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THE NUCLEAR POWER PROGRAM IN CIS-COUNTRIES. STATUS AND TRENDS

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ABSTRACT - The status and prospects of nuclear power development in the newly-independent states in the territory of the former Soviet Union are considered. The prerequisites as well as the scientific - technical and industrial basis for the implementation of the national nuclear programs are discussed. The tendencies in development of a new generation of advanced reactors are described.

The Soviet Union undoubtedly pertained to the industrially developed countries and was legitimately considered one of the world leaders in such fields as nuclear power and new power technologies. The Soviet nuclear power programme adopted in the early 1980s had an adequate scientific and industrial base and every prospect of success.

It included the following items:

- very rapid growth of the nuclear electricity-generating capacities;

-expansion of the sphere of nuclear energy utilization by its introduction into industrial and residential district heating;

-rapid development of the fast breeders aimed at long-term fuel supply of nuclear power;

- development of low-power nuclear power installations for remote areas as well as development of civil nuclear shipbuilding.

The rate of expansion being achieved by the Soviet nuclear industry in the mid-1980s comparable with that found in countries regarded as engaged in "rapid deployment" of the technology (USA, France, Japan). There was an annual 4-5 GWe increase of nuclear generating capacity, nuclear units as large as 1,5 GWe were successfully put into operation, while 35- 40% of total electricity in some regions was generated by NPP's.

The program of nuclear power development in the USSR was based on the developed infrastructure of the nuclear fuel cycle. The nuclear-industrial complex developed for military purposes includes all the productions essential for functioning of the nuclear power industry. It should be noted that about 80% of the nuclear-industrial complex was concentrated in Russia. The industrial and raw-materials potential of this complex enables even now the operation of NNPs with an installed capacity of about 100 GW. Moreover, there is the potential for using tens of tons of plutonium and hundreds of tons of highly-enriched uranium from nuclear weapons.

The technological crisis of 1986 entailing very hard consequence stopped the program of forced development of nuclear power in the USSR. On the whole, research works, construction and extension of NPP were interrupted on 39 sites of total capacity 109 GW. But Chernobyl did not eliminate Soviet nuclear power. No nuclear power units on the former Union territory (with exception of the Armenian NPP) were put out of operation after 1986 in the direct connection with the accident.

The subsequent political crisis, which divided the Soviet Union into fifteen independent states, could not immediately liquidate the common fuel- energy complex with common electricity, gas and oil supply systems, nuclear power complex whose key productions proved to be on the territories of several ex-USSR countries (Russia, Ukraine, Kazakhstan etc.). This situation as well as the evidence of growing reintegration processes in the CIS permit us to go beyond the limits of Russia in the consideration of nuclear power program and to make an attempt to estimate the prospects of the whole region which had been a single country not long ago.

With the establishment of their new borders many of the politically independent countries of the former Soviet Union have found themselves in the economic dependence on their neighbors and, first of all, on Russia. It is reasonable that in elaborating the energy policy of the new independent states all the above circumstances played an essential role and led, in some cases, to serious intentions of developing the nuclear sector of the energy economy not only on Russia (Ukraine, Armenia, Kazakhstan, and probably Belarus).

Following are the comments to the current status and the prospects of nuclear power in the individual countries of the former Soviet Union.

Russia. The part of nuclear energy production has increased from 11% in 1990 to 12,4% in 1993 and fell to 11,2 in 1994. It should be noted, that this rate is considerably higher in industrially developed regions of the European part of the country (24% - in the Central region, 48% - in the North-Western region). The stable nuclear energy production continued up to 1994.

With the all commercial production recession of 20,9% in 1994 comparing with the 1993 level, production of the energy resources reduced by 6,3%. The electricity generation dropped by 92% of the 1993 level. The fall in the nuclear electricity output was the most significant one: by 18%. It should be emphasized that the crisis in the Russian nuclear power was caused by purely economic rather than by technological factors and is associated with the growth in nonpayments for the electricity supplied to the consumers. Overcoming this crisis, in order to reach the level of 1990, may by forecasted, using the most optimistic scenario, in the year of 2007 the lowest scenario - after 2020). Proceeding from these assessments, as well as from some economic factors and technical preconditions, the scenarios of evolution of nuclear power facilities in Russia up to 2015 were prepared.

Ukraine. Ukraine's nuclear power originated in starting up the first Chernobyl NPP unit of 1000-MWe capacity. At present fourteen units are in operation at five NPPs. The total installed (gross) capacity of the NPPs is 12,8 million kW. The nuclear share in Ukraine's electricity output varies from 30 to 40% (amounting to 44% in the 1994 winter peak-load period). After the Ukraine's Supreme Council abolished the moratorium on putting new NPP capacities into operation, works on restoration and reconstruction of the unfinished units were begun. Three units are in the stage of completion (80- 95%). Three more power units can be put into operation for 7-10 years.

Armenia. Formerly country received 96% energy resources consumed in the Republic from Russia, transported then through the territories of Azerbaidzan and Georgia. Today it has become an extremely hard problem. Under the conditions of the most severe blockade of the communications of the Republic, which has no fuel resources of its own, and shutdown of the NPP in 1989, the electric power production in Armenia reduced by 2,5 times and the electricity deficit in 1993 amounted to more than 50%. In accordance with the foregoing the Armenia Parliament and Government made a decision to resume the NPP operation, with Unit-2 being started up in the 1995.

Kazakhstan. The installed capacities of Kazakhstan's power plants total above 18 GW to meet about 90% of national electricity needs. Most of the capacities fall on coal-fired thermal plants. The industry of the republic is characterized by a great share of energy-intensive, ecologically harmful metallurgical and chemical productions. Combined with the expansion of the coal-fired power engineering this creates a tense ecological situation in many industrial cities.

The analysis of the dynamics of energy production and consumption, the ecological situation and the projections of the economic development in Kazakhstan allows a conclusion about the expediency of the creation and development of the national nuclear power.

During the period of 2005-2015 several NPP with Russian 640-MW (e) reactor units is planned to be build. In addition, the construction of NDHPs is targeted for the same period.

Republic of Belarus. With total need of national economy of 53,3 million. tons of conventional fuel per year, annual production in this country makes just about 15% of this amount.

In 1992 the Council of Ministers of the Republic of Belarus approved the Power and Power Saving Development Program up to 2010. According to the program the main type of organic fuel for electric power stations and district heating will be natural gas. But this program is envisaged to put into operation a nuclear power unit with the capacity of not less than 500 MW till 2005, and till 2010 another one with the capacity of not less than 1000 MW. At present the works connected with the preparedness for NPP construction in the Republic are being carried out.

There are also prerequisites for some other countries (Georgia, Moldova) to enter the "nuclear club", however today their discussion is somewhat untimely.

Table 1. Status of Nuclear power (April 1995)

	Number of NNP	Total power GW	Number of power units	RBMK	VVER	Others (BN, EGR)	Number of units in final stage of construction
Armenia	1	0.8	2		2		
Kazakchstan	1	0.1	1			1	
Lithuania	1	2.5	2	2			
Russia	9	21.2	29	11	13	5	4
Ukraine	5	12.8	14	2	12		3

The current status of nuclear power in the post-Soviet countries is illustrated by Table 1.

The choice of the advanced reactor concepts for accomplishment of the next in turn stage of nuclear power development in the CIS countries with developed nuclear industry, has been practically completed. The dominant world and domestic experience with operation of the pressurized water reactors, obvious discredit of the water- cooled graphite reactor concept after the Chernobyl accident, made the PWR concept the basic of nuclear power development in Russia, Ukraine and, possibly, other CIS countries at least till the year 2010.

As it usually happens in development of a new generation of advanced reactors two tendencies interacts and are realized. On the one hand, this is the maximum utilization of tested and proven designs with some backfitting ensuring evolutionary increase in safety and economy so that the need in construction of pilot plants would be ruled out. On the other hand, this is the search for innovative technical solutions promising a cardinal improvement of the safety parameters and possibilities of extension of application sphere.

The first trend reflects the intense development of the designs based on the next generation of the VVER reactors, which is under way in Russia. These designs will have a higher level of safety, better power indices and fuel utilization than the existing designs. It should be noticed that in the Program of nuclear power development in the Soviet Union, adopted in the early 80s and in the first post-Chernobyl years the main designers efforts were directed to designing the large power (1000-1100 MWe) VVERs, namely the VVER-88, VVER-91, VVER-92, basing on the experience with the most used Soviet reactor VVER-1000 (design 320). However soon the center of designers attention returned to development of the medium power reactors but at a new technology level. These are the reactors with which in the 60s the Soviet nuclear power began, having demonstrated once more the truth of the spiral law of evolution. Among the arguments in favor of development of the advanced medium power reactors such as reduced construction time, lower financial risk, potential extension of market, the most important is undauntedly the possibility to increase the reliability and safety of NPP operation at the expense of simplified design and reduced reactor unit power. In this class of reactor designs the VVER line is realized by the VVER-640 (640 MWe).

The common feature of the advanced medium power VVER developments is the increased use of passive safety systems for preventing severe accidents and avoiding radioactive release above the permissible levels. Naturally, reduction in the core power density and the possibility of using additional passive protection systems are the main advantages of the VVER-640 design.

An innovative trend in PWR development, permitting the number of events resulting in accidental situations to be reduced is designs of the water reactors with integral arrangement of reactor equipment. In Russia this trend is represented by the VPBER-640 design. The design is supported by many technical solutions tested during the long Soviet experience with nuclear shipbuilding.

It should be pointed out that the line of the advanced VVER reactors is currently the most prepared for construction, and most Russian sites for erection of the new

NPPs and extension of the operating ones are oriented for 640 or 1000 MW VVER reactors.

To make the picture complete it should be noted that the supporters of the channels-type uranium-graphite reactors propose the design of an advanced reactor of enhanced safety -a multiloop boiling power reactor (MKER-800) with natural coolant convection. They also hope to create at least a pilot plant.

The review of the innovative ideas in the field of light water reactors (LWR), to be realized in Russia, should be added with a far advanced development of a reactor unit for single-purpose nuclear district heating plants with the highest currently available level of self-protection. Development of nuclear district heating plants for regions which need heating for most months (Russia, Kazakhstan) promises and essential improvement of the ecological situation in large cities. There are enough grounds to hope that the first district heating plant (ready by 80%) would be commissioned in the next few years.

Another promising application of the light water (as well as other types) reactors, specific for Russia and some other countries, should be mentioned here. Enormous thinly-populated regions with settlements concentrated, as a rule, around valuable raw material (rare and non-ferrous metals etc.) mining enterprises makes development of power supply systems based on power networks unpromising even in the long-term perspective. Small nuclear power (from a few MWt to 100-150 MWe) is being considered as an effective solution for mastering, for example, the northern Russian territories which make up about half of the country.

Thus, the light-water reactors, which have enormous practical experience, proven technologies of equipment and material production, necessary industrial infrastructure, will undoubtedly create the basis of the nearest phase in development of nuclear power in CIS countries. Even in those countries which are planning their own way in nuclear power (Kazakhstan, Belarus) any other way of development (e.g., basing on heavy-water reactors) is unlikely as it is quite natural for them to orientate to Russia's powerful potential.

At the same time, LWR has some disadvantages difficult to overcome. These disadvantages involve potential hazards (large reactivity margin, high water pressure, large chemical energy stored) which do not give ground to exclude a credible accident, low temperature potential, inefficient uranium utilization, large amount of long-lived nuclides generated in the fuel cycle. All these factors stimulate great efforts to look for a other reactor type.

One of the ways to overcome a low temperature potential and bring the nuclear reactors into the extending region of high-temperature technologies (commercial heat supply, metallurgy, chemical production, oil refining, etc.) was known long ago and has began to be developed in Russia since the 60s. In the 80s developments of the high-temperature gas-cooled reactors came to the stage of completed designs. Among them the most advanced one was the design of the pilot commercial installation VG-400 (400 Mwe) for supply chemical industry processes with up to 950°C heat. It should be emphasized that development of HTGR in Russia was based not only on accumulation of the world experience (USA, Germany, Grear Britain, etc.) but also on the high technologies proven during creation of domestic nuclear propulsion prototypes where, in particular, the world record on using the temperature in the nuclear gas-cooled reactor up to 3000 K was set up. It appears that the high temperature gas-cooled reactors are ahead of their time, and therefore the programs of their implementation were suspended both in the USA and Germany and in Russia. However the HTGR concept with its capabilities of reaching unique temperatures, use of high reliable ceramic fuel, low heat release into the environment seems to have every reason to be included into the long-term program of power development.

From the very beginning of nuclear power development it was clear that nuclear power cannot be the technology of the future without the fast breeders. In the USSR from the beginning of the fast reactors development a high attention was paid to the doubling time. It was considered that fuel breeding rate must be not less than the rate of the energy development (doubling time: 8-10 years). In the 70-s the opinion existed that the doubling time for the fast reactors must be 5-6 years.

Due to the slowing down of the power development rate the outlook on the future of the fast reactors has changed significantly. Now, the main attention should be paid to solving the economical ecological and safety problems of this reactors type.

In the time when the preferences were given to the reactors with the short doubling time, the sodium-cooled fast reactors (SCFR) had large advantages in comparison with the fast reactors with other types of coolants. The SCFR development strategy in Russia is based on experience gained in operating this reactor type for 85 reactor-years in the CIS countries (BN-350, BN-600).

The next step on the way of construction advanced FBR is the project of a small-series NPPs based on the BN-800 reactor. The BN-800 reactor will be fueled with uranium-plutonium oxide. This stage is of fundamental importance for further FBR development. It should precede FBR large-scale introduction to the nuclear power structure. If FBR power units are comparable with those of LWRs in terms of specific capital and generated electric power costs, the real way will be opened up for constructing a two- component nuclear power production system on the basis of FBR and LWRs. In this case, FBRs will provide a necessary fuel production, a weapon-grade plutonium utilization, and an actinide transmutation at a minimized thermal and radiological impact on the environment.

So, for creating the reliable and safe large-scale nuclear power system for long future we should have redundancy and diversity of reactor designs and scientific and technological decisions.

CIS Nuclear Power Outlook up to 2015

Gw(e)