The Role of Nuclear Power in Slovak Republic
Safety Upgrading Program for WWER Reactors

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General overview

The Slovenské elektrárne, joint stock company (SE) is the dominant electricity generator in the Slovak Republic with a total installed generating capacity of 6,147 MW at the end of 1997, which represents approximately 86% of the total installed capacity of power plants in the SR. In the year 1997, SE supplied 25,246 GWh (88%) of the electricity consumed in Slovakia (of which 14% was imported). SE generated in their own sources 21,170 GWh, from which 51 % at nuclear, 29 % at thermal and 20 % at hydro-electric power plants. In addition, the Company produced 11,937 TJ of heat, used mainly for residential heating but also for industrial purposes.

Fig. 1

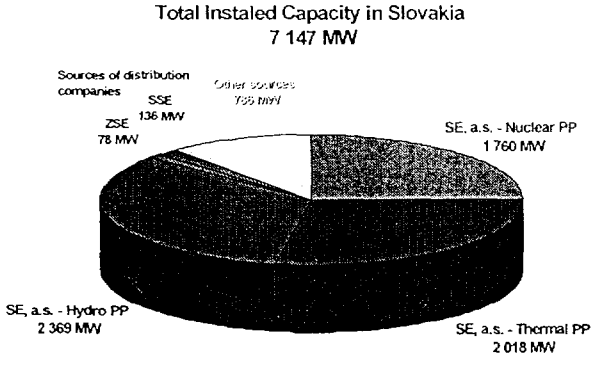
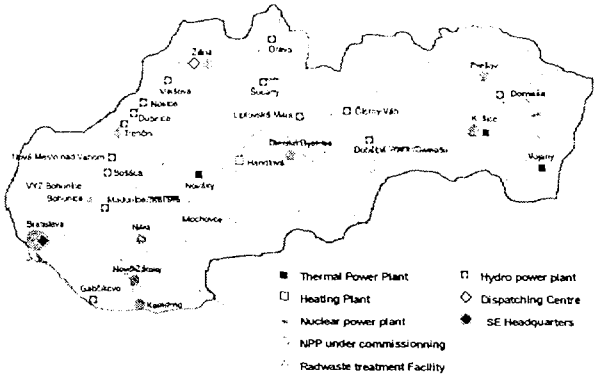


Fig.2 Power sources of SE



Besides one nuclear power plant in operation in Bohunice site (4 units WWER 440/2x V213, 2x V230) and one under construction at Mochovce site (4 units WWER 440/V213), three thermal power plants and 23 large hydro-electric power plants, the Company owns and operates the national high voltage transmission grid, which consists of: 1,514 km of 400 kV and 962 km of 220 kV transmission lines, 21 transformer stations and 3 other switchyards of 400 kV with 8,110 MVA of installed capacity and the central dispatching centre.

Management of Slovenské elektrárne, aware of dominant position of company on Slovak energy market, declared the main company goals, which includes following targets :

- *safe, ecological, reliable and economical* operation of electric and heat energy sources and power system

- ensure - in accordance with governmental program of economy development - *balanced* consumption and production of energy (do not exceed 15 % share of electricity import)
- *increase safety* of nuclear sources and keep them on international acceptable level of nuclear safety
- apply *Least Cost Planning* methods in development plans and design energy sources with reasonable costs for future
- decrease long term *ecological impact* in according with international commitments of SR
- intensify co-operation *UCPTE and CENTREL* countries and gradually integrate power system of EU and Slovak Republic

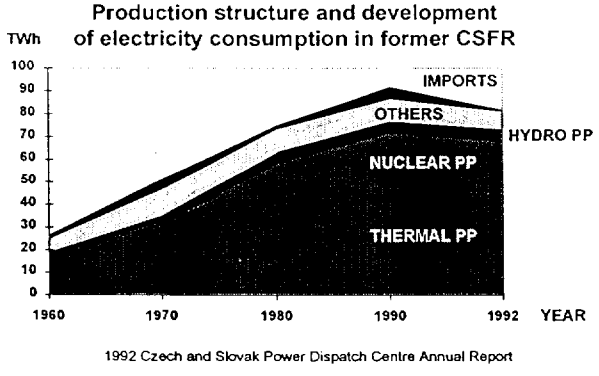
The development of power production base structure in the former Czechoslovakia back to the seventies can be described as follows:

- nuclear energy sector development started in the 70-ties with an extensive development in the 80-ties at Bohunice and Dukovany sites
- growing power consumption up to the year 1990 followed by a decrease in the beginning of the 90-ties due to economy transformation process.

The 1991-1996 Slovak Republic power production and consumption diagram highlights the following:

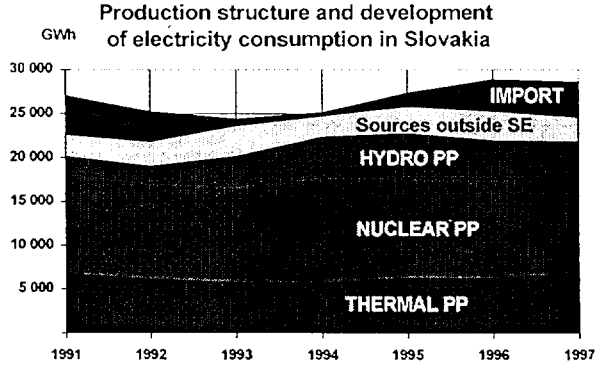
- indispensable role of the nuclear energy sector in power production base represented over by a 50% permanent share in the SE power generation (about 40% of total consumption in Slovakia)
- increased power generation from hydro power sector in 1993 as a result of a successful commissioning of the Gabčíkovo Hydro-Power Plant
- permanent increase of electricity import since 1994, which covers the rise of electric power demand caused by recovery of Slovak industry and economy

Fig.3



1992 Czech and Slovak Power Dispatch Centre Annual Report

Fig.4



Recent development of electricity consumption in Slovak Republic and forecast for future shows the shortage of electricity, which is necessary to cover by import. Review of current production base forces SE to take a decisions how to replace those sources, which will reach the end of their life time in a near future.

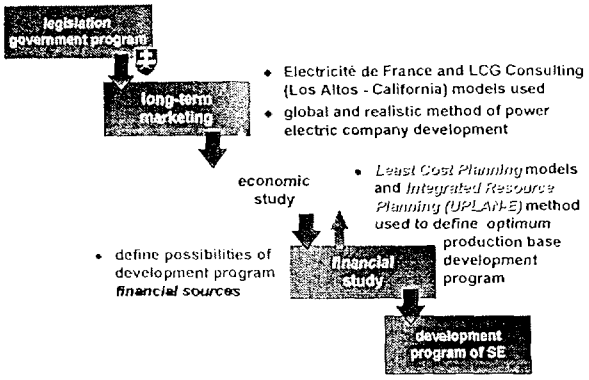


Fig.5 Production Base Development methodology

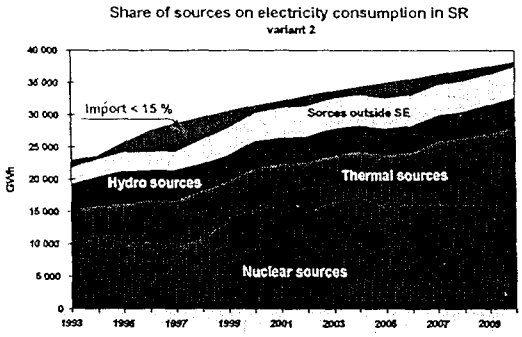
To ensure a safe, reliable, ecological and economical electric power sources for future, SE company elaborated „Production base Development Program". This program is based on Least Cost Planning (LCP) models of Electricité de France and Integrated Resources Planing (IRP) methodology which allow to define optimal production base development conditions. At the beginning of Investment planning method is defining of long-term marketing based on state government program, proposed growth of GDP and state legislation. Results of marketing study are used by economic study which shows the optimal alternative of electric power system development program financial sources.

As result of all these studies is elaboration of several variants of SR energy system development. Management of SE decided to implement variant with the lowest costs - variant No.2. Production base development program of SE according variant 2 represents completion of Mochovce NPP in accordance with current international nuclear safety standards, nuclear safety upgrading of Bohunice V-1 NPP and modernisation of technological equipment and safety systems of Bohunice V-2 NPP, reconstruction and implementation of large ecological projects at thermal power plants and effective usage of hydro potential of Slovak Republic. Program includes a participation of SE on combined cycle units construction, co-operation with independent power producers and analysing of renewable sources.

Fig.6 Different variants evaluated by LCP methodology

VARIANT		1	2	3	4	5	6	7 a	7 b
SOURCE	V-1	2000	2005		2010	2005	2000		
	V-2	in operation						2001	
	EVO1,2	in operation from 1998				uncompleted			
	EVO3,4	in operation from 2003/ 2004			uncompleted				
	TEKO1	in operation to 2005, replacement with Combined Cycle (CC)							
	ENO C	decommissioning - 1998							
	EVO2	denitrification of 6 units							
	HPP Gabčíkovo, since 1998 balanced share			desulphurisation of ENO B and 2 units EVO1					
	replacement of 4 units EVO1 with fluid units			fluid unit ENO A					

Fig.7



Electricity generated at nuclear power sources will still play very significant role at energy power system of Slovakia. As it was shown the power generated in recent period and also in future by the nuclear power plants represents approximately 50% of the Slovenské elektrárne electric power generation. Due to such high level of commitment of nuclear power in the overall power generation system, a special attention is given to safe and reliable operation of the existing NPPs.

Bohunice V-1 Units Nuclear Safety Upgrading

Safety upgrading and operational reliability improvement was carried out by the Bohunice NPP staff continuously since the plant commissioning. By now, more than 1000 minor or major modifications have been implemented, either by the NPP maintenance staff or by the

contractors. A number of IAEA and other international missions took part on the safety evaluation of the Bohunice NPP since 1990. Suggestions and recommendations of these missions were accepted by the utility and Bohunice NPP management, and a number of them have already been implemented.

General safety upgrading strategy at Bohunice NPP takes into account deterministic as well as probabilistic principles, although the probabilistic approach gains the more significant role in recent years. On the basis of combination of both approaches prioritisation and scope of measures to be implemented are taken.

In the 1990 - 1993 period, the following extensive projects have been realised:

- successful annealing of Unit 1&2 reactor pressure vessels during 1993 annual refuelling outages, carried out jointly by the Bohunice staff and the Skoda company
- installation of a large number of diagnostic systems on technological equipment
- development of Probabilistic Safety Assessment (PSA) study in co-operation with the Electrowatt.

Based on findings of safety assessment missions invited by Bohunice NPP in 1990 -1991, the Czechoslovak Atomic Energy Commission (ČSKAE) issued a lists of 81 safety upgrading measures to be taken in different areas. These improvements are referred to as the "**Small Reconstruction of the Bohunice V-1 NPP**". As a result of the "Small Reconstruction", a total cost of which was 2,0 bil. SKK ($ 67 mil.), the standards of both the nuclear safety and operational reliability have been significantly improved and the Core Damage Frequency has been decreased from $1,7 .10^{-3}$ / reactor.year down to $8.8 .10^{-4}$ / reactor.year.

Fig. 8 PSA results and goals of Bohunice V-1 safety upgrading

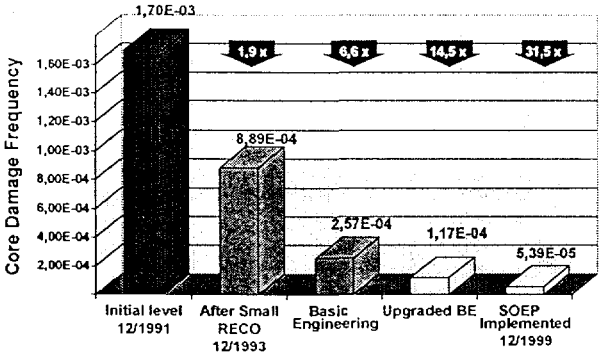
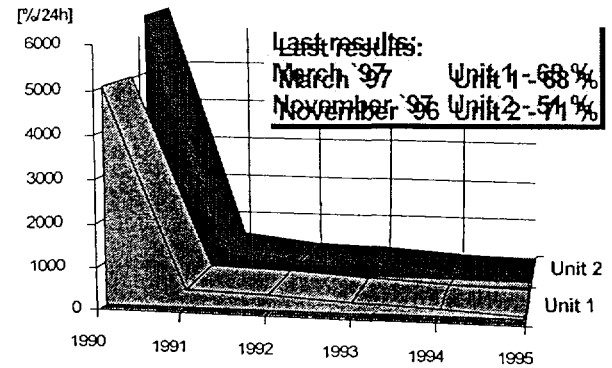


Fig.9 Improvement of Bohunice V-1 hermetic zone tightness



During the period of the Small Reconstruction the development of a Safety Report for the Gradual reconstruction has been completed. Based on this report the SR Nuclear Regulatory Authority issued the Decision No.1/94, in which requires 59 upgrading measures in different areas to be addressed. The development of Basic Engineering of the **Gradual Reconstruction** has been contracted to the Siemens AG. Implementation of safety measures are provided through contract with the consortium REKON (which consists of Siemens AG company and Nuclear Power Plants Research Institute Trnava) and other Czech, Russian and Slovak companies. By the Gradual Reconstruction the Bohunice NPP intends to fulfil the following targets:

a) deterministic targets:

- to cope with the new defined maximum DBA (LOCA 2 x Φ 200) by a conservative approach, and coping with BDBA (LOCA 2 x Φ 500) using the Best Estimate Method

- the confinement leaktightness and accident localisation system must assure that dose equivalents (50 mSv for the whole body and 500 mSv for thyroid) are not exceeded in the monitored vicinity of the power plant during DBA LOCA 2 x Φ 200, and 250 mSv for the whole body and 1500 mSv for thyroid during BDBA LOCA 2 x Φ 500 using the BEM
- seismically upgraded engineered safety features to withstand 8° MSK-64

b) probabilistic targets:

- safety systems must have failure probability less than 10^{-3} / year
- Core Damage Frequency (CDF) lower than 10^{-4} / reactor.year
- the failure probability of the reactor trip system should be less than 10^{-5} / year

The process of safety upgrading, which takes place *gradually* during extended refuelling outages and overhauls in the course of 1996 through 1999 (the origin of the term „Gradual Reconstruction" include implementation of the following modifications:

- integrity of reactor coolant system
- modifications of the emergency core cooling system including residual heat removal in case of a seismic event and provisions for a sufficient boric acid concentration in the reactor coolant system (separation to 2 x 100 %) primary side Bleed and Feed
- confinement integrity and installation of isolation valves at the confinement boundary pipes
- confinement strength at maximum overpressure during LOCA 2 x Φ 500 mm
- backfitting of the accident localisation system to cope with accidents within the confinement
- hydrogen monitoring and hydrogen recombinators inside the confinement
- modifications of the sprinkling system (separation to 2 x 100 %)
- building up the essential service water system for safety related systems
- electrical systems (motor-generators, diesel-generators, emergency power supply system, internal consumption power supply, power transmission, redundancies of switchboards and consumers...)
- secondary side Bleed and Feed (emergency feed-water pumps and the steam generators steam dump systems)
- significant seismic upgrading of the technological equipment
- fire protection improvements
- modifications of the ventilation systems.

The total estimated cost of this extensive upgrading program is SKK 5,5 bil. ($ 180 mil.).

By implementation of the above measures achievement of an internationally acceptable nuclear safety level and maintaining the designed operational life-time at the V-1 NPP is anticipated.

Bohunice V-2 Units Nuclear Safety Upgrading

Since the commissioning of Bohunice V-2 NPP more than 300 hardware modifications and software improvements have been carried out. As a main result of first comprehensive program for safety enhancement, developed in 1986 and updated in 1987, is implementation a number of measures at hardware installation, redundant power supply, instrumentation and control, fire protection, seismic reinforcement area.

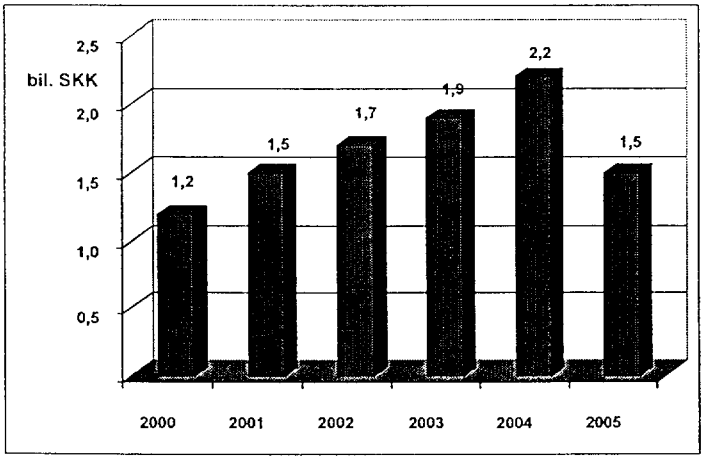
For further safety enhancement of Bohunice V-2 units are appointed following targets:

- increasing of nuclear safety to the currently acceptable level according to standards issued by Slovak Republic Nuclear Regulatory Authority (SR NRA) as well as IAEA recommendations
- creation of conditions allowing extension of Bohunice V-2 units lifetime to 40 years in compliance with the SE Production Base Development Program
- build up conditions allowing increasing of nominal installed capacity of these units

Probabilistic approach has become a basis for any further upgrading considerations also at V-2 units. It is based on PSA studies produced by Bohunice experts in co-operation with the Nuclear Power Plants Research Institute Trnava and RELKO, Ltd. The PSA methodology was reviewed, approved and highly valued by the IAEA Peer Review Mission in January 1995 in terms of the input database and in terms of technical approach. Calculated CDF based on Unit 3 PSA model is 6,41. 10^{-4} / reactor.year. Implementation of symptom-oriented emergency operating procedures (in co-operation with Westinghouse) and emergency feed water system modifications should decrease the CDF to 7,84 . 10^{-5} / reactor.year. From probabilistic point of view were determined targets listed bellow:

- safety systems failure probability $< 10^{-3}$ /year
- Core Damage Frequency $< 10^{-4}$ / reactor.year
- probability of radioactive emissions into the environment exceeding limits for population $< 10^{-5}$ /year
- reactor protection system failure probability $< 10^{-5}$ / year

Fig. 10 Planned investment costs of V-2 units upgrading



To reach these appointed targets the Program of Upgrading and Safety Improvement of Bohunice V-2 Units is prepared. However, time schedule for the implementation of nuclear safety enhancement programs at the Bohunice V-1 and V-2 Units has to take into account the requirement of a uniform distribution of financial costs and human resources at Bohunice site in the future. Therefore there are several periods of safety upgrading process of Bohunice V-2 units running:

- **1st stage** - resolving necessary actual issues, represents modifications with lower costs, which is possible to implement while Gradual Reconstruction of V-1 NPP is running, new safety evaluation of the Bohunice V-2 units - identification of safety deficiencies and prioritisation of measures
- **2nd stage** - period of implementation measures from Decision of SR NRA No. 4/96, 2nd and 3rd category safety measures presented in document IAEA WWER-EBP03/96, measures from Final Safety Analyses Report (updated after 10 years of operation), elaboration of preparatory and safety documentation for further stages of reconstruction - Initial design,

- 3rd stage - implementation of measures included in Initial design and measures concerning to increasing of nominal installed capacity
- 4th stage - implementation of measures regarding to reach designed and extension of lifetime of Bohunice V-2 units up to 40 years

General Bohunice Projects

As a result of all projects mentioned above which are already implemented a number of them with a general effect on Bohunice site safety is evident:

- Quality Assurance Program and Personal Training Program - in co-operation with the Nuclear Electric Plc. and funded by the UK government
- Multifunctional simulator - development of a simulator with international co-operation with CORYS, BELGATOM and Siemens, funded by the European Commission
- Installation of a number of diagnostic systems (evaluated as a „Good Practise" by OSART 96)
- AKOBOJE Site Security System - implemented by CEGELEC-TERMATOM
- Teledosimetric system - monitoring of the 15 km radius area around the Bohunice site (evaluated as a „Good Practise" by OSART 96)

Fig. 11 Bohunice NPP diagnostic systems

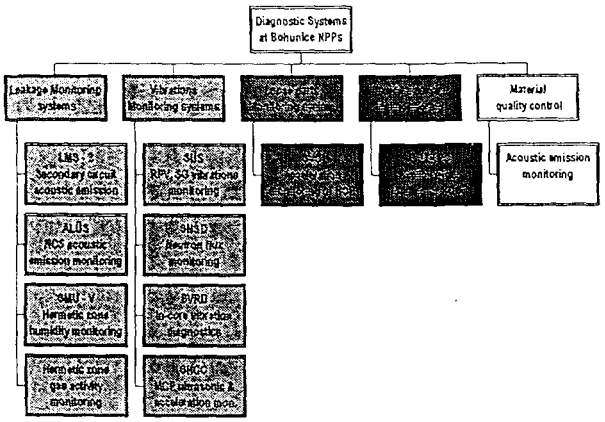
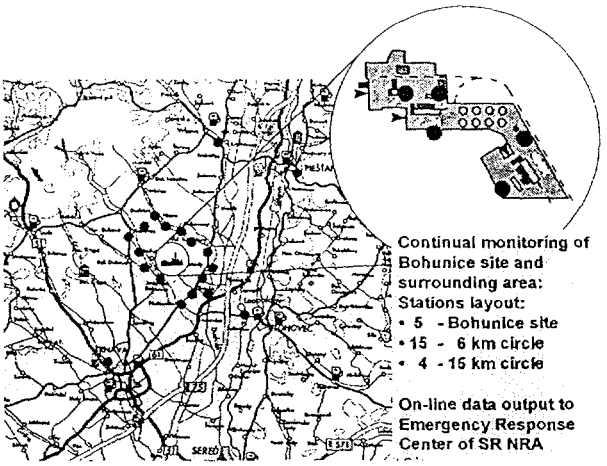


Fig.12 Bohunice NPP teledosimetric system



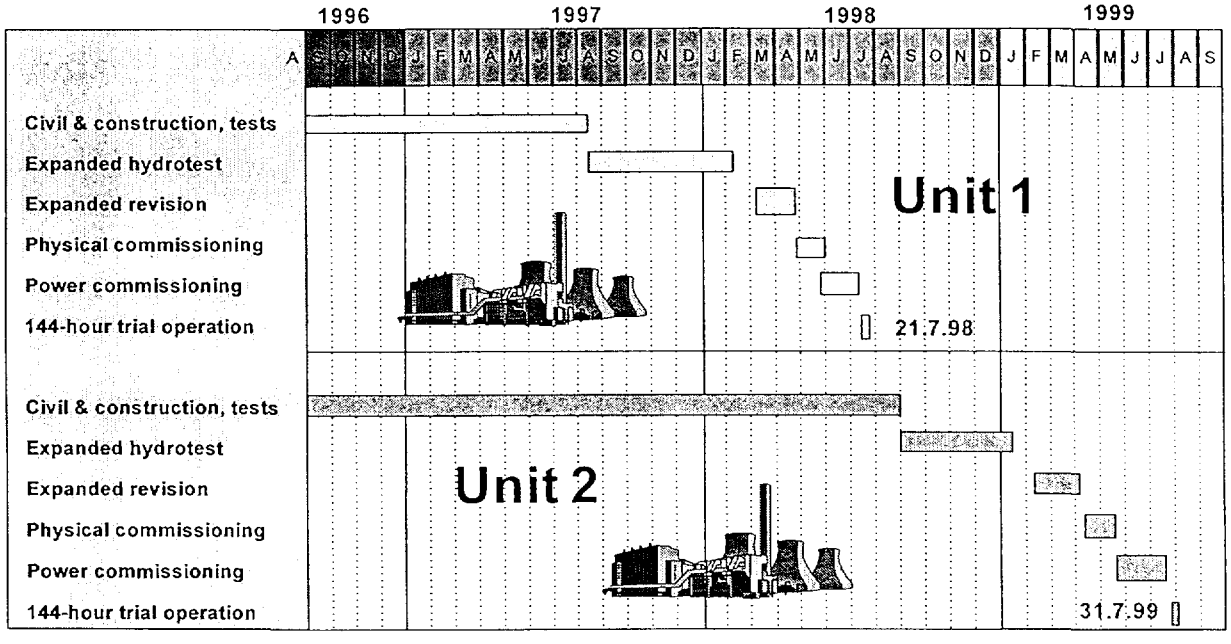
Mochovce Nuclear Power Plant Safety Installations

Completion and commissioning of the Units 1 and 2 of the Mochovce NPP at June 1998 and June 1999 is a strategic goal for meeting the future power demand and key environmental issue. Completion of Mochovce Unit 3 and 4 is under consideration and it is a subject of independent study, which has to show effectiveness of this source of energy compare with other kinds of electricity sources.

Our interest to operate only nuclear power plants with high standards of nuclear safety we can declare on preparation of completion and commissioning of Mochovce Nuclear Power Plant. Wide co-operation of our company with International Atomic Energy Agency and west European institutions and companies has been started with aim to fulfil the nuclear safety requirements for Mochovce NPP. Based on recommendations of safety analyses reports listed below the program of safety enhancement of Mochovce NPP was developed:

- IAEA, WWER - SC-108, Safety Issues and their Ranking for WWER 440 Model 213 Nuclear Power Plant, (7 April 1995)
- IAEA, WWER - SC-102, Mochovce Safety Improvement Review Mission, (8 September 1994)
- RISKAUDIT report No. 16, Evaluation of Safety Improvements Mochovce Nuclear Power Plant, (20 December 1994)

Fig. 13 Time schedule of Mochovce NPP completion and commissioning



Set of 87 safety measures was prepared to implement at Mochovce Unit 1&2. Ranking of these safety issues, according the IAEA SC-108 report, shows that there are no issues from 4th category, 8 measures from 3rd category, 49 measures in 2nd category and the rest - 30 measures in the 1st category. All these measures are devoted to increase safety in different areas: reactor core coolant systems, primary circuit component's integrity, instrumentation and control systems, electric power supply, internal and external hazards, fire protection, operational instructions, etc. More than 70 % of these measures, mainly form the more serious category 3 and 2 will be finished before start up of the Mochovce Unit 1.

Conclusion

Implementation of Slovenské elektrárne Production Base Development Program, where all these safety upgrading projects of nuclear power sources at Slovak Republic are included will ensure first of all safety of nuclear power sources on internationally acceptable level, operational reliability of nuclear power units, balanced consumption and production of electric energy in Slovakia and decrease of long term ecological impact in according with international commitments of Slovakia. This is the way, how management of Slovenské elektrárne, a.s. wants to meet the goal declared above: *safe, ecological, reliable and economical* operation of electric and heat energy sources and *increase and maintain safety of nuclear sources on internationally acceptable level.*