BULGARIA

Experience and prospects in Bulgaria

Nuclear's share of electricity is expected to grow

by B. Dobrev and L. Spasov

The rapid economic and social development of the People's Republic of Bulgaria in the years following World War II necessitated an accelerated development of power production, in particular electric power. Consumption of electricity increased from 311 million kilowatt-hours in 1944 to 45 925 million kilowatt-hours in 1985.

Bulgaria is not rich in primary energy sources. Having no other alternative, the country decided to speed up the development of nuclear power, which is conducive to a greater concentration of capacity and improved power system economics and technology.

In 1974, with the commissioning of the first reactor at the Kozloduy nuclear power station, Bulgaria became one of the then 20 countries in the world possessing nuclear power. In 1985 Kozloduy generated more than 13 000 million kilowatt-hours of electric power, accounting for more than a third of the total electricity produced. In regard to nuclear's share of total electricity, Bulgaria ranks among the first not only in Europe but also in the world.

Plant commissioning

The Kozloduy nuclear power station is one of the most reliable and stable elements in the Bulgarian power system. The utilization of its installed capacity exceeds 7000 hours per year on average. It was built with the technical assistance of the USSR and is the pioneer of nuclear power in the Balkans.

The power station consists of four units with WWER-440 reactors. Construction on the first stage began in April 1970. The first unit went into industrial operation in September 1974 and the second in November 1975. The third and fourth units, belonging to the second stage, are of earthquake-resistant design and were commissioned in January 1981 and May 1982.

The total duration of commissioning operations for Units 3 and 4 was 210 to 240 days, as compared to the planned 360 days. This significant reduction was possible thanks to the personnel of units already operating, who co-operated in commissioning operations for the new units, and to the organizational and technical help of the Soviet team working at the Kozloduy station.

Apart from reduced times for individual stages of commissioning, considerable reductions were achieved in the times for physical and energy startup and for attainment of the rated power of a unit. Thus, for example, while Unit-1 required 90 days to reach full power, Unit-2 took 39 and Unit-3 27 days.

Results of commissioning operations at the four units with the direct organizational and technical assistance of Soviet specialists confirmed the correctness of major design options and showed the high manufacturing and operating quality of Soviet nuclear equipment for units with WWER-440 reactors.

Operations experience

Total capacity of the station is 1760 megawatts-electric (MWe), delivered to the power system through 220- and 400-kilovolt (kV) transmission lines. The 220-kV Kozloduy-Craiova (Romania) transmission line is used for parallel operation of the Bulgarian power system with the "Druzhba" unified power system of member countries of the Council for Mutual Economic Assistance (CMEA).

The reliable and safe operation of the Kozloduy station for 10 years bears witness to the high manufacturing quality and technical availability of Soviet nuclear equipment. On the basis of the technical and economic performance achieved at the station, we have every reason to say that it is operating in a reliable, safe, and economical manner. A comprehensive exchange of experience between Soviet and Bulgarian nuclear power engineers in scientific, technological, and administrative matters has contributed greatly to the safe operation of these units with WWER-440 reactors.

Based on the data, we can conclude that the Kozloduy personnel have fully mastered the operation of reactor facilities with series-produced WWER-440 reactors under the different operating conditions required of units in the Bulgarian power system. (See accompanying table for operations experience.) This has been made possible by collaboration with Soviet specialists in improving power plant management and maintenance, by continuous training of personnel, by reducing fuel loading and unloading times, by optimizing flowsheets, by lowering production costs, and by enhancing plant safety.

Electricity consumption in Bulgaria

Year	Gross consumption of electric power		
	Million kilowatt-hours	Average annual growth (per cent)	Kilowatts per capita
1945	401		58
1950	819	15.4	113
1955	2106	20.8	281
1960	4685	17.3	596
1965	10 232	16.9	1246
1970	19 407	13.7	2286
1975	28 860	8.3	3320
1980	38 667	6.0	4360
1985	45 925	3.5	5135

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Improving efficiency, safety

A number of organizational and technical measures have been introduced to improve the efficiency of the units.*

A promising way of improving the safety and economics of the Kozloduy facilities is seen in the possibility of more thorough analysis of all nuclear and radiation safety characteristics with the use of a system of microcomputers to monitor the operation as part of the standard system of power plant monitoring and control. Experiments on a Bulgarian microcomputer system for processing the results of startup operations in WWER-440 reactor units were completed successfully in 1981-82 on the control panels of Units 3 and 4 — the second stage of the Kozloduy plant.

Still further improvements in safety are to be made. These include perfecting and expanding the automated in-core measurement system, designing an automated system for dosimetric and radiochemical monitoring, and training personnel on simulators for the operation of the WWER-440 and WWER-1000 reactors.

Radiation emissions

Radiation levels, both in the power plant buildings and in the environment, during the entire period of operation have been well below the maximum permissible values laid down in the health and safety standards. Annual releases of gases and aerosols through the stack do not exceed the design values for 7 to 10 days. It is interesting to note that during the period in March 1977 following the earthquake in Romania, the radiation levels in the power plant buildings and in the environment remained unchanged while the units of the first stage continued operating at 100% power.

A special automatic earthquake protection system based on emergency shutdown of the reactor at a particular level of seismic activity has been designed and implemented.

Greater nuclear share foreseen

Development of nuclear power in Bulgaria is closely associated with a move towards concentration of capacities, which is a characteristic indicator of technical progress in power engineering. In 1987 the installed capacity of the Kozloduy station will reach 3760 MWe. The fifth unit, with a WWER-1000 reactor, is almost ready for physical startup and the sixth unit is under construction.

Establishment of the Kozloduy nuclear power complex was confirmed by decision of the Bulgarian Government. Apart from the nuclear power station, this complex includes a workshop for repair of power station equipment and production of spare parts and accessories, a workshop for centralized repair of the primary-circuit equipment, a spent-fuel storage, a workshop for repair and production of specialized measurement and control instrumentation and apparatus, and a training centre for operating personnel, among other things.

The policy of concentration will continue — the construction of Bulgaria's second nuclear power station, Belene, with an installed capacity of 4000 MWe, has started. The USSR-Bulgaria Inter-Governmental Agreement on its construction has already been signed. By the year 2000, Bulgaria intends to produce more than 40% of its electricity from nuclear power plants.

As nuclear power technology is developed and assimilated, there will appear new possibilities for its multipurpose and combined utilization in various sectors of the national economy. Of special topical interest to Bulgaria is the speedy introduction of nuclear district heating plants, which are immensely important for improving source material and fuel balances.

A number of specialists from Bulgaria have improved their skills, thanks to the opportunities offered by the IAEA to participate in events organized by it and to receive specialized training.

Main technical and economic characteristics of the Kozloduy nuclear power station, Units 1-4

	1980	1981	1982	1983	1984
Installed capacity*	880	1320	1760/ 1540	1760	1760
Electric power production					
Unit-1	3080	3066	2902	3069	2979
Unit-2	3072	2912	3018	3177	2868
Unit-3	13	3141	2875	2969	3383
Unit-4	—	—	1951	3102	3505
Total	6165	9119	10 746	12 317	12 735
Load factor**					
Unit-1	83.80	83.42	79.17	83.50	80.74
Unit-2	83.58	79.25	82.36	86.52	76.87
Unit-3	—	85.46	78.44	80.63	90.16
Unit-4	—	—	79.11	84.39	94.03
Overall	82.13	82.71	79.83	83.76	85.47
Operating time ratio (per cent)					
Unit-1	85.94	85.71	89.72	90.73	91.47
Unit-2	82.71	81.68	88.40	91.62	84.98
Unit-3	—	89.58	92.12	83.60	93.42
Unit-4	—	—	—	92.64	93.79
Power station internal load factor(per cent)***					
Unit-1	7.37	7.47	7.45	—	7.61
Unit-2	7.13	7.31	7.60	—	7.50
Unit-3	—	7.76	7.74	—	7.33
Unit-4	—	—	7.58	—	7.21
Overall	7.28	7.52	7.59	7.44	7.40

* Average capacity over the year, in megawatts-electric.
** Percentage of average installed capacity over a year for 420-MWe unit.
*** Including startup periods and time of power operation off-load.

* For example, after experiments to determine the efficiency of the ball self-cleaning system in the K-220-44 turbine condensers of Unit-3 in 1981, it was decided to install this system for the pipes of all turbine condensers (Units 1-4) by the end of 1985. With a view to improving the reliability and fail-safe properties of the secondary-circuit equipment, experimental results of corrective water chemistry introduced in 1981 (with proportioning of hydrazine solution in the condensate channel of the K-220-44 turbine of Unit-1) were analysed, and it was decided to use this system in all eight turbines of Units 1-4 (hydrazine concentration of 150-200 μg/kg). This will substantially reduce the concentrations of corrosion products and deposits on the heat-exchanger surfaces of the secondary-circuit equipment. Moreover, installation of filters for full 100% turbine condensate purification began in 1981, and this measure, too, will improve the reliability and economics of the units during their entire service life.