SET 3
PLEX Case Studies

Content

Authors:
Ing. Antonia Wenisch, DI Markus Meissner
for the Czech Case study also Edvard Sequens, Calla
Austrian Institute for Applied Ecology
Seidengasse 13, 1070 Vienna, Austria
www.ecology.at

Overview - national PLEX programs

France

The 58 pressurised water reactors in France have a single operator Electricite de France (EDF). Another feature is the standardisation of the nuclear power plant fleet, with a large number of technically similar reactors, justifying a "generic" presentation. In 2003 the PWR reactors supplied approximately 80% of the electricity generated in France. They are located into 19 nuclear power generation sites (NPPs), which are on the whole similar. All are equipped with two to six PWR units 8 (PWR), giving a total of 58 reactors, built by the same company, Framatome. The 34 older of the the 58 units are 900 MWe reactors including:

- the CP0 series, comprising the two Fessenheim reactors and the four Le Bugey reactors (units 2 to 5),
- the CPY series, comprising the other 900 MWe reactors, which can be subdivided into
  - CP1 (18 reactors at Dampierre, Gravelines, le Blayais and le Tricastin) and
  - CP2 (10 reactors at Chinon, Cruas and Saint-Laurent-des-Eaux);

The CPY series differs from the Bugey and Fessenheim reactors (CP0 series) in the building design and in the addition of an intermediate cooling system between the circuit for containment spraying in the event of an accident and the circuit containing river water. It also provides for a more flexible reactor control. (CNS F NR 2004)

Until 2002 the French regulator was the Direction de la Surete des Installations Nucleaires (DSIN). February 2002 saw the creation of the Directorate General for Nuclear Safety and Radiation Protection which, with the support of the Divisions for Nuclear Safety and Radiation Protection within the Regional directorates for research, industry and the environment, constitute the new **Nuclear Safety Authority (ASN)**, in charge of Nuclear Safety and Radiation Protection. At the same time the former technical support organisations of the regulatory authorities both IPSN (nuclear safety) and OPRI (radiation protection) were merged into the Technical Support Organisation (TSO) responsible with technical assessment and research: the Institute for Radiation Protection and Nuclear Safety (IRSN). (CNS F NR 2004)

France does not give its NPPs a license for a specified period of time. The original design life of the units is 40 years. The Safety Authorities give an authorization to restart each unit after reloading at the end of each cycle (roughly every 12 to 16 months). (IAEA 2002)

In 2002, French nuclear safety authorities have signed off a decade of operation for Electricite de France's (EDF) 900-MW-class PWRs, marking the end of a systematic safety review and upgrade process that itself took more than a decade.

The French chief regulator decided that the safety level of EDF's oldest reactors at Fessenheim and Bugey (the six-unit CP0 series) is now equivalent to that of the other 28 standardized units in 900-MW PWR series and that the exercise had significantly raised the safety of the entire series. EDF can thus continue to operate the plants until their 30-year statutory outages. That means EDF's 900-MW units are licensed to operate, for the youngest among them, until 2015. Before the 30-year outages a new safety review cycle will be initiated for the plants. (NNI 2005).

The standardisation has advantages for the owners, but it also creates an obligation to anticipate any risk of occurrence of generic defects. This first of all concerns the problem of ageing for both the primary system and for the civil engineering side. **Preparation for the 900 MW third ten-yearly outage is under way but the time-frame of the files prepared by EDF is still limited to 40 years. At the same time EDF is talking about the possibility of extending the life of some power plants beyond that**. Tests and checks conducted during the ten-yearly outages are an opportunity for owners and authority to gain a clear picture of the current safety of the installations. This proactive approach must therefore continue and will lead to back-fitting work, for which the completion dates must be both justified in terms of safety and realistic in terms of implementation. The operator must also aim to improve safety through periodic safety reviews which compare the reactors with the most recent standards. ASN will be continuing to update the basic safety rules and develop probabilistic safety studies, within the framework of a realistic approach to risk reduction. (CNS F NR 2004).

Japan

In Japan the regulatory authority is the Ministry of International Trade and Industries (MITI). The operational licence for a NPP is granted for an indefinite period. There is no specific regulatory point of view, therefore no specific regulatory process is in place for plant life extension. A periodical inspection system is defined, and a nuclear power plant is shut down yearly to undergo annual inspections before approval to operate for another year. MITI endorses the safety of a plant as long as it meets the safety standards at the time. Nuclear power plants can continue to operate as long as the operator can prove annually that the plant can operate safely for one more year. In addition, periodical safety review shall be conducted at each plant at approximately 10-year intervals.

In 1996, MITI has launched a program to provide a conceptual framework by which the integrity of ageing nuclear power plants are examined and addressed, using three plants that have been in operation since 1970/71 (Mihama 1, Tsuruga 1 and Fukushima Daiichi-1) as pilot projects. This programme assumes that the plants will operate for 60 years. (IAEA 2002)

Borssele NPP - The Netherlands

Borssele is the only NPP in operation in the Netherlands. It has a net power of 480 MW(e) and is owned and operated by NV Elektriciteits Productiemaatschappij Zuid (EPZ).

Borrsele NPP has been put in commercial operation in 1973 and had a 40 years technical design life. Actual licensing regulations require a PSR every ten years to continue the license. The plant original investment being paid off in 1993, EPZ decided to invest and upgrade the plant to 1993/94 state of the art technologies in order to run it for another 20 years. A new safety concept was developed were a new design basis based on deterministic regulations combined with the findings of PSA was defined. The new predominant external events considered were: earthquake (0.1g); The main steam and feed water piping, which cannot be demonstrated to have leak-before-break were replaced. To meet the new design basis back fitting measures were implemented in seventeen areas including: decay heat removal; emergency core cooling system; emergency power system; reactor protection system and backup control room fire protection; and containment. Among the key modifications are: a new emergency power system; additional redundant decay heat removal, new primary safety/relief valves; etc. Following the back fitting the total core damage frequency improved from 5.6 E-5/year to 4.5 E–6/year. (IAEA 2002)

In January 2006, the centre-right coalition government of the Netherlands submitted a draft contract to the Parliament, to be signed between the State of The Netherlands, the EPZ utility and its two shareholders, the Delta and Essent utilities. This contract will guarantee Borssele to serve a 60 year lifetime, up to 2033.

Moreover the contract states that, if the Borssele plant will be closed by the government for any other reason than safety deficiencies, all extra cost and all lost revenues up to December 2033 will be compensated for by the State. In return for the 60-year lifetime, EPZ and its shareholders will donate 250 million Euro for sustainable energy projects.

The EPZ utility will ascertain that the Borssele reactor will remain in the group of 25% safest reactors of water-cooled reactors in Western countries. A commission of experts will be charged with periodic evaluation of this. EPZ will also start the decommissioning process immediately after shut-down in 2033. (WONUC 2006), www.wonuc.org)

Dukovany NPP - Czech Republic

At Dukovany NPP 4 units WWER 440/V213 are operating. Their originally planned operational time was 30 years, thus ending in 2015 and 2017, respectively for the first and for the second double block.

picture 1: Dukovany NPP

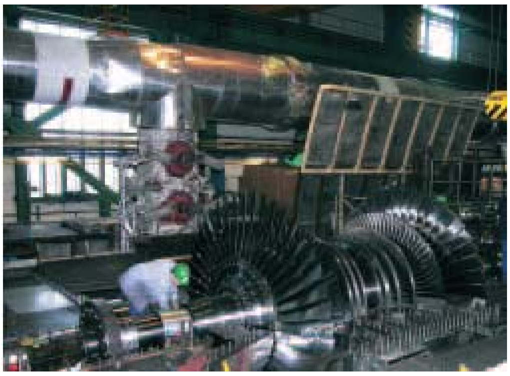
Nuclear safety reassessment of the units began in the early 1990ties: analyses, application of support programs and evaluations performed within various international activities including OSART, ASSET, IAEA missions as well as WANO and WENRA reports. Also some common activities by VVER 440/V213 reactor operators took place. The results of all analyses was used as input data for the project called **"Modernization Program for Dukovany NPP**". (CNS CZ NR 2004). Safety improvements have been implemented concerning fire protection (coating of cables) and prevention of explosions after LOCAs by installation of a hydrogen recombination system inside confinement.

Dukovany participated in the **PHARE/TACIS PH 2.13/95 project – Bubbler Condensate Experimental Qualification** (BCEQ) and the following experiments of the **joint project for Dukovany, Bohunice, Mochovce and Paks NPPs ,** were pre-test and post-test analyses were performed. The bubbler system verification was completed in 2003 (CNS CZ NR 2004). **With this testing program the confinement integrity has been proved in case of all design base accidents; The behaviour of the bubble condenser in case of beyond design base accident has not been investigated.**

In addition, Dukovany NPP actively participated in the 5th Framework Program of the EU within the VERLIFE project aimed at **controlling life span of components and piping of the VVER power plants** and further in the VERSAFE project comprising of two parts. The first one addressed problems related to serious accidents and the second one dealt with extension of VVER reactors life span. (CNS CZ NR 2004)

MORAVA Modernization Program for Dukovany NPP

This program for modernization was established in 1997-1998. Essentially, the program represents a prioritized list of partial projects, their schedule for preparatory works and implementation and assessment of their feasibility. The implementation of the modernization program is in progress. **The purpose of the MORAVA program is to achieve compliance with worldwide safety practices.** (CNS CZ NR 2004)


picture 2: Working at the turbine of DUkovany unit 3

In 1999 the emergency cooling pumps were replaced, in 2000 the super-emergency feed water system was improved, in 2002 measures were carried out to minimize the vulnerability of the steam and feed water pipes on level 14,7 m (shock absorbers).

The most important project currently under way is the **replacement of the I&C system** on safety-important parts for digital systems. **The replacement is and will be performed gradually during refuelling outages of units and its completion has been scheduled for 2010**. A tender was conducted for preparation and implementation of the project and a **contract was signed in September 2000 with a consortium of FRAMATOME and Schneider Electric. Implementation of the I&C system renovation was commenced in 2002 for unit 3 and in 2004 for unit 1.** (CNS CZ NR 2004)

The **major alteration** concerns the reactor core, where the **fuel cycle is to be prolonged from 3 to 5 years, resulting in a higher burnup of the fuel,** i.e. higher radioactivity of the fuel elements connected with a decrease of safety margins, potentially higher emissions in case of an accident and a higher radioactive inventory in the spent fuel storage facilities.

Safety evaluation of Dukovany NPP units is required every 10 years of operation: After ten years, an overall revision of the Safety Report is regularly prepared. A precondition for the SUJB decision for grant of ten-year license allowing the Dukovany

NPP units to operate after 2005 is the revision of the Safety Report. In 2003 the Periodic Safety Review Process was also updated for the Dukovany NPP after 20 years of operation in accordance with new requirements of the IAEA Safety Guide. The Safety Review will be carried out in 14 areas including equipment qualification, ageing, risk analyses, human factors, emergency planning.

This Safety Review process shall help in providing documentation for preparation of the operating licenses renewal for the Dukovany NPP units after 2015. The final report on PSR of the Dukovany NPP will be submitted in 2007. (CNS CZ NR 2004)

Probabilistic Safety Assessment (PSA) of the Dukovany NPP:

The first PSA of the Dukovany NPP was completed in 1993. Currently the level 1 PSA study has established the resulting Core Damage Frequency (CDF) for the Dukovany NPP:

- CDF = 1,27.10E-5/reactor-year for operation at full power
- CDF = 3,69.10E-5/reactor-year for low-power modes and outage
- Total CDF = 4,96.10E-5/reactor-year for all operating modes (summary of previous values) (CNS CZ NR 2004)

Plant Life Management (PLIM)

The Ageing Management Program has been used at the Dukovany NPP since the beginning of operation. In view of the fact that Dukovany NPP exceeded already half of its life originally set by the design and further that ČEZ a. s. declared a strategic objective for its NPPs to stretch out the life span by 10 year, the work was commenced in order to develop Long Term Operation program in accordance with world wide experience. (CNS CZ NR 2004)

A component life monitoring program focuses particularly on the main plant components important for nuclear safety. The primary circuit equipment residual service life is monitored of the reactor (pressure vessel, steam generator, main circulation pumps, pressurizer, main circulation pipeline). For the secondary circuit a similar program focuses on the piping systems, where the erosive corrosion is the most significant damaging phenomenon. (CNS CZ NR 2004)

The most important component in Dukovany as in every other NPP is the reactor pressure vessel (RPV). The neutron flux inside of the reactor core causes embrittlement of the RPV. The Dukovany RPV is made from a pure steel - therefore embrittlement is not that much advanced as it was in Bohunice. Thus annealing of the RPV is not in discussion for Dukovany. However, embrittlement is more advanced at the RPV's welds as it is proofed by the in-vessel samples.

It seems that NPP Dukovany is on to extend the operating time beyond the planned life-time of the NPP, without any public debate. The modernization program will not solve all safety deficiencies of the Dukovany plant e.g. the problems with missiles from turbine failures, or the qualification of the reactor building concerning airplane crashes. Also the lack of qualification of the bubbler condenser in case of a beyond design base accident at the VVER 440/V213 series reactors is not concerned by the modernization program. Moreover, the modernization program includes significant changes in the reactor core which will lead to a reduction of safety margins, to higher radioactive inventory which means a bigger source term in case of an accident, and a higher radioactive inventory in the spent fuel storage facilities.

Bulgaria

Kozloduy 1/2

In 2002 the two oldest WWER 440/ V230 plants in Kozloduy have been closed - according to Bulgaria's accession process to the European Union.

Kozloduy 3/4

Under the acession treaty Kozloduy 3 and 4 have to be closed in 2006. At the moment it seems that Kozloduy seeks to extend the operational period for unit 3 & 4 beyond the agreed closing date. In 2002 a separate independent study of the safety level of units 3&4 was carried out, including a comparative study with model V-213 reactors. The results of the study performed by a ENCONET confirmed compliance of the new design status of units 3&4 with the current requirement for light water reactors in operation. The general conclusion of the study is quoted in the National Report to the CNS in 2004:

„The *safety level achieved at upgraded Kozloduy NPP 3&4 is comparable with that of operating plants of similar vintage in the West and in the East with respect to international safety standards and practices. It did not find any safety issues that would prevent further operation of the plant." (CNS BG NR 2004)*

The unit 3 license was issued in June 2003 with an 8 years term of validity and the license of unit 4 was in February 2003 with a term of validity of 10 years.

Financing

The implementation of the Modernization program for Unit 3 & 4 is completed. It was financed mainly from the Kozloduy NPP's own investment program resources. For the implementation of the activities of the last stage between 2000 and 2002, USD 99 Million were spent. (CNS BG NR 2004)

The issued long-term licenses demand that Kozloduy NPP execute a complex of long-term programs for continuation of the activities in certain aspects. Financing of these programs in the next three years is planned to be 28.4 Million, 91% of which are Kozloduy's own resources and the rest are already granted by the EU PHARE program.

Kozloduy 5/6

The younger reactors in Kozloduy units 5 & 6 are WWER-1000/V320. They were commissioned in 1988 and 1993, respectively. The design life of the units is 30 years. These Plants are subject to a Modernization Programme (MP) with the aim to eliminate some safety deficiencies of the design, which date to early 70s, and to increase the plants availability.

The MP comprises modernization of the I&C systems, severe accident management, replacement of mechanical equipment of the basic production and safety systems, modernization of electrical equipment and systems for reliable power supply, replacement of monitoring and control systems with state-of-the-art digital control systems, Improvement of fire protection and seismic resistance. (CNS BG NR 2004)

To guarantee a high quality of implementation Kozloduy hired an international team of experts for consultancy. According to the implementation schedule the units 5&6 modernization program should be completed in 2006.

In October 2003, the Nuclear Regulatory Agency granted licenses for Units 5 & 6 operation with term of validity of 6 years.

By the end of 2005, the activities on main technological systems and replacement of electrical and I&C equipment should be completed. It is planned to complete the final studies, including update of units' Safety Assessment Report in 2006.

Financing

According to Bulgaria's CNS Report (CNS BG NR 2004) the implementation of the modernization program for units 5 & 6, was funded by:

- EURO 135 Million from the cash flow of Kozloduy NPP
- EURO 212 Million - EURATOM (loan)
- USD 80 Million - ROSEXIMBANK (loan)
- USD 76 Million - CITIBANK (loan)

Cost comparison of different PLEX programs

In 2002 the IAEO published a report on investment cost for PLEX programs based on experiences in different countries. Not all countries participating in the project agreed to publish their investments in the report. In this report the economic advantages of continuing operation of these plants should be demonstrated in the framework of cost-benefit analysis. One important factor for this analysis is the cost needed to continue operation beyond the planned life.

The technical report on “Cost Drivers for the Assessment of NPP Life Extension” develops a methodology to determine the cost inputs required to perform cost-benefit analysis for plant life extension schemes and presents cost and technical data on life extension/life management collected through a questionnaire sent to selected Member States.

The report was prepared in 1999–2001, by the Nuclear Power Engineering Section and Planning and Economic Study Section under the Department of Nuclear Energy. PLEX/PLIM cost data were reported for five PWRs, one BWR, one Magnox, four WWERs and six PHWRs.

The IAEA report provides us with a compilation of cost data estimations from different countries, which are not necessarily directly comparable and they have to be interpreted considering, different types, size, design and vintage of the plants; different regulatory and environmental requirements, spent fuel and radwaste storage policy, the extent of modifications, labour cost etc. Even if we consider all differences and uncertainties we find some instructive results:

Comparison of PLEX cost estimation in US$/kWe

group 1: <120 US$/kWe
Borssele (PWR 450 MW), Kozloduy-5 (WWER 1000), Kola (WWER 440/V230)

group 2: 120 - 250 US$/kWe
small BWR (400-500 MW) Japan, PWR 900 MW France

group 3: 250- 410 US$/kWe
small PWR (500 MW) Korea, PHWR India

group 4: 410 - 680 US$/kWe
Gentilly 2 (630 MW CANDU), Fort Calhoun (PWR 470 MW) USA

group 5: > 680 US$/kWe
small Magnox (120 MW) UK, Pickering A (PHWR/CANDU 500 MW) CAN,
small PWR (300-400 MW) Japan

Since PWRs are the majority of reactors in operation and the first models were of a small capacity, 400-500 MWe PWRs are the most investigated subjects for the PLEX cost estimation in the IAEA technical report (IAEA 2002).

The cost distribution reaches from the cheapest group to the most costly PLEX programs In this spectrum we find reactors with completely different initial situations in the same price group, and reactors with a similar initial safety status in the low and the high price groups as well.

Most astonishing is that Kola the most criticised old Russian PWR type reactor, a plant without any containment and only marginal safety systems shall be operated safely for 45 years for the same cost as an old Western PWR which originally had a distinctly higher safety standard.

Glossary

ASN	French Nuclear Safety Authority	PLIM	Plant Life Management
CEZ	Czech electricity utility	PSA	Probabilistic Safety Assessment
CNS	Convention on Nuclear Safety	PSR	Plant Safety Report
DSIN	Direction de la Surete des Installations Nucleaires	CDF	Core Damage Frequency
EDF	Electricite de France	PWR	Pressurized Water Reactor
IAEA	International Atomic Energy Agency	RPV	Reactor Pressure Vessel
IEA	International Energy Agency	TSO	Technical Support Organisation
LTO	Long Term Operation	SG	Steam Generator
NEA	Nuclear Energy Agency / OECD	SUJB	Czech Nuclear Safety Authority
NNI	No Nukes Info source	VVER	Russian type of PWR
NPP	Nuclear Power Plant	WONUC	World Council of Nuclear Workers
PLEX	Plant life Extension		

Literature

CNS BG NR 2004: National Report on Fulfillment of the obligations of the Republic of Bulgaria on the Convention on Nuclear Safety, 2004

CNS CZ NR 2004: Convention on Nuclear Safety; Czech Republic National Report, 2004

CNS F NR 2004: Convention on Nuclear Safety, France National Report 2004

IAEA 2002: International Atomic Energy Agency: Cost drivers for the assessment of nuclear power plant life extension,TECDOC-1309, Vienna, 2002

NEA 2000: Status Report on Nuclear Power Plant Life Management, NEA/SEN/NDC (2000)6

NEA 2002: International practices with respect to licence periods/terms for nuclear facilities in NEA member countries, NEA/CNRA/R(2002)1

NNI 2005: http://www.ecology.at/nni/, No Nukes Infosource, webservice provided by Österreichisches Ökologie-Institut.

UBA 2005: Becker O., Hirsch H., Lercher J., Seibert P., Wenisch A., UBA(editor): Report to the Austrian Government - EIA procedure for the lifetime extension of Paks NPP: Statement on the Preliminary Impact Assessment Study, Vienna, 2005

WONUC 2006, http://www.wonuc.org, 2006