009 Addenda to ASME/ANS RA-S-2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Ap-plications p 352
[5] http://rb.mchs.gov.ru/folder/8961
[6] U.S. AEC "Theoretical Possibilities and Consequences of Major Accident in Large Nuclear Power Plants" U.S. Atomic Energy Commission WASH-740 1957
[7] U.S. Nuclear Regulatory Commission Fault Tree Handbook (NUREG 0492) 1981 p 209
[8] U.S. Nuclear Regulatory Commission Guidance on the Treatment of Uncertainties Associated with PRA's in Risk-Informed Decision Making (NUREG-1855) Draft Report for Comment 2007 p 113
[9] U.S. Nuclear Regulatory Commission PRA Procedures Guide (NUREG/CR 2300) Vol 1 1983 p 487
[10] U.S. Nuclear Regulatory Commission PRA Procedures Guide (NUREG/CR 2300) Vol 2 1983 p 181
[11] U.S. Nuclear Regulatory Commission Reactor Safety Study *An Assessment of Accident Risk in Commercial Nuclear Power Plants* WASH-1400 (NUREG-75/014) Main report 1975 p 226

[12] U.S. Nuclear Regulatory Commission Reactor Safety Study *An Assessment of Accident Risk in Commercial Nuclear Power Plants* WASH-1400 (NUREG-75/014) Appendix III Failure data 1975 p 104

[13] U.S. Nuclear Regulatory Commission Reactor Safety Study *An Assessment of Accident Risk in Commercial Nuclear Power Plants* WASH-1400 (NUREG-75/014) Appendix V Quantitative results of accident sequences 1975 p 142

[14] U.S. Nuclear Regulatory Commission Reactor Safety Study *An Assessment of Accident Risk in Commercial Nuclear Power Plants* WASH-1400 (NUREG-75/014) Appendix VI Calculation of reactor accident consequences 1975 p 500

[15] U.S. Nuclear Regulatory Commission Reactor Safety Study *An Assessment of Accident Risk in Commercial Nuclear Power Plants* WASH-1400 (NUREG-75/014) Appendix VII Release of radioactivity in reactor accidents 1975 p 292

[16] *Safety of nuclear power plants* Design IAEA Vein 2016 p 116

[17] *Safety of nuclear power plants* Commissioning and operation IAEA Vein 2017 p 88

[18] http://enis.gosnadzor.ru/activity/control/116-Ф3.pdf

[19] Barbin N M, Titov S A, Kobelev A M 2021 Accidents that Occurred at Nuclear Power Plants in 1952-1972 *IOP Conf. Series: Earth and Environmental Science* 666 (2021) 022018 doi:10.1088/1755-1315/666/2/022018

[20] Strategy for the development of nuclear energy in Russia in the first half of the XXI century Ministry of the Russian Federation for Nuclear Energy. Moscow 2001 p 20-28

[21] Kalin B A, Polish V I, Yakushin V L, Chernov I I 2010 Materials research environmental problems in the field of nuclear power: Manual M.: NIYaU MEPhI p 99

[22] Lessons of response to radiation emergencies (1945-2010) of IAEA VIENNA January 2013 p 99

[23] Prister B S, Klyuchnikov A A, Baryakhtar V G, Shestopalov V M, Kukhar 2016 Security of nuclear power *Lessons of Chernobyl: monograph under the editorship of the academician of NAAN of Ukraine B.S. Prister the 2nd prod. additional NAN of Ukraine Ying t of security of the NPP Chernobyl (Kiev. Region): Ying t of security of the NPP* p 24

[24] Solovev D B, Merkusheva A E 2017 Increase in Efficiency of Use of Pedestrian Radiation Portal Monitors *IOP Conf. Series: Materials Science and Engineering* 262 Paper № 012200 Available: https://doi.org/10.1088/1757-899X/262/1/012200

[25] Accidents and incidents on nuclear power plants *The manual under the general edition of f m of N professor S P Solovyov Obninsk IATE* p 220