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# TSO Assistance towards the Improvement of Nuclear Safety in Lithuania: Achievements and Perspectives

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**Abstract:** This paper explores the improvements that have taken place at INPP in both the engineering and operational aspects of nuclear safety, discussing as example some areas where there has been a large involvement of international experts. The development of the Lithuanian Nuclear Regulatory Authority VATESI, and also the technical support organisations for both the regulator and the NPP are discussed. In each of these sections the paper describes some of the successes and also the areas where there have been some problems. Many of the problems have been resolved but challenges remain for the future. The paper only deals with the assistance towards enhancing the safety of the NPP up to the time of its closure. Regulation of decommissioning is an important area for the future and is receiving urgent attention and active planning at the present time.

## 1. INTRODUCTION

Ignalina Nuclear Power Plant is Lithuania's only nuclear power plant. INPP dominates electricity production in Lithuania. In the last decade, INPP contributed between 73 % to 84 % of total generated output per year. Consequently, the plant is important to the Lithuanian economy. INPP was built as part of the Soviet Union's North-West Unified Power System. It consists of two units, commissioned in December 1983 and August 1987. Both units of INPP are Soviet-designed RBMK-1500 reactors, and are different from the RBMK-1000 operating or operated in Russia and the Ukraine. They have a larger nominal capacity 4800 MW<sub>th</sub> (1500 MW<sub>el</sub>) per unit, but currently each is restricted to 4200 MW<sub>th</sub>. As the other RBMK of 2<sup>nd</sup> and 3<sup>rd</sup> generation they have some improved safety features such as an Accident Localisation System. The Lithuanian Government has taken the decision that Unit 1 will not be operated after 2004. For Unit 2 the operating life time is still to be decided.

The Ignalina NPP is unique among all RBMK type reactors in the scope and comprehensiveness of the international studies that have been conducted to verify its design parameters and analyse its level of risk. Right from the start, when Lithuania assumed control of the Ignalina NPP (after the demise of the Soviet Union in 1991) the plant, its design and operational data has been completely open and accessible to Western experts. Many states with significant nuclear expertise have contributed assistance for evaluation of the safety level of Ignalina NPP. As a consequence, international experts base the information and conclusions about safety level of the Ignalina NPP on a number of exhaustive studies.

## **2. IMPORTANT SAFETY STUDIES**

### **2.1. In-depth Safety Assessment of the Ignalina NPP**

In the years 1994 to 1997 an in-depth safety assessment of the Ignalina NPP was carried out as a condition of the Grant Agreement between the Lithuanian Government, Ignalina NPP and the European Bank for Reconstruction and Development (EBRD) to fund a project of safety upgrades. A Safety Analysis Report (**SAR, 1994-1996**) was prepared by the plant with the aid of Western engineering organisations from Canada, Sweden, UK and the USA, and the reactor chief designer RDIPE. A thorough on-line review (**RSR, 1995-1997**) of the SAR was carried out by a team of Eastern and Western Technical Safety Organisations (TSOs) from France, Germany, Italy, UK, USA, Lithuania and Russia. The SAR / RSR project was unique because it was the first undertaking to produce a plant-specific Western-style SAR, with a common review by Eastern and Western safety experts.

Common Guidelines were used as the basis for production and review of the SAR. They did not specify everything that would be required for a full Western SAR as basis for a license application, but described the safety philosophy to be used in the in-depth assessment. In general, Lithuanian/ Russian regulations in force at that time were considered to constitute an adequate framework, but a number of areas were identified where Western practice was to be taken as the basis for comparison for the plant.

A full Western-style SAR would have required several times the resources budgeted for the Ignalina SAR. During the planning of the SAR it was recognised and accepted that time and resources would not be sufficient. However, the independent reviewers concluded that the Ignalina SAR has dealt with the majority of essential issues.

The SAR made a large number of improvement recommendations and concluded that none of the identified and analysed safety concerns required the immediate shutdown of the plant. The RSR team agreed with most of the SAR team's recommendations for improvement and made some additional recommendations. However, they were not able to agree that a fully adequate Safety Case had been demonstrated for the period until the improvements would be implemented.

SAR and RSR were overseen by a panel of international safety experts, the Ignalina Safety Panel (ISP), who gave their own conclusions and recommendations following the completion of the projects.

Ignalina NPP has responded to the SAR and RSR results by its Safety Improvement Programme 2 (SIP-2) which addressed almost all of the recommendations, see Section 3.3. Major safety issues had to be resolved before a regular license could be granted to Ignalina-1 in 1999.

### **2.2. BARSELINA PSA**

Among the RBMKs the INPP has a unique documentation in terms of their PSA level 1 and 2 studies. The work on PSA for INPP started in 1991 when the Barselina project was formed as a co-operative project between Lithuania, Russia and Sweden. The analysis was made for INPP Unit 2 and the PSA level 1 models were gradually developed in a series of phases along with increased information availability and with growth of knowledge.

The present Phase 5 work was evaluated by an IAEA IPSART mission in mid 2000 and is recently updated to address the comments received. In 1997 the work started on PSA level 2, now as a Lithuanian and Swedish co-operation. An IPSART mission in October 2001 evaluated the level 2 work. Part of the mission was also a follow-up of the previous level 1 mission.

Barselina has been a main vehicle for introducing and developing PSA applications on RBMK in Lithuania for the benefit of expertise within INPP, within LEI as the main Lithuanian TSO in this area and also within VATESI. This first RBMK PSA work has also provided valuable input to other RBMK PSAs. The level 1 models have been used for identification of risk dominant sequences and for prioritisation and assessment of modification projects. In many ways the work has also been of great value for the SAR/RSR and the Unit 1 licensing review. The objectives of the level 2 study were to evaluate proposed accident management procedures for different severe accident scenarios and to assess the releases to the environment. The INPP now has an established PSA group within its organisation that gradually has taken over the initiatives for the progress of work. Important work related to Barselina is also the development of the five symptom-based Emergency Operating Procedures (EOPs) and a system for reliability and maintenance management, which both are implemented at INPP.

### **3. ENGINEERING IMPROVEMENTS**

#### **3.1. Post-Chernobyl Modifications**

After the Chernobyl accident, a number of technical modifications and organisational changes were prepared and implemented in order to improve the operational safety of all NPPs with RBMK reactors, including Ignalina. These changes had the objective of making the direct causes of the accident impossible or exceptionally unlikely. The main improvements were:

Measures to reduce the positive void coefficient by

- installing additional fixed absorber rods in the core,
- increasing the minimal allowable operational reactivity margin (ORM),
- increasing fuel enrichment.

Measures to accelerate the shutdown process and to enhance the shutdown reactivity by

- modifying some of the shutdown rod channels to be gas-filled rather than water-filled, allowing the installation of fast-acting shutdown rods (insertion in 2.5 seconds),
- correcting the deficiencies of the control rods to eliminate a positive scram effect,
- increasing the number of bottom rods and including them in the protection system.

Operational improvements such as

- enhancement of computational capacities to calculate important reactor parameters such as ORM more frequently,
- alarm at low ORM,
- introduction of improved administrative measures, e.g. now requiring the reactor to be shut down if the ORM is less than 48-52 (53-58 in Ignalina) equivalent rods - it used to be 32 (40) - or if power falls below 700 MW<sub>th</sub> (1000 MW<sub>th</sub>).

The measures succeeded in improving the neutronic characteristics of the reactor and increasing the emergency protection system effectiveness and thus reduced greatly the chances of an uncontrolled increase in reactor power.

### 3.2. Ignalina Safety Improvement Programme 1

Immediately after the Chernobyl accident, the first international programs of safety evaluation of the RBMK concept were undertaken, and a significant number of bilateral initiatives were also started. A number of technical areas were identified for short-term safety improvements, as well as for further in-depth safety analyses.

Efforts to upgrade the Ignalina NPP safety were accelerated when Lithuania assumed control of the plans in 1991. To meet the safe operation goal, the management of the Ignalina NPP together with the Lithuanian Ministry of Energy and assisted by Western experts prepared a safety improvement programme, later referenced as the Ignalina NPP Safety Improvement Programme 1 (SIP-1, 1994-1999). It was approved by VATESI in 1993. The objective of the safety upgrading program was to increase and maintain the Ignalina operational safety level until the station is permanently closed. Lithuania's original intention was to contribute about \$5 million of its own funds to plant improvements. Because of general difficult economic situation within Lithuania, it was quite clear that part of the SIP-1 could be realised only with technical as well as financial assistance from Western countries. A Grant Agreement was signed in London in 1994 between the Lithuanian Government, the INPP and the European Bank for Reconstruction and Development (EBRD) on behalf of the Nuclear Safety Account (NSA). The grant funded a project of safety upgrades in order to support the implementation of the SIP-1. The Lithuanian Authorities agreed, (as a condition to the Grant Agreement), that the operation of both units at INPP would not be prolonged beyond the time when their reactor channels will have to be changed. In addition, an in-depth safety assessment of the plant was undertaken, and a Safety Analysis Report (SAR/RSR) was produced and reviewed. A Panel of international nuclear safety experts (the Ignalina Safety Panel - ISP) was selected by agreement between the Lithuanian Authorities and the EBRD to monitor the study, review its results and make their recommendations.

The grant was to fund short term safety upgrades in support of the SIP being implemented at Ignalina plant. As part of the overall improvement programme, the EBRD funds were to support 20 projects in three areas:

- Operational safety improvements,
- near-term technical safety improvements,
- provision of services.

The successfully implemented projects included:

- in-service inspection equipment,
- a full scope simulator,
- hydrogen monitoring units,
- upgrading of the TITAN computer system,
- new main safety valves and motorised gate valves,
- fire protection improvements,
- new trip parameters on low flow in multiple fuel channels and low operational reactivity margin.

In addition, the Ignalina NPP has ongoing bilateral co-operative projects with Sweden, USA, Germany, UK, France, Belgium, Italy, Switzerland, Canada, Finland and Japan. These have resulted in a large number of engineering improvements, including (for example) fire protection equipment, inspection equipment, improved pressure relief of the reactor cavity, physical security and communication upgrades. Some of these are discussed in more detail below.

### **3.3. Ignalina Safety Improvement Programme 2**

A second Safety Improvement Programme (SIP-2) was set up in 1997 to implement the recommendations made by the SAR, RSR and ISP. The recommendations of ASSET and OSART missions and SIP-1 experience were also taken into consideration.

The SIP-2 Programme was divided into three parts:

- List of short-term measures based on the ISP recommendations,
- list of measures based on SAR results and INPP's own proposals,
- list of measures based on RSR recommendations.

The SIP-2 measures contain three main types of activity:

- Measures to upgrade equipment and new projects,
- improvement of organisation and management (including QA issues),
- evaluation measures and safety analysis.

The original SIP-2 programme (and its subsequent annual revisions) contained committed dates for completion of the individual measures. Measures that have been completed cover areas as diverse as:

- Changes in organisational management,
- installation of additional reactor protection systems,
- Safety Cases for:
  - Control and Protection System (CPS),
  - Reactor Coolant System (RCS),
  - Accident Localisation System (ALS),
- fire hazard analysis (FHA),
- improvements to emergency operating procedures.

In the context of licensing Ignalina Unit 1 the measures were prioritised by VATESI. INPP completed the 38 items required for licensing by July 1999, together with about 75% of the remaining items.

The remainder of the programme (60 lower priority items) has been rescheduled during 2001 and is planned to finish in 2005. At the present time 13 measures from the remaining 60 have been implemented and officially approved by VATESI.

### 3.4. Examples of Specific Nuclear Safety Issues and their Resolution

**Reliability of scram:** It was shown in the SAR and RSR accident analysis that, in certain transients with a relatively high probability of occurrence, a failure to scram the reactor effectively would rapidly lead to a severe accident situation. The existing protection system shares some components with the control system, thus failing to comply with international practice and also with the Lithuanian nuclear safety regulations. It also consists of sufficiently redundant but non-diverse equipment at several stages of the scram process and is therefore susceptible to common cause failures. The SAR, RSR and ISP all recognised the high importance of this issue and recommended that a second independent shutdown system be installed.

On units 1 and 2 a compensatory system (DAZ), providing independent and diverse scram initiation signals and voting logic, has been installed to respond to the transients that were shown to be of most concern in the SAR. This has enabled the regulator to accept that the reactors could operate for a number of additional years while a fully independent and optimally diverse shutdown system (DSS) was being developed to give further reliability improvement and diverse response to all design basis accidents. At the present time the project for procurement of the DSS has reached the stage of completion of technical specification and preparations for tendering. It is expected to be installed in Unit 2 in the maintenance outage of 2003. The project is being supported by the EC Phare programme, who are also supporting a review team of Lithuanian and Western experts who will assist VATESI in coming to a decision about the acceptability of the solution that is achieved.

**Low flow in multiple fuel channels:** The venting capacity of the reactor cavity in the case of multiple pressure tube rupture has been increased with the support of the Swedish bilateral programme so that up to 9 Pressure Tubes could rupture without the venting limits being exceeded. Nevertheless it is theoretically possible that flow reduction of a general nature in one group distribution header (GDH), by either blockage or flow stagnation in a very precisely sized LOCA, could cause high temperatures and ruptures in up to 40 channels, thus exceeding the venting capacity. To guard against this a system of scram and ECCS initiation on low flow in sampled channel attached to one GDH was installed as part of the Nuclear Safety Account grant project administered by the EBRD.

This system initially suffered from problems with the reliability of the individual channel flow meters used to provide input signals. These are the original flow meters installed in the channels for inlet flow control and have a tendency to provide noisy signals and to be subject to failure during operation. These problems have been resolved by Ignalina by modification to the signal handling equipment and by procedures for controlled substitution of faulty flow meters. The operating experience with these measures in place is shortly to be reviewed by VATESI and its technical support experts, to verify that the problem is finally solved.

**Reactor Coolant System integrity:** To provide a comprehensive safety justification of the integrity of the reactor coolant system (RCS), a significant amount of new work had to be done to expand the data on material properties and on the design of the circuit in relation to modern code requirements. Western experts provided training to show how such safety justifications needed to be constructed, and also provided extensive support in the purchase of inspection equipment and the training of inspectors. Ignalina's in-service inspection teams are now qualified to Western standards and are routinely engaged in comprehensive monitoring of the RCS for defects requiring repair. A Safety Case for the RCS has been produced and reviewed.

Nevertheless, the incidence of inter-granular stress corrosion cracking in some welds of the large RCS pipe-work is of some cause for concern, since it shows a specific deterioration from the design condition. The problem is seen at most RBMK units. The extensive inspection programme gives reassurance that cracking is unlikely to escape detection, but a solution that attacks the problem at its source and is less costly in radiation dose to the inspection team needs to be found. This is currently the subject of strenuous attention over the whole range of RBMK designs, via a programme of study co-ordinated by IAEA.

The integrity of the pressure tubes has also been studied extensively. This has benefited from the unique availability of data on zirconium properties, oxides and hydrides from a laboratory (Studsvik) outside the country. The testing that gave rise to the data has been reviewed by an international panel.

**Monitoring of gas gap closure process in Unit 1:** Measurements and analyses concerning the gas gaps between graphite and the Pressure Tubes were performed during the Unit 1 outage in summer 2000 for about 100 of the channels which have experienced the highest total burn-up. The measurements, made with modern equipment provided by Sweden, demonstrate that the progress toward ultimate gap-closure has slowed down in the last two years compared to earlier closure rates and earlier projections. These measurements now match well the latest predictions from finite element codes modelling the irradiated graphite behaviour. The INPP analyses were confirmed by independent analyses both by Lithuanian and Western TSOs. The analyses demonstrate high confidence that no fuel channel gas gaps will close in Unit 1 before at least 2002.

**Fire protection:** The work at INPP with improvements of the fire protection was in 1991 heavily affected by shortage of resources. As INPP started its co-operation with the West assistance was provided in this area both with equipment for installation at the plant and expertise for analysis. A large number of improvements have been made over the years. Presently, fire hazards analysis is ongoing in co-operation between INPP and experts from Lithuanian and Western Technical Safety Organisations (TSOs) with the aim to verify the adequacy of the implemented modifications.

#### **4. IMPROVEMENTS IN OPERATIONAL SAFETY AND IN MANAGEMENT OF SAFETY**

Both before and during the SAR and RSR a number of deficiencies were identified in these areas at INPP, and have been gradually improved since that time. The first safety improvement programme included as an example a full scope training simulator provided with assistance from the EBRD administered grant. After the SAR the event-based Emergency Operating Procedures (EOPs) were upgraded to include a number of scenarios identified and highlighted in the report. Later, Symptom-Based EOPs were developed at Ignalina with the assistance of US and Swedish experts.

The plant's Director General has initiated a programme of safety culture improvement at Ignalina and this has been progressively implemented. Quality assurance procedures have been introduced and implemented through a several year long effort in co-operation with experts from one Swedish nuclear power plant. Also a programme of training in modern approaches to NPP management has been given for the management team. One of the outcomes from this programme was the creation in 1997 of a nuclear safety committee at the plant.

This operated for a number of years, dealing effectively with many of the modifications to the plant undertaken as part of the SIP-2. However, it recently fell into disuse, mainly due to conflicts between the practices adopted by the committee and the normal line management control of safety at the plant. In 2001 an external audit of the safety committee drew up a set of recommendations for reconstituting the committee with some changes to its practices and composition, such that it should be able to integrate better into the management system. The plant management team and the committee members were fully co-operative with the audit and themselves provided several of the solutions proposed. The Director General chose to implement fully all of these recommendations. The new committee has now been inaugurated and is expected to strengthen greatly the plant's ability to take active responsibility for its own safety performance.

Improvements in these areas at any nuclear plants are well known to require a long process since culture and practices depend on the attitude and training of a large number of staff, and these can only be changed slowly. Progress with the improvements at Ignalina has been steady and needs to be maintained as a continuous process so that the plant can claim to be operated in a manner that is compliant with best international practice, for example as described in INSAG-13. This subject will be given due scrutiny by VATESI and its support organisations during the review of the Safety Analysis Report for Unit 2 and the preparations for licensing.

## **5. REGULATION OF NUCLEAR SAFETY**

### **5.1. Development of VATESI and its TSOs**

Last month VATESI had its 10 year celebration. The organisation started with the small group of site inspectors from the old system together with a handful of key experts recruited for this new regulatory authority. These core staff experts represent a long experience from operation and inspection of INPP. Over the past ten years VATESI has grown to a reasonable sized organisation with 38 staff through recruiting of qualified experts but for obvious reasons with limited experience in nuclear regulatory work. For several years the hard economic situation for the country restrained VATESI's development both in terms of hiring new staff and sending staff on training activities. It has also had a shortage of funds for equipping its office with necessary tools (computers, copiers, telephones etc) and developing their international contacts. The situation regarding funds for new staff is now greatly improved and VATESI is at the moment recruiting 10-15 additional experts by the end of 2002. VATESI's workload is increasing and additional recruitment seems to be necessary also later on. Funds for expenses and for contracting TSOs are still short. This needs to be improved so that VATESI can make sure that their TSOs are developing in the regulatory regime to be available to respond to VATESI's needs. VATESI has a well-developed contact network that includes international organisations, regulatory organisations and TSOs.

The Lithuanian TSO competence mainly stems from the Lithuanian Energy Institute (LEI), from Institutions in the universities and from a few private companies. Although on a high scientific level and experience from advanced technical projects, these experts had before 1991 rather limited contact with the nuclear sector in Lithuania. Since then, a strong development has taken place through work contracted by the INPP and by VATESI. A number of projects and activities based on bilateral co-operation and contracts with the Phare programme have played a great role.

LEI now represent, in areas such as accident analysis, structural analysis of the primary system and PSA a unique competence on RBMK safety issues outside Russia. However, the Lithuanian TSOs still lack competence in some important areas, such as human factors and management assessment and a continued strong development is necessary, including strong support from Western partners. The TSOs have in several areas a good international contact network.

For Lithuania being a small country it is inevitable that the same TSO organisation has contracts, in different areas, with the industry as well as the regulator. This situation is monitored by the special TSO Council that co-ordinates all nuclear TSO contracts. It is important that independence in the review work can be kept and proven through transparency of the contracting and performance procedures. The restraints in the state budget have in many cases also limited the possibilities for the TSOs to develop as needed including equipping their laboratories with modern instruments and tools. Bilateral and Phare-based efforts have in many cases been extremely valuable in giving such assistance.

The present Lithuanian procedures and rules regarding budgeting, procurement and contracting of services from TSOs seem, at least judged from some recent examples, not very effective as they tend to lead to a slow process. The root cause is to be found in the national administrative process.

The consequence is unfortunately delays in important review tasks and uncertainties for the future. This is unfortunate because INPP has several important review milestones scheduled in the next few years.

Two major ongoing review activities for VATESI and their TSOs are the implementation of a diverse shutdown system at INPP Unit 2 and the safety analysis report (SAR) for that unit. The work is planned for finalisation in 2003.

## **5.2. Nuclear Law and Nuclear Regulations**

***Nuclear Law in Lithuania:*** A modern Nuclear Law came into place in 1996 after several years of development with assistance also from international experts. The Law includes essentially all provisions related to design and operation of nuclear facilities as well as to nuclear material and in general to decommissioning. It sets the requirement of a license for the operator of a nuclear facility and also for contractors that deliver services or equipment to such facilities. The Law defines VATESI as the nuclear safety regulatory authority that performs the licensing. It also defines the roles in relation to nuclear safety of a number of other authorities with which VATESI has a close co-operation, for instance in context of review and issuing a license for operation. Western experts have worked for a long time giving assistance to a proposition for development of the legal system aimed at giving INPP a more independent and well-defined role as an enterprise. The proposition has been discussed in the Lithuanian parliament several times but a decision has not so far been reached.

***VATESI nuclear regulations and guidelines:*** Starting in 1991 with essentially a set of regulations inherited from the old system VATESI has gradually replaced the most important ones with newly developed Lithuanian regulatory documents. There are now regulations in place on general requirements for safety, requirements on safety for reactors, on licensing of nuclear reactors and specifically for licensing of Unit 1, on quality assurance, maintenance, modifications and several other areas.

The RBMK specific issue of Pressure Tube gas gap closure is dealt with in a regulation for in-service inspection and safety justification for pressure channels. Several regulatory documents also exist in draft form in different stages of completion, e.g. on emergency power supply, fire hazard analysis, equipment qualification and testing of the accident localisation system. VATESI has for many of these documents used the assistance provided through bilateral programmes and the Phare programme in different stages of the work. There can be mentioned as examples the Phare Regulatory Assistance project for Licensing Requirements, both bilateral work and Phare TSO project for Equipment Qualification, and the LAP experts (bilateral) assistance with the Pressure Tube regulations.

**Emergency preparedness plan of VATESI:** Lithuania has an established organisation for managing civil security situations involving many authorities, both on central and local levels. As VATESI is the authority uniquely competent in nuclear safety it has its specific function within the national organisation. VATESI established at an early stage a simple but functional “on-call” system so that inspectors could be reached at all times. The inspectors in the site group clearly had a major role in the preparedness due to their competence and closeness to the plant. When the numbers of VATESI staff grew it became possible to man a more sophisticated organisation at the head office in Vilnius. A review was carried out during 2001 of the regulatory documents and national organisation regarding the nuclear emergency preparedness in Lithuania. Comprehensive support has been provided to VATESI for the development of the concept of the VATESI Emergency Centre (EC), see below.

**Information services:** VATESI has now a well-established in-house information competence that also co-operates successfully with external experts providing a sort of TSO function in this area. VATESI realises the importance of active information from the side of the regulator, especially in times when safety concerns and limitation of INPP lifetime are being debated.

### 5.3. Facilities and Equipment

**Document Management System:** An electronic Document Management System (DMS) developed for a German TSO has been installed at VATESI headquarters. Powerful hardware such as mass storage devices and a fast scanner was procured with international assistance. The DMS allows for effective archive and retrieval operations for documents in any electronic format in Lithuanian, Russian and English language. The DMS features classification of documents, use of key words, mail functions, hierarchical access, use of passwords, etc. Intensive training in the use of the DMS was provided to VATESI staff.

**Emergency Centre:** Technical specifications for the equipment needed for this centre have been defined and the relevant equipment has been procured in the frame of a Phare project. VATESI is now equipped with an Emergency Centre that would enable them to manage a nuclear emergency situation in much better conditions than before.

**Training Centre:** Comprehensive support has been provided for the development of training procedures and programs for inspectors of VATESI. The training needs for the Lithuanian experts were identified and an associated training programme was elaborated with the support of Phare during 2000-2001. The project identified the needs of technical equipment for the VATESI Staff Training Centre, prepared the respective technical specification and performed the procurement activities. The training centre will be of great importance in the education of VATESI's new experts as well as their TSO experts.

## 5.4. Training and Coaching by Western TSOs

The transfer of Western knowledge and techniques has been one of the main activities of the experts from Western technical safety organisations engaged in the assistance programmes in Lithuania. This has been of particular value to VATESI and its own TSOs in the areas where techniques or analysis tools have been developed in the West or where the subject did not receive extensive attention in the former Soviet Union.

Training has been provided by the Western TSOs via the support of the European Commission in a series of Phare projects, and also in a number of programmes of bilateral support from member countries. The following are examples of the areas of training provided for VATESI and its TSOs. In some cases technical training has been provided to staff from the NPP at the same time (where this would not have caused conflicts) and, in parallel, extensive separate training to the NPP and its own TSOs has also been provided by a number of national programmes of assistance.

***Lines of Defence Methodology:*** This is a technique initially developed in France and further developed for special applications in the UK. It is valuable for making judgements of the acceptability of defence in depth, especially when a facility has been built to earlier standards and has features which are not typical of the majority of current designs. It is based on demonstrating a certain minimum number of strong defences against accidents, where a strong defence needs to have good deterministic engineered features such as tolerance of single failures, automatic operation (if an active system) and qualification for purpose.

***Safety Case (SC) production and review:*** This training aimed to show the importance of well-argued safety justifications and how they differ from bare reporting of analysis. The recipients learned how to assess the quality of SCs and carry out formal review. This was important for the major Safety Cases reviewed by VATESI in the preparations for Unit 1 licensing, i.e. the Safety Analysis Report, the Reactor Coolant System SC, the Accident Localisation System SC and the Control and Protection System SC.

***Inspections, equipment qualification and non-destructive examination (NDE):*** These have been important areas of training for TSOs, and have also been areas of focus for training at the NPP. As in many of these areas, the regulatory authority and its TSOs needs to be kept up-to-date with the modern techniques being used at the NPP. Most efforts have been spent on NDE and material technology which also has included transfer of equipment to the TSOs: NDE systems similar to those in use at inspections at INPP, material testing equipment and an electron microscope. Experts from VATESI and TSO have also been trained in ultrasonic technology and certified as inspectors in accordance with European Standard EN 473. TSOs have also been involved in the examination of INPP confinement building structures in the context of the Safety Case for the Accident Localisation System. The quality of the concrete was tested and the location of the reinforcement bars was verified in comparison with design information using high energy X-ray (Betatron). Methods for localising leakage paths were also developed.

***Core physics, thermal-hydraulics and confinement computer codes:*** Training has been provided since 1992 in detailed use of GRS computer codes ATHLET, QUABOX/CUBBOX, RALOC, COCOSYS and SUSAN. The German/Lithuanian assistance programme has also included transfer of these codes to the Lithuanian Energy Institute. In the recent past training and code transfer have been extended to other Lithuanian safety organisations in order to broaden the basis of technical expertise for VATESI. Similar assistance was provided by the U.S. with regard to the RELAP5 and CONTAIN computer codes.

**Safety management at NPPs:** This training described the features expected to be shown in the management system at well-managed NPPs and indicated how the quality of the management system could be assessed by the regulatory authority.

**Human reliability assessment (HRA):** The fundamental principles of HRA as applied to NPP operating staff were covered in this training, together with the wide variety of techniques used to make qualitative or quantitative assessments.

**Quality assurance for a regulatory authority:** VATESI undertook to create a quality management system for its own organisation and assistance was given by a number of countries by describing their own experiences of introducing QA to similar organisations. A programme is currently underway of more detailed training with national regulatory bodies, and assistance with the development of internal procedures.

## **5.5. Assistance in Review**

**Review of INPP submittals during licensing of Ignalina Unit 1:** Bilateral and EU-financed projects provided assistance to VATESI in their preparations for the licensing of Ignalina Unit 1, and in the regulatory decisions that were needed in the interim period. This was achieved by coaching by Western TSOs, information transfer and review assistance in utilising the results and conclusions of the Ignalina Safety Analysis Report, interpreting the conclusions and recommendations of the independent SAR review, assessing the proposals of the Ignalina Nuclear Power Plant for safety improvements according to their Safety Improvement Programme 2, and by monitoring of the implementation of these necessary safety measures at Unit 1.

After the licensing of Ignalina Unit 1 and in view of the coming challenges such as monitoring of the lifetime of the pressure tubes, review of the implementation process for a diverse shutdown system in Unit 2, and need for a systematic review of the Safety Analysis Report for Unit 2, VATESI have requested that the Western TSOs with experience of RBMK technology and familiarity with the situation in Lithuania continue to provide assistance.

**Review of INPP submittals for Diverse Shutdown System in Unit 2:** The processes of selecting a design option and to prepare a tender dossier for a diverse shutdown system in Unit 2 are now underway. Western TSOs with familiar with RBMK-1500 are providing assistance in the systematic review of the technical design specifications and the tender documents. They are ready to review the Safety Case and to closely follow the implementation on behalf of VATESI.

## **5.6. The Licensing Assistance Project (LAP) Mechanism**

The Licensing Assistance Project (LAP) was created to strengthen the co-ordination of the various bilateral and international assistance programmes to VATESI in view of their work related to granting a licence for continued operation to INPP Unit 1. A Steering Group was formed in October 1996 with participants from six involved countries (France, Finland, Germany, Sweden, UK and the US). The LAP Steering Committee meets regularly about four times a year. In addition, workshops on critical technical issues are organised by LAP. The LAP Steering Group receives reports on the progress with safety improvement measures, disseminates technical information between its member organisations, and co-ordinates activities underway in international and bilateral assistance projects in order to avoid duplication and to promote synergy. Technical issues important to VATESI's regulatory work are evaluated and advice is offered to assist in the preparation of regulatory decisions.

## 6. CONCLUSIONS

The Ignalina NPP is unique among RBMK reactors in the scope and comprehensiveness of the safety analyses that have been conducted to verify its design parameters and analyse its level of risk. Large international studies such as the BARSELINA PSA, SAR, RSR and follow-up safety analyses have provided a strong basis on which to assess the plant's safety.

The Ignalina NPP has not only developed a comprehensive Safety Improvement Programme, but has also implemented it to a major extent. Many successful plant improvements have taken place since the time of the Chernobyl accident. The immediate safety improvement programme included measures for dealing with the safety deficiencies revealed by the Chernobyl accident and the closely following studies. For example the coolant void coefficient of reactivity has been greatly reduced, the deficiencies of the control rods (positive scram effect) have been corrected, and fast-acting shutdown rods have been installed.

The safety improvement programme 1 (SIP-1) associated with the grant of EBRD included for instance the installation of new scram parameters on low flow in multiple channels and low operational reactivity margin.

The safety improvement programme 2 (SIP-2), currently underway, has responded to the findings of the SAR and RSR. A major part of it has already been implemented. Amongst many other measures, the installation of a scram system on negative rate of change of reactor coolant circuit steam pressure is to be mentioned. Additional compensatory measures aiming at improving the shutdown function (DAZ system) have been installed in both units to reduce the probability of an ATWS event. As a comprehensive solution for Unit 2, a new diverse shutdown system (DSS) is to be implemented. All these additional systems respond to deficiencies found in safety analyses. Safety cases have been produced for the reactor coolant circuit and the accident localisation system (ALS). These have resulted in a much clearer picture of the integrity and value of these systems and system improvements have resulted. The leak-rate of the ALS has been significantly reduced, thus greatly improving its expected performance in design basis accidents.

Operational and management issues have likewise been addressed following these studies. Symptom-based emergency operating procedures have been produced. A full-scope simulator has been installed and is used for operator training. A programme of safety culture improvement has been instigated by the plant Director General. A plant Safety Committee has been constituted. Quality assurance procedures for all aspects of management and operation of the plant have been developed. These improvements have initially progressed well but need to be further developed as part of a continuous process.

After the international review of the safety of Ignalina NPP in the SAR and RSR, both funded by the EBRD, the licensing of Ignalina-1 has been dealt with by the regulator VATESI in a comprehensive way, resulting in feedback to the plant that has enhanced its safety. The review process for the Safety Analysis report for Unit 1 and the Safety Cases for the key systems important for safety has been enhanced by a series of projects of TSO assistance from Western countries, funded from bilateral resources, from the EBRD, and from the European Commission. This assistance has consisted of transfer of experience and technical training, and teaching by parallel review activities, from which both VATESI and its Lithuanian technical support organisations have benefited. Among the most recent achievements are the installation of an Emergency Response Centre and a staff training centre at VATESI headquarters. The support to VATESI from Western countries has been co-ordinated by the Licensing Assistance Project (LAP), a steering committee of international regulators and technical experts.

This arrangement is unique amongst countries operating reactors of Soviet design and has been beneficial in motivating timely and cost-effective assistance programmes from EC and national governments. Its role has been to prioritise assistance, to promote synergy and to prevent duplication between the assistance programmes.

## **7. OUTLOOK**

Lithuania is now entering a new phase during which it is focussing on the programme for eventual accession to the European Union. While Ignalina NPP is trying to become less dependent on the principle designer and therefore to rely more on technical know-how available in Lithuania, the regulatory authority VATESI is also developing a wider network of Lithuanian TSOs. The SAR being prepared for Unit 2 will be more comprehensive than that for Unit 1, and will take account of many changes in plant systems, both improvements and also further ageing processes. The result is that the current Lithuanian TSOs will need continuing assistance from Western experts during the review of SAR-2.

The future presents challenges for Ignalina NPP and also for the VATESI and its TSOs. The aim by the plant will be to present the argument that the safety improvements have reached the stage at which Unit 2 can be considered acceptably safe for continued operation.

Studies have been performed on Ignalina, deterministic and probabilistic analysis as well as in-depth safety review. This provides a basis for assessment of Ignalina safety that is unique among the RBMKs. Studies also continue in some areas to extend this basis. Based on probabilistic analysis the safety level of INPP is comparable to many Western reactors. In the deterministic assessment INPP draws some criticism seen from Western regulatory perspective. The safety justification of some aspects of the design such as the partial confinement still need to be developed further to reach a comprehensive safety argument.

VATESI has taken the improvements into account and issued a licence for Unit 1. It now has to consider the latest studies and the current situation for both units and apply Western practice to its future regulatory decisions. It is in the best interests of Lithuania that these decisions are well founded and well supported.