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Review of the Norwegian-Russian Cooperation on Safety Projects at Kola and Leningrad Nuclear Power Plants 2005–2009

Statens strålevern
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Key words:
Kola Nuclear Power Plant. Leningrad Nuclear Power Plant. Nuclear Safety. WWER. RBMK.

Abstract:
The report reviews Norwegian-funded projects on nuclear safety at Kola and Leningrad nuclear power plants in the period 2005–2009. The report also reviews the safety level, lifetime, decommissioning plans and plans for new reactors at the two plants.

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Rapporten gir en oversikt over norskfinansierte sikkerhetsprosjekter ved Kola og Leningrad kjernekraftverk i 2005-2009. Rapporten tar også opp sikkerhetsnivået, levetid, dekommisjoneringsplaner og planer for nye reaktorer ved de to anleggene.

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Approved:

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Norwegian Radiation
Protection Authority
Østerås, 2010

Contents

Summary

In this report, Norwegian Radiation Protection Authority (NRPA) has reviewed the Norwegian funded projects on nuclear safety performed in the period 2005-2009 under the Norwegian Action Plan. NRPA has evaluated the progress of eight projects implemented by the Institute for Energy Technology (IFE) at Kola Nuclear Power Plant (KNPP) and Leningrad Nuclear Power Plant (LNPP). NRPA has visited the plants, inspected delivered equipment and discussed the projects implementation with relevant personnel at the plants. One of NRPA findings is that the equipment has been delivered to KNPP and LNPP, it is in regular use by competent personnel, and the equipment contributes to safety of both plants. Furthermore, the cooperation between three main project partners - IFE, LNPP and KNPP, seems to be very productive.

NRPA's main conclusion is therefore that the projects have been implemented as described in IFE's project reports and that the goals are met. Furthermore, this report reviews safety levels at the KNPP and LNPP. Safety parameters at the plants indicate that the safety level has been significantly improved since early 1990s when the cooperation between Norway and Russia was initiated.

Probabilistic safety assessment (PSA) values and number of INES (International Nuclear Event Scale) events, two internationally acknowledged safety parameters, indicate that the safety level has been much improved since the early 1990s when the cooperation between Norway and Russia started. Although it is clear that the Norwegian-funded projects have contributed positively to this development it is difficult to quantify the contribution.

Moreover, the report also reviews the planned life-time of and the decommissioning plans for the reactors at KNPP and LNPP. Construction of new LNPP reactors has started and it is estimated that they will be operational in 2013-2015. The license of the oldest reactor at LNPP expires in 2018 and if the new reactors are in operation by that time, it is unlikely that the older reactor will be granted a new license for operation. In Kola, there are official Russian plans to build four new reactors, planned to be put into operation in 2017-20, but construction of these has not been initiated yet. Russian officials have stated that the licenses for reactor 1 and 2 at KNPP will not be renewed when they expire in 2018 and 2019.

1 Introduction

Norway's cooperation with Russia on nuclear safety started in the beginning of the 1990s and has, since 1995, formally been organized under the Norwegian government's Action Plan for Nuclear Safety [1]. The Action Plan covers several different areas, such as nuclear submarines, radioisotope thermoelectric generators, radioactive waste, and nuclear safety. The aim of cooperation is to strengthen Russia's control and supervision of nuclear material and installations as well as to reduce the risk of nuclear emergencies and accidental releases of radioactivity into the environment. The Action Plan is managed by the Norwegian Ministry of Foreign Affairs (MFA) which grants funding to relevant projects. The role of the Norwegian Radiation Protection Authority (NRPA) is to oversee the projects implementation and report to the MFA whether the intended goals of the projects are being reached.

This report covers the part of the Action Plan focused specifically on nuclear safety [2] and covers projects implemented in the period 2005-2009 at the two nuclear power plants in north-west Russia, Kola and Leningrad Nuclear Power Plants. Since 2005 MFA has granted money for two projects periods, 2005-2007 and 2008-2011. Thus, some of the projects are in the implementation phase and a final conclusion about the outcome of the projects cannot be drawn. This is not a major drawback as many of the projects are a direct continuation of earlier projects. In recent years the projects have followed up earlier implemented measures such as the delivery of spare parts and training.

The report is one in a series of reports that the NRPA has published about Norwegian funded activities at the nuclear power plants in north-west Russia performed under the Action Plan ([3][4][5][6][7]). In 2005-2009 eight projects were performed by IFE at the two power plants.

The conclusions in the current report are based on information from several different sources, e.g. from IFE's bi-annual progress reports on the projects and from the meetings on a subject matter between NRPA and IFE personnel. Furthermore, NRPA representatives have visited Russian power plants to examine how Norwegian funded projects have been implemented. The most recent such visits to both plants were conducted during the summer 2009. NRPA has also held bi-annual meetings with the Nuclear Safety Authorities in Sweden and Finland, which also have on-going nuclear safety projects with Russian nuclear power plants. The main goal of these meetings was an exchange of information and experience.

Kola NPP (Photo: Kola NPP)

2 Norwegian-funded safety projects

2.1 Projects at Kola nuclear power plant

The cooperation between KNPP and Norwegian organisations started in the early 1990s. This report describes seven projects and their contribution to safety. Four of the projects are on-going while three were implemented and finalised in 2005-2007.

2.1.1 On-going projects

Improved operator training (Project nr. RUS-09/50)

KNPP performs extensive training of the control room personnel at the KNPP training centre. This centre is located in the perimeter of KNPP and contains two control room simulators. One is a full-scale simulator of the control room for reactors 3 and 4, the other is a functional simulator of a control room for reactors 1 and 2. In principle, modelling of the reactor parameters is the same for the two simulators, but the human-machine interfaces and ergonomics are different. In the functional simulator the interface is provided graphically on computer screens, while the full-scale simulator is an identical copy of the control room.

In 2007, Russian authorities issued new standards which require an upgrade and modernisation of control rooms simulators at NPPs. The current project is part of the measures to implement these requirements.

<u>Project activities</u>

The project is granted 4.5 MNOK by the MFA for the period 2008-2010. The project is co-financed by Rosenergoatom and KNPP (1.5 MNOK). The project consists of two parts:

1. Modernisation of two simulators and rooms used for personnel training.
2. Training of personnel for reactor start-up, shut-down as well as during the emergency procedures.

<u>Contribution to safety</u>

Operator training is an important contributor to safety. It reduces a risk for human errors, helps to develop and maintain a good safety culture. In addition, it is an important tool for knowledge transfer between experienced and new personnel at KNPP.

Modernisation will make the simulators more alike with the control rooms. As a result, the training can be done in a more realistic environment, which in turn improves the quality of trainings. Start-up, shut-down and emergency procedures are the areas where KNPP has a record of registered human errors. Simulator training will be provided in these areas in order to reduce further risk for human mistakes.

Non-destructive testing (Project nr. RUS-09/048)

The term non-destructive testing commonly refers to a set of techniques used to evaluate the properties of a material, component or system. Non-destructive testing does not cause any damage or permanently alter the tested material. Prior to NPP operation, a non-destructive testing is used to document and verify that the NPP material, components and systems have a quality required by the operator and regulator. During NPP operation, non-destructive testing makes it possible to, at an early stage, identify small defects which might develop and cause larger accidents. Early detection then allows initiating compensating and mitigating measures.

<u>Project activities</u>

The project has been granted 4.96 MNOK by the MFA for the period 2008-2011. The project covers delivery of equipment and training of personnel for proper use of delivered equipment. In 2005-2007 the following equipment was delivered:

- Metallographic equipment. This equipment is used to investigate the physical structure and components of metals. The equipment is used to investigate piping system, bolts and allows to, at an early stage, identify cracks in primary- and secondary systems.

- Image processor. This machine is used to support material integrity investigations. The machine delivered in the current phase of the project is used in contaminated areas at KNPP. A similar machine, delivered in an earlier stage of the project, is in use in non-contaminated area. With two machines, the control of the material integrity is improved since comparison before and after use in contaminated area can be made.

- Equipment for fuel change operations. Training was provided for using the delivered equipment.

- Eddy current instrument is used to investigate cracks and material defects in the primary and secondary circuit. Training in using the equipment and analysing the data has been performed.

- Ultrasonic equipment is used to measure cracks in pipes and weldings in the primary and secondary circuit. Spare parts to earlier delivered equipment have also been provided.

- Chemical analyser is used to investigate of materials and weldings. The instrument is complements earlier delivered equipment.

In the current period, 2008-2011, the following equipment has been, or is planned to be, delivered:

- Video endoscope will be used to visualize the spaces between the pipings in the steam generators.

- Mobile metallographic analyser will be used to analyse and identify defects in purchased material before it is put in operation.

- Radiation monitors will be used for ground measurements around KNPP. The results will be used to inform the public about the levels of activity around the plant.

- Portable neutron spectrometer will be used to monitor the neutron dose, especially during fuel handling and for measuring dose levels outside the reactor hall.

- Ultrasonic equipment will be used to detect cracks and corrosion in the primary circuit. Training in using the equipment will also be provided.

- Mechanical instrument will be used to investigate material properties in the primary and secondary circuit.

- Training will be provided for using delivered equipment.

Contribution to safety

Good surveillance and control of the primary and secondary systems is a very important safety measure. It will allow to document and verify quality requirements. It will also allow early identification of deviations from quality requirements so that corrective actions can be taken. The training part of the project allows KNPP to maintain the competence of the personnel which ensures that the delivered equipment will be continued to be used.

Vibration control and underwater TV-monitoring (Project nr. RUS-09/049)

Vibrations might influence the structural integrity of the material at a nuclear power plant. Vibration measurements and diagnostics are performed to be able to at an early stage identify defects that might increase and eventually cause breakdown of pumps or other equipment. Measurements are also made to identify if vibrations are transferred to the piping system where they can cause pipe breaks.

Underwater TV-cameras are used for surveillance of fuel change operations which are made under water. The cameras are also used for inspections, e.g. of the reactor tank and of spent fuel rods.

Project activities

This project is granted 3.35 MNOK by the MFA for the 2008-2011. This project started in 2003 and has been performed in several stages. In 2005-2007 the following equipment was delivered:

- Underwater TV-cameras and spare parts. TV-cameras are used for surveillance of fuel change operations.
- Software for vibration analyses is used for vibration analyses of the main turbines which is especially important in the starting-up and closing-down of the reactor.
- Equipment for vibration measurement and analysing software is used for vibration analysis of rotating machinery.
- Spare parts for control of the main circulation pump.

In 2008-2011, the following equipment has been, or is planned to be, delivered

- Cable for underwater TV-cameras. A 50 meter cable to the TV cameras used for surveillance of the reactor tank.
- Equipment for underwater TV-cameras. Equipment for improved movements of the underwater cameras.
- Equipment for vibration analyses. A portable data collector and signal analyser will be used to measure frequency and spectrum of rotating machinery.
- Spare parts for vibration control and diagnostics.
- Training. Training in vibration analyses and diagnostics.

Contribution to safety

The part of the project related to vibration measurements has delivered equipment for vibration measurements and software for analyses and diagnostics. This will allow early detection of defects that may lead to breakdown of pumps or pipe breaks. Early detection allows for counter-measures to be taken at an early stage and will prevent development to larger accidents.

The part of the project related to underwater TV-cameras have delivered equipment to improve the surveillance of the fuel and fuel operations. This will allow for early detection of fuel damage and for enhanced control of fuel change operations.

Water chemistry control
(Project nr. RUS-09/047)

The steel in the pipings of KNPP is sensitive to degradation due to chemical reactions with substances present in the cooling water. If these substances are present in the water over time it could lead to corrosion and crack formation. However, there are also substances which should be present in specified amounts in the water. Water chemistry measurements will ascertain that the amounts of all substances are kept within the specified limits.

Project activities

This is a continuation of a project started in 2003 and for the 2008-10 is granted a sum of 3.4 MNOK by the MFA. In 2005-2007 the following equipment was delivered:

System for water chemistry control (Photo: IFE)

- On-line water chemistry equipment. Equipment for on-line surveillance of the water chemistry in the secondary circuit was delivered.

- Hydrogen and oxygen analyser and spare parts. This is used to analyse water samples from the primary and secondary circuit in reactor 3. Corresponding equipment has earlier been delivered to reactor 1 and 2.

- Spare parts to the following was delivered:
    - Ion chromatograph is used to analyse water samples for corrosion products in the primary and secondary circuit.
    - Water Capillary Ion Analyser is used to analyse water samples for elements that can cause corrosion in the primary and secondary circuit.
    - Water facilities at the laboratories is used by the laboratories to produce ultra pure water.
    - Panel for on-line surveillance of secondary circuit.

In 2008-2010 the following equipment has been, or is planned to be, delivered

- On-line chloride analyser. This will be used for water analysis of the secondary circuit.
- On-line chemistry surveillance. This will be used to measure water from the steam generators. The delivered equipment will replace old equipment.

- Spare parts to the following will be delivered:
    - Hydrogen and oxygen analyser,
    - Water capillary electrophoresis instrument.
    - Water facilities at the laboratories.
    - Oxygen analyser.

- Training.
    - Training in use, service and maintenance of the hydrogen and oxygen analyser for the primary system. Three staff members from KNPP have been trained.
    - Training in use of the hydrogen and oxygen analyser, delivered in an earlier phase of the project. Five staff members from KNPP have been trained.

Contribution to safety

Water chemistry control will ensure that the chemical composition of the water in the primary and secondary circuit is kept within specified limits. Early detection of deviations allows for counter measures to be taken at an early stage which will prevent development to larger accidents.

2.1.2 Projects 2005-2007

Upgrading of the SPDS system for reactor 1 and 2. Adaption to the training simulator. (Project nr. 3055007)

In the control room, the reactor is operated and the safety functions are kept under surveillance. The operators in the control room have to control parameters displayed on panels located in different places in the control room. However, the safety level is a combination of different parameters which makes it difficult for the operator to maintain overview at all times.

The Safety Parameter Display System (SPDS) is a computerised system which monitors safety parameters and gives an overview of the results. SPDS was installed in reactor 1 and 2 at KNPP in 2000 and in reactor 3 and 4 in 2004. After the installation, reactors 1 and 2 have been substantially upgraded. To be able to continue to use the SPDS system at KNPP there is a need to upgrade it and adapt it to the new instrumentation and safety systems. The SPDS system is a requirement in western plants and the system installed at KNPP is based on the system installed at Loviisa NPP which also operates VVER-440 reactors.

The SPDS has also been installed in the control room simulator for reactor 3 and 4. The simulator should, to the extent possible, be identical to the control room and an update of SPDS in the control room should be reflected by a corresponding update of the simulator.

Project activities

This project was granted a sum of 4.3 MNOK by the MFA for 2005-2007. The project was co-financed by STUK with 1 MNOK. The project was not continued in the current period.

In December 2005, the SPDS system for reactor 1 and 2 was updated. During the first half year of 2006 the installed system was tested and in December 2006, the system was approved by KNPP. The upgraded system is now in daily use.

The adaption of the SPDS system to the training simulator for reactor 1 and 2 was ready in January 2007. The system was tested during 2007 and approved by KNPP in November 2007.

Contribution to safety

The SPDS has earlier been installed at KNPP and its purpose it to improve the operator's ability to handle emergency situations. Continued use of this system will decrease the risk for human errors in emergency situations and thus reduce the risk for incidents to develop to larger accidents. The upgrading implemented in this project allows for continued use of the system at reactor 1 and 2 at KNPP.

The update has also made the SPDS system in reactor 1 and 2 compatible with reactor 3 and 4 which makes upgrading of the systems more cost effective. The update also facilitates access to spare parts and maintenance from Russian suppliers. These measures will also allow for continued use of the system at KNPP.

The SPDS has also been updated at the simulators of reactor 1 and 2 which allows for improved training. Operator training is an important safety measure. It reduces the risk for human errors, helps to maintain a good safety culture and is an important tool for knowledge transfer to new personnel. It is also important to train for emergency situations. Emergency situations rarely occur but it is important that the operators are prepared so that the correct countermeasures can be taken to take control of the situation.

Adaption of the core surveillance system SCORPIO to new type of fuel (Project nr. 3055006)

SCORPIO is a surveillance system for the reactor core which can also be used for safety analyses. The system comprises functions for on-line core monitoring and predictive analysis with interfaces to plant instrumentation and physics codes. It combines measurements and simulations to continuously provide a best estimate of the core status. It can calculate core behaviour during planned power transients.

In a previous phase of the project, SCORPIO was installed at the Nuclear Safety Department at KNPP for reactor 3 and 4. In 2005, KNPP planned to take a new fuel type into use. In order to do this, new accurate calculations of the power distribution were required to ensure that the safety margins were maintained. It was therefore a need to update the SCORPIO system to allow for these calculations.

Project activities

This project was granted sum of 1.4 MNOK from the MFA for 2005-2007. The project was not continued in the current period.

In September 2005, the upgraded SCORPIO system was installed at the Nuclear Safety Department at KNPP. In October 2005 to June 2006, the system was successfully tested at the Nuclear Safety Department at KNPP and in July 2006 the system was taken into regular use.

Contribution to safety

The reactor core is the most critical part of a nuclear reactor and surveillance and calculations of the core conditions are very important to safety. Implementation of the current project allows KNPP to continue to use the previously installed SCORPIO system for core calculations. This will allow the safety margins to be maintained and reduce the risk for fuel failure.

It should be noted that SCORPIO is only installed at the Nuclear Safety Department and not in the control room as was initially planned. According to KNPP, it proved to be more difficult than expected to get a license for this. Thus, not all features of the SCORPIO system can be used by KNPP.

KNPP liaison with the Halden Reactor (Project nr. 3075011)

To simplify the communication between Norwegian and Russian partners, a representative from KNPP has been stationed at IFE/Halden.

Project activities

This is a continuation of a project started earlier and for the period 2005-2007 was granted a sum of 2.1 MNOK by the MFA. The project was not continued in the current period.

An experienced and English-speaking Russian expert has been stationed in IFE/Halden in the period 2005-2007. The primary tasks have been to simplify the communication between IFE and KNPP and suppliers in Russia. The representative has made translations concerning specifications, software and technical details and has also served as an interpreter at meetings and courses but also negotiated contracts with Russian subcontractors.

Contribution to safety

This project has not directly contributed to improve the safety level at KNPP but it has contributed to reduce misunderstandings between Norwegian and Russian partners. In essence, this project has contributed to the effective implementation of the other projects.

The overall experiences from this project are positive both from the Norwegian and the Russian side.

2.1.3 Overall assessment of projects at KNPP

NRPA has evaluated the status and progress of the abovementioned projects. This evaluation has been performed after a site visit and discussions with IFE and KNPP. KNPP was positive about the cooperation with Norway which was described as very pragmatic.

NRPA has inspected equipment delivered under the Norwegian Action Plan and met with personnel using the equipment to discuss how the equipment is used. NRPA could inspect all requested equipment and could see that it was in use. NRPA also had an open dialogue with KNPP representatives about the projects and also about other issues, such as safety, decommissioning and new reactors (cf. 3.1 and 4.1).

A general problem for several of the projects has been that delivery of equipment has been delayed due to Russian administration. These problems were solved but caused delay in the completion of the projects.

NRPA has also met with Russian local authorities to learn about their knowledge and view of the projects. In September 2009, NRPA met with the mayor of Polyarnye Zori and a representative from FMBA in Polyarnye Zori. They were both well aware of the Norwegian projects and were positive to the cooperation with Norway.

2.2 Projects at Leningrad Nuclear Power Plant

The cooperation between IFE and LNPP started in 1999 and all activities have been connected to the Training Centre at LNPP and the use of VR technology (Virtual Reality). Training of refuelling machine operators and their cooperation with the operators in the control room was from the start identified as an important project where IFE could contribute to the needs of LNPP.

2.2.1 On-going projects

There is currently one on-going project at LNPP, which is a continuation of a project that started in 1999.

Using Visualization Technology for Training and Decommissioning at LNPP (Project nr. RUS-09/051)

One of the special features of RBMK reactors is that fuel can be changed while the reactor is in operation. The fuel change is done approximately once a day using a specially designed refuelling machine. During fuel change there is a close collaboration between the operator of the refuelling machine and the operators in the control room.

In order to reduce the risk for human errors during this operation, a training simulator was installed at the training centre at LNPP. In 2002 a training simulator for fuel change operations (RMS-VR-OPT) was installed and in 2003-2004 a simulator for training on maintenance procedure was installed (RMS-VR-MPT).

There are two full-scope simulators (one for reactor 1 and 2 and one for reactor 3 and 4) at the training centre at LNPP. The refuelling machine simulator is integrated with one of them to allow training communication between the refuelling machine operator and the control room operator. Integration with the other full-scope simulator of the control room is part of the current phase of the project.

Project activities

The project is granted 5.0 MNOK by the MFA for 2008-2010. The project has included simulation and training of maintenance procedures for the refuelling machine.

In 2005-2007, the two simulator systems were further developed. The largest effort was to develop a refuelling machine procedure trainer (RMPT). The RMPT system is a development of the RMS-VR-MPT system which includes guides and access to documentation.

In the current period, the focus is to continue to develop the simulators but also to use the VR-technology in preparation for decommissioning activities. In the current period, the following activities have been or are planned to be performed:

- Updating the refuelling machine simulator to reflect recent updates of the refuelling machine.
- Integration of the refuelling machine simulator and the full-scope simulator
- Developing the scenario for moving spent nuclear fuel from the reactor to an adjacent storage building.
- Developing tools to prepare for decommissioning.

Contribution to safety

The reactor core is the most critical part of a nuclear reactor and refuelling is a procedure which is closely related to safety, especially for RBMK-reactors where refuelling is carried out while the reactor is in operation. Although it is clear that the training simulators delivered within this project have contributed positively to safety, it is difficult to quantify the contribution. There were no examinations of the skill of the personnel before and after the installation of the training simulator. However, there are other indicators showing the usefulness of the installed simulators. For example, LNPP have stated that that by June 2009 there had not been reported any “errors” by the refuelling machine operators after the installation of the simulator. Another indicator is that in 2004 Rosenergoatom who operates all Russian nuclear power plants evaluated the use of VR for training at LNPP. It was concluded that the simulator was a very effective training tool and support was given to use it also at other Russian NPPs. The refuelling machine simulator was installed at Smolensk NPP and Kursk NPP in 2006 and 2007, respectively. These installations were fully financed by Rosenergoatom.

The VR-simulator is used by LNPP on a daily basis. In total, about 100 people have been trained in the refuelling machine simulator (refuelling machine operators, and supervisors for all four reactors). Each operator has to train 130 hours in the simulator before s/he can start working with the refuelling machine. In addition, three days re-training per year is required. There are two refuelling machine simulators since there are two different refuelling machines, one type which is used in reactor 1 and 2 and another used in reactor 3 and 4. It is important that the simulators are updated when updates of the actual systems are made.

NRPA visits the Training Centre at LNPP in July 2009 (Photo: NRPA)

2.2.2 Overall assessment of projects at LNPP

NRPA has discussed and evaluated the status and progress based on site visits and on discussions with IFE and LNPP.

NRPA has inspected equipment delivered under the Norwegian Action Plan. NRPA has also met with relevant personnel using the equipment and discussed how the equipment is used. NRPA could inspect all requested equipment and could see that it was in use.

NRPA also had an open dialogue with LNPP representatives about the project and also about other issues, such as safety, decommissioning and new reactors. Taking the Russian engagement into account, including the availability of funding, this project seems to have met a need not only at this facility, but also at other sites with RBMK reactors, both in Russia and in Ukraine.

3 Overall Safety Level at Nuclear Power Plants

The safety level at a nuclear power plant depends on the safety in the design and construction, operational safety and human factors. There is not one single parameter that can give a complete description of the safety at a nuclear power plant. Two internationally acknowledged safety indicators, PSA and INES, are described here.

Probabilistic safety assessment (PSA) is a systematic and comprehensive methodology to evaluate risks at nuclear power plants. It is used to evaluate the probability for an accident to occur and the severity of the consequences if it should occur. PSA helps to identify areas where safety could be improved at the plant. PSA is divided in three levels, where the first level describes accident sequences which could lead to core damage. The PSA value describes the frequency for core-melt per year. PSA is a large-scale examination of the safety and a recognised tool for safety assessment.

Another indication of the safety level at a nuclear power plant is the number of safety related events. INES (International Nuclear Event Scale) is a tool for communicating to the public the safety significance of nuclear incidents and accidents. INES was introduced by IAEA for classification of deviations from normal operation. INES have 7 levels where levels 4-7 are accidents and levels 1-3 are incidents while level 0 is deviations without safety significance [11].

Modern reactors use the principle of defence-in-depth with multiple layers of protection that will prevent and mitigate accidents and minimise the release of radioactivity in case of an accident. The first three are the fuel matrix, the fuel cladding and the primary cooling system. The fourth layer is the solid containment that will prevent radioactivity to be released to the environment. This is standard in all Western reactors but was not included in the design of the early Russian reactor types, such as the VVER and the RBMK. The containment of the VVER and RBMK reactor types are different, and the generations of these reactors have again different solutions.

The safety level is also influenced by the role of the regulator. In Russia, the regulator has local organizations at each power plant, responsible for inspection, both regular, daily inspections but also larger inspections. It seems that the local regulators have become less independent due to recent internal changes within Rostechnadzor. Rostechnadzor, previously an independent organization, is now placed under the Ministry of Ecology and Natural Resources. The work of the local organizations is to a large extent controlled from Rostechnadzor in Moscow.

A new act about inspection and control was adopted by the Duma in 2010 and will come into force from 1 January 2011 [10]. This act will further limit the activities of Rostechnadzor. All construction companies in Russia, including the ones involved in building nuclear facilities, will be self-regulated.

3.1 Safety at Kola Nuclear power plant

KNPP have made long-term safety upgrades based on results from IAEAs safety missions to KNPP in the 1990s and all generic deficiencies have been eliminated or compensated for, either by technical or organisational means [7].

The first generation VVER reactors were designed so that, in case of a serious accident, the valves in the containment would open to release the overpressure directly to the environment [12]. A solution where radioactivity is released directly to the environment is contrary to modern safety thinking and in the 1990s this was compensated for by introducing a jet-stream condenser whose aim is to reduce the pressure in the containment by condensing steam to water. The leak tightness of structures around the primary system has at the same time been improved. This was further improved in the second generation VVER reactors when a bubble condenser was introduced for reducing the pressure in the containment [[7], [13]].

Table 1 shows the number of reported INES events at KNPP. It can be seen that the total number of reported events has decreased significantly since 1993 and the number of serious events has also decreased. Since 1999 there has been only one INES-1 event at KNPP.

The last reported PSA values from KNPP are shown in Figure 1. The values for unit 3 and 4 are values that will be reached in 2011 and 2014, respectively, after planned safety upgrades. The values are all below the value of 10^{-4}, which is the acceptable level recommended by IAEA [17].

Apart from Norway, KNPP has also an extensive cooperation with Sweden and Finland on nuclear safety.

Table 1: Number of INES events at KNPP in the period 1993-2009 [[3], [8], [15], [16]].

Year	Total	Below scale	INES-0	INES-1	INES-2	INES-3
1993	41	4	19	14	2	2
1994	38	0	32	5	1	
1995	20	4	16	-	-	-
1996	17	2	14	1	-	-
1997	7	1	6	-	-	-
1998	10	3	7	-	-	-
1999	10	4	5	1	-	-
2000	1	0	1	-	-	-
2001	7	1	6	-	-	-
2002	3	1	2	-	-	-
2003	5	1	4	-	-	-
2004	3	3	-	-	-	-
2005	1	1	-	-	-	-
2006	4	1	3	-	-	-
2007	4	2	2	-	-	-
2008	2	1	1	-	-	-
2009	2	2	-	-	-	-

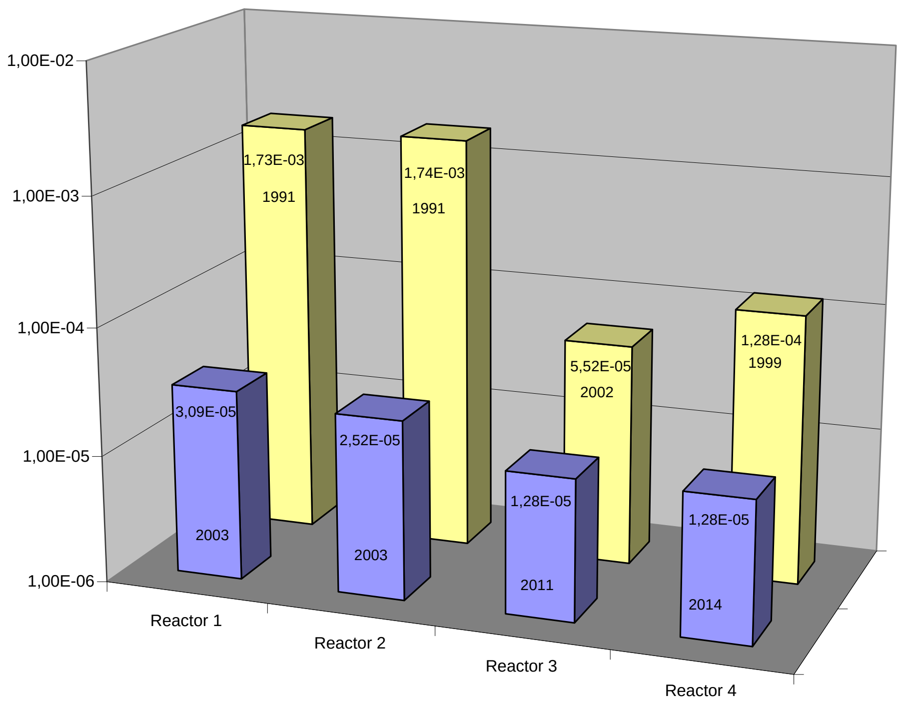

Figure 1: PSA (Level 1) for the four reactors at KNPP. The PSA levels for reactor 3 and 4 will be reached in 2011 and 2014 respectively, after planned updates [8].

Table 2: Number of INES events at LNPP in the period 1998-2009 [[8], [15], [16]].

Year	Total	Below scale	INES-0	INES-1	INES-2	INES-3
1998	8	3	5	-	-	-
1999	9	1	8	-	-	-
2000	14	6	7	1	-	-
2001	7	-	7	-	-	-
2002	8	-	8	-	-	-
2003	2	1	1	-	-	-
2004	11	5	6	-	-	-
2005	3	2	1	-	-	-
2006	7	4	3	-	-	-
2007	4	-	4	-	-	-
2008	6	2	4	-	-	-
2009	4	-	4	-	-	-

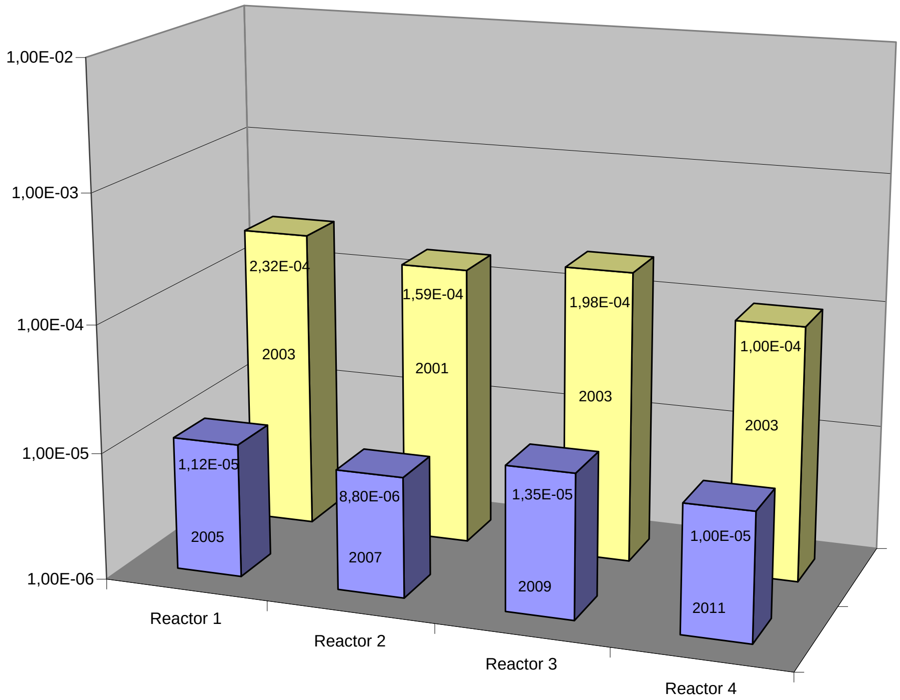

Figure 2: PSA (Level 1) for the four reactors at LNPP. The PSA levels for reactor 4 will be reached in 2011 after planned updates [8].

3.2 Safety at Leningrad Nuclear Power Plant

First generation RBMK reactors were not designed with a confinement comparable to those found in western reactors. However, the second and third generation RBMK have an improved confinement system with reinforced concrete structures and a pressure suppression system. However, this system encloses only part of the main circulation system and excludes several other important systems [[6], [14]].

LNPP have made long-term safety upgrades based on results from IAEAs safety missions to LNPP in the 1990s but also based on results from safety missions to other similar reactors. These upgrades have been made to meet increased demands from regulatory authorities.

During the last 10 years LNPP has only reported one single INES-1 event, as seen in Table 2. It has been suggested that some of these events should be re-classified to a higher level. Such a re-classification has been done by STUK but even after that the statistics compares well with Western reactors [18].

The PSA values, as seen in Figure 2, at LNPP are approximately 10^{-5}. The values are all below the value of 10^{-4}, which is the acceptable level recommended by IAEA [17].

Apart from Norway, LNPP has also an extensive cooperation with Sweden and Finland on nuclear safety.

4 Plant life time, decommissioning and plans for new reactors

Russia has decided to continue to operate all Russian reactors currently in operation 10-20 years after the initially planned 30 years [9]. The practice of Russian regulatory authorities is, like in many other countries, to give new license according to the actual safety level at the plant rather than looking at the age and the initially planned life time of the reactor. Thus, even if the planned life time has already been extended, further extension may be envisaged. The life time of a reactor is determined by the life time of its non-exchangeable parts. For VVER reactors this is the reactor tank, the containment and some building structures. For RBMK reactors it is the metal structures in the reactor, the graphite block and the structure around it, outer release barriers, steam separators and some building structures [8].

The term decommissioning is used to describe the process of removing a nuclear facility from regulatory control. Decommissioning includes decontamination, dismantling and removal of radioactive materials from the plant. Russia, like many other countries, is facing a period where many of their reactors will reach the end of their life-time and a decommissioning process will start. Russian authorities are currently preparing for the decommissioning phase. A new legislation is currently worked out which is planned to be approved by the Russian government in 2011.

According to the current Russian legislation, the plant operator should develop decommissioning plans five years before the operating license expires [20].

4.1 Kola Nuclear Power Plant

The reactors at KNPP have license to operate until 2011 (unit 3), 2014 (unit 4), 2018 (unit 1) and 2019 (unit 2). At the Norwegian Russian Commissioning meeting in September 2009, Rosatom stated that reactor 1 and 2 would not extend their license period. KNPP plans to upgrade unit 3 and 4 to 470 MWe, and apply for a new license when the current license expires. The operator's current plan is to operate these two units until 2036 and 2039.

New reactors at KNPP are part of the Russian governments plan for the nuclear expansion, as decided by the Russian government on September 20, 2008 [19]. In these plans, four new reactors are planned to be taken into operation at KNPP in the period 2017-2020. However, there are several open questions related to these plans, for example regarding reactor type, capacity and time frame. Two reactor types have been discussed; one is the AES-2006 model, an evolutionary model of the VVER reactor type of 1200 MWe, currently under construction at Novovoronezh NPP and Leningrad NPP; the other is a not specified middle-sized reactor type of 600-650 MWe. If a model which is already licensed by Rostechnadzor is chosen, such as the AES-2006, the procedure to get a construction license would be relatively fast and simple. The choice of reactor type depends also on the capacity of the electricity grid and on the electricity demand in the region.

There is a site already dedicated for new plants about 7 km from the present site. It seems unlikely that a possible new plant would be built elsewhere in the Murmansk region since the entire infrastructure needed is already in place at KNPP.

4.2 Leningrad Nuclear Power Plant

Construction work for two new AES-2006 VVER 1200 MW reactors (LNPP II) started in 2008 and is built close to the present LNPP site. The first reactor is currently planned to be operational in 2013 but it is now estimated that there will be a delay and the reactors might not be ready for operation until 2014 or 2015. These reactors are built by Rosenergoatom, but by a separate company from the current LNPP.

The reactors at LNPP are currently planned to operate 15 years after the initially planned 30 years. The oldest unit, unit 1, is planned to operate until 2018 and the last unit is planned to operate until 2026. Major upgrades have been made to allow for the 15 year extended operation at all four reactors. LNPP is now considering if the reactors should be further upgraded to allow for extending the lifetime beyond 2018. However, since the new VVER reactors are planned to start operation earlier than this, it is not likely that such a major upgrade will be performed. It is also possible that reactor 1 could be phased out earlier than 2018 if additional capacity becomes available.

LNPP is currently preparing for the decommissioning phase. The decommissioning plans for LNPP can be summarized in three steps:

1) After closing down, the fuel and some systems and equipment will be removed
2) The whole reactor will be put in a confinement for approximately 50 years
3) The final decommissioning of the reactor will be performed

A new facility is currently under construction adjacent to the reactor where spent nuclear fuel will be cut into pieces, packed into transport casks and shipped to Krasnoyarsk for long-term deposit.

LNPP II Site in August 2008 (Photo: LNPP)

5 Conclusions

In this report, NRPA have reviewed the Norwegian funded projects on nuclear safety performed in the period 2005-2009 under the Norwegian Action Plan. NRPA has evaluated the progress of eight projects implemented by IFE at KNPP and LNPP. NRPA has visited the plants to inspect the delivered equipment and discussed the implementation with personnel at the plants. It was concluded that equipment has been delivered and is in regular use by competent personnel. The cooperation between the three main parties in the projects (IFE, LNPP and KNPP) seems to work well.

Thus, the main conclusion is therefore that the projects have been implemented as described in the project reports and that the project goals have been reached. The cooperation is also positive for the Norwegian experts in the projects as they also profit from the increased knowledge of Russian nuclear power plants. Norwegian and Russian experts have, after many years of cooperation, established a direct and frank communication which facilitates fast exchange of first-hand information.

The overall goal for many of the projects is to reduce the probability for incidents and accidents and the safety level at the two power plants are described in the report. The safety level depends on several factors and there is not a single parameter that can give a complete description of the safety level at a nuclear power plant. PSA values and number of INES event, two internationally acknowledged safety parameters, indicate that the safety level has been much improved since the early 1990s when the cooperation between Norway and Russia started. Although it is clear that the Norwegian-funded projects have contributed positively to this development it is difficult to quantify the contribution. NRPA would therefore like to better understand the connection between the projects and the overall safety level. In the future, all projects should, where feasible, consider how to monitor the safety levels after implementation.

Concerning the planned life-time and plans for decommissioning, there is some difference between Kola and Leningrad. In Leningrad, the building of new reactors has already started and they are estimated to be operational in 2013-2015. The license of the oldest reactor expires in 2018 and if the new reactors are in operation by then, it is unlikely that this reactor then will be granted a new license. In Kola, there are official Russian plans to build four new reactors planned to be taken into operation in 2017-20 but construction of these has not started yet. Russian officials have, at the Norwegian Russian Commission meeting in 2009, stated that the licenses for reactor 1 and 2 at KNPP will not be renewed when these expire in 2018 and 2019.

6 List of Abbreviations

EUR	Euro
IAEA	International Atomic Energy Agency
IFE	Institute for Energy Technology
INES	International Nuclear Event Scale
KNPP	Kola Nuclear Power Plant
LNPP	Leningrad Nuclear Power Plant
MFA	Ministry of Foreign Affairs
MW	Megawatt
MWe	Megawatt Electric Effect
NEA	Nuclear Energy Agency
NGO	Non-Governmental Organization
NOK	Norwegian Crowns
NRPA	Norwegian Radiation Protection Authority
OECD	Organisation for Economic Co-operation and Development
PSA	Probabilistic Safety Analysis
RBMK	*Reaktor Bolshoy Moschnosti Kanalniy*; Russian reactor type
SPDS	Safety Parameter Display System
STUK	Radiation and Nuclear Safety Authority in Finland
VR	Virtual Reality
VVER	*Vodo-Vodyanoi Energetichesky Reaktor*; Russian reactor type

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Statens strålevern
Norwegian Radiation Protection Authority

StrålevernRapport 2010:1
Virksomhetsplan 2010

StrålevernRapport 2009:2
A novel dosimetric protocol for high energy photon radiotherapy beams in Norway using radiochromic film (electronic version only)

StrålevernRapport 2010:3
Om kvalitetskontroll av linac

StrålevernRapport 2010:4
Mal for utarbeidelse av faglige anbefalinger for strålebehandling i Norge

StrålevernRapport 2010:5
Overvåking av radioaktivitet i omgivelsene 2008–2009

StrålevernRapport 2010:6
Estimerte kostnader forbundet med radonmålinger og radontiltak i barnehager, skoler og boliger i Norge

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