CREATION OF NUCLEAR HEATING PLANTS IN RUSSIA: PRESENT STATUS AND PROSPECTS FOR THE FUTURE

L.V. GUREEVA, A.V. KURACHENKOV
OKB Mechanical Engineering,
N. Novgorod, Russian Federation

Abstract

History of heating reactor developments in two sites, Gorky and Voronezh, using AST-500 was reviewed. After interruption of construction for several years, decisions were made to resume the constructions. At Voronezh, based on the environmental assessment and the review of the IAEA OSART mission, the construction was resumed in 1996. In the course of construction resumption, design upgrading has been implemented in the following aspects: reclassification of station-level equipment concerning its importance for safety; control and instrumentation systems retrofitting with reliance on new generation element bases; application of self-actuated safety devices; and implementation of additional instrumentation for extended operating conditions. In Tomsk, Siberia, feasibility study is underway, which aims to replace the currently operating reactors with a twin-unit heating stations with AST-500 in order to provide heat to the district heating grids. In the study the NHP design is being assessed by a joint Russian-American Study Team from evaluation criteria such as design applicability and constructability, maturity of the design, safety aspects, technical uncertainty, available infrastructure, engineering and construction capabilities, site suitability, cost and schedule. Positive possibilities are foreseen to reuse the components previously delivered to the Gorky site, according to the assessments of structures and technological tools necessary for the reerection work were, man-power needed for the equipment dismantling, inspection and reerection and storage conditions. The construction cost is estimated as US$446 per KW(th).

1. INTRODUCTION

1.1. The following conditions are needed for practical application of nuclear heating plants (NHPs):

* heating loads and availability of centralized district heating systems with powerful heat-distributing grids;
* economical efficiency compared to fossil-fueled plants;
* licensability from the nuclear and environmental safety authorities (GAN) and the Ministry of Nature for siting, construction, operation;
* regional and federal authorities approval on the NHP deployment.

In the late 1970s, all the necessary conditions for NHPs were met in two Sites in Russia: (Gorky and Voronezh), where construction of the two pilot nuclear district heating plants (AST-500) started in early 80s. Somewhat later, preparative works began also at the Archangelsk Site. The governmental decision was adopted to construct NHPs at a number of other Sites: Ivanovo, Bryansk, Khabarovsk, etc.

In ex-USSR all NPPs were invested from the State budget and plenty of machine-building plants were involved by the governmental decrees in the production of equipment necessary for the nuclear power generating and heating only plants. Unfortunately, the established nuclear equipment production cooperation collapsed lately. (A new cooperation is being created now, involving some defensive machine-building plants that have to convert their production).

In 1990 decisions were adopted by regional administrations to cease the NHP construction in Gorky and Voronezh. Until that time two sets of AST-500 RP components were delivered to the Gorky Site and one set to Voronezh. By that time construction and erection works of the first unit of the Gorky NHP was 83% complete (in cost term) and more than 30% on the Voronezh Site.

1.2. In 1995 a level of centralized district heating loads was about 1,200 x 10^6 Gcal (in 1990 it was 1,550 x 10^6 Gcal) in the European regions of Russia. This declining trend in the district heating loads is explained by macro-economical difficulties and the significant reduction in the industrial heating loads. However, the district heating loads in the region are now starting to buildup and are expected to rise further in future.

Specialists forecast the following values of household district heating loads in the European regions of Russia (Gcal) in the year 2010.

North-West	140 x 10^6 Gcal
Center	620 x 10^6 Gcal
Middle Volga	210 x 10^6 Gcal
Ural	370 x 10^6 Gcal

The European regions are remote from the fossil fuel production areas and the cost of fossil fuel tends to rise so that it is expected to reach the level of West-European market cost in nearest future. Furthermore, impact of conventional power industries on the environment is most hazardous in large cities. On the other hand, there are many suitable places for the NHP siting in these regions.

In addition, more than 50% of running heat generating plants in the region have exhausted their lifetime or approaching to its lifetime. Therefore, many difficulties arise when it becomes necessary to get licenses every year from the regulatory authorities for continued operation of these fossil-fueled power and heat generating plants. Federal and regional funds available for these plants' modernization are far from actually needed. Private banks and firms are not very interested to invest money in this business. Hence, the following factors are characteristic of the present situation:

* the cost of fossil fuel in many regions of Russia is approaching to the level of the West-European market costs;
* lifetime of many heat generating plants is being exhausted;
* more strict requirements are imposed by the environmental regulations; and
* positive trends in the public attitude toward nuclear energy.

All these factors are objective prerequisites for "renaissance" in the nuclear heating field. The first task on this way is to resume the construction activity on the Site of Voronezh NHP.

2. VORONEZH NHP. PRESENT STATUS

Until the suspension in 1990 of the NHP construction work at the Voronezh Site, one set of AST-500 reactor plant (RP) components were delivered to the site and more than 30% of construction-erection work was completed.

In 1994, under pressure of the acute district heating problem in the city, the regional administration initiated the NHP environmental impact review by the team of a public commission composed of qualified local scientists and engineers. After a comprehensive study and consideration of the design materials, and visiting the NHP Site, a conclusion was drawn up that confirmed the assured safety of the plant for both the local inhabitants and the environment. Also, recommendations were given by the Commission for the administration to make a decision on the resumption of the NHP construction as soon as possible. One of the positive factors was the results of the IAEA OSART mission by the experienced international review team on the Gorky NHP with the same RP AST-500 (1989). Main findings of the review were very positive.

In 1995 the Russian Federation (RF) Ministry of Nature performed the State level environment review. The Committee confirmed the previously made conclusion about a possibility to resume the plant construction. Based on this confirmation the regional and city's administration adopted the decision to proceed with the plant construction activity and to put it into operation.

As a result the construction work on the plant Site was resumed in 1996. The programs have been developed for the NHP design updating in conformity with the requirements of latest norms and rules for nuclear power plants and RP's equipment inspection being currently in force in Russia. Inspections for the plant's equipment available at the Site have been started lately aiming at its preparation for erection.

The design documentation and appropriate licensing materials are under consideration now by the State Regulatory Body (GAN), in order to grant the permission for the station construction resumption. The approval and license may be obtained in the first half of 1998.

Station design updating includes, in particular, the following aspects:

* reclassification of station-level equipment concerning its importance for safety (for some equipment items that are located outside the Reactor Island);
* control and instrumentation systems retrofitting with reliance on new generation element bases;
* application of self-actuated safety devices; and
* implementation of additional instrumentation for extended operating conditions.

Additional validation work should be carried out as well.

The Governmental Decree on the NHP construction resumption and operation has been prepared.

3. PROSPECTS FOR FUTURE. TOMSK NHP

The feasibility study aiming at the NHP deployment at the Tomsk Site in Siberia started in the 1980s. The nuclear heating station was considered as a new energy source to replace the weapon-grade Pu-production nuclear reactors after their lifetime expiration. These reactors are currently generating more than 900 Gcal/h for both the Tomsk and the Seversk district heating grids.

Under the US-RF agreement, Pu-production facilities in Seversk and Zheleznogorsk must be closed by 2000. Then these reactors would be possible to be operated in the "power only" mode (through their conversion) till the end of their lifetime.

The RF Ministry of Atomic Energy (Minatom) has already made the decision to use a twin-unit heating station with AST-500 reactors at the Site of Siberian Chemical Combine in Seversk. This design was evaluated along with other potential types of heat sources by a Joint Russian-American Study Team.

In the feasibility study the NHP design was assessed using nine decision making criteria such as: design applicability and constructability, maturity of the design, safety aspects, technical uncertainty, available infrastructure, engineering and construction capabilities, site suitability, cost and schedule. The Joint Team visit to the site gave an opportunity to review the proposed area for the NHP siting and to better understand geographical relation between the existing facilities and the proposed reactor plant.

Review of the AST-500 design identified no aspects that could raise undue safety concerns. Based on the greater design maturity and minimum research and development work requirements it was concluded that the AST-500 could be implemented with the greatest degree of confidence. This design uses proven technologies, relies on the completed tests of basic components as well as on solid

experience of marine NSSSs; also, the AST-500 reactor plant can be operated with bigger margin at low process parameters in the primary circuit (pressure, temperature).

The implementation of the AST-500 for the Seversk Site raises no serious construction issues. The proposed site is located near the city of Seversk and the existing infrastructure (power, transportation network, skilled labor, construction and engineering facilities, etc.) was judged to be sufficient to support the large-scale construction activity for the Project. Considering the near-term district heating demands in Seversk, the AST-500 should be the best choice to locate because of its appropriate design features, lower capital cost and shorter construction period.

The economic analysis of AST-500 was done in parallel by the US specialists using the American methodology (EEDB) and by the Russian specialists using the Russian procedure, respectively. The results of the American estimations were as follows (1994 dollars):

Total Direct Cost	280×10^6
Total Indirect Cost	108×10^6
Contingency	58×10^6
Total Plant Cost (2x500MWth)	446×10^6
Unit Cost, $/kW(th)	446

Although the methodologies used by the Russian and the American specialists were different, the results turned to be very close (within the range of a few percent).

This year materials have to be prepared for the receipt of the permission for the Seversk NHP siting and construction.

In order to expedite the station construction it was proposed to utilize the components previously delivered to the Gorky NHP. With this aim, the work was carried out on validating the first reactor unit dismantling at the Gorky site followed by their reerection on the Seversk Site. Structures and technological tools necessary for the work were designed, and the man power needed for the equipment dismantling, inspection and reerection was evaluated. Storage conditions for the RP components (delivered to the Gorky NHP in 1984 to 1989) allow good expectation of their satisfactory state.

At present the main task for designers is to obtain licenses for the start of construction work at Seversk. Now the RP designers are working on several engineering modifications for improving the AST-500 annual heat production capability and its economics, such as:

* increase an annual operating time up to 7000 h;
* connection of additional heat loads;
* electricity production during a non-heating period; and
* increase in a unit heat capacity of up to 600 MW.

Pilot AST-500+25%...Ggrid → 600 MW, Tgrid 122/32°C

The 25% increase in the grid water flow allows an increased heat delivery to the grid up to 600 MW.

4. DESIGN ACTIVITY ORGANIZATION

OKBM is the Chief Designer of the reactor plant, the RCC "Kurchatov Institute" is the Scientific Supervisor for the Project. VNIPIET (St.-Petersburg) was the General Designer (Architect-Engineer) of the Gorky pilot station and NIAEP, N.Novgorod, is General Designer of the Voronezh NHP. For the

Tomsk Site VNIPIET is nominated as the General Designer of the NHP and NIAEP as the General designer of the AST-500 Reactor Island.

Joint efforts of the designers will allow a consolidation of best engineering solutions, available experience and lessons that were gained for the period of the pilot NHP_S construction. Selection of the solutions being made with regard to updated safety and economic requirements with reliance on the OKBM experience in construction and operation of different $NSSS_S$.

Our experience confirms the following conditions are necessary for the efficient organization of activities to construct a nuclear power plant:

* Single "master" of the entire Reactor Island (design philosophy, safety concept, economical and technical requirements)
* Safety culture and highest quality in all phases of design life cycle;
* Equal reliability of all components.

The latest design of serial advanced NHPs (AST-500M) includes practically all reactor plant components that were designed by OKBM (main equipment items, safety systems, non-safety systems, control and instrumentation systems, etc.).

5. NHP COMPETITIVENESS ENHANCEMENT

The NHP designers have all grounds to consider the AST-500 as a new-generation reactor plant that meets the internationally recognized safety requirements. It also has quite real potential of economic advantages as compared to fossil-fueled plants, particularly with regard to the new fuel and economic trends in Russia.

Now AST-500 NHP designers are working to achieve better economic characteristics of the plant. The following measures are under consideration:

* increase in annual generating time at rated power up to 7000 hours;
* increase in annual heat production;
* decrease in staff quantity required;
* electricity production during non-heating seasons;
* increase in heat capacity using the identical main equipment; and
* improved reliability and lifetime of auxiliary systems and equipment.

Standard marine NSSS equipment items and technology are the basis for the NHP auxiliary equipment designs (i.e. heat exchangers, valves, filters, etc.). The long-term successful operation of the prototypic equipment has proved its high quality and reliability.

Better reliability and operating characteristics of the auxiliary equipment over its life lead to the less total quantity of systems and equipment, shorter maintenance terms, reduced staff quantity and, as a result, reduction in capital and operation costs. Moreover, it is possible to eliminate some systems and equipment within the reactor island and minimize maintenance work scope taking into account infrastructure available on the Site (as it will be for seen for the Tomsk NHP).

6. CONCLUSION

Objective conditions exist now in Russia which could promote activities in the field of nuclear energy application for district heating. Main goals on this way are as follows: to resume construction work on the Site of Voronezh NHP and to start construction on the Site of Tomsk NHP.

All review missions carried out by various commissions and experts (a pre-OSART mission by IAEA, the Joint Russian-American Study Team, the State Review Committee of the RF (the Ministry of Nature, the State Regulatory Body, etc.) have drawn conclusions about a sound basis of the AST-500 RP designs, well-provenness of technologies, completed testing of all key components, the conformity with requirements of national norms and rules and with IAEA recommendations as well as about the possibility of proceeding with the Voronezh plant construction work and initiating the Tomsk NHP construction.

Experience gained in the design, fabrication and construction of the pilot NHP_S, and conformity with general principles of the internationally recognized safety culture and assured quality identify the basis for the optimization of activity in this field. It is expedient to expand the role and responsibilities of the Chief Designer role in Project management of nuclear facilities. Such approaches allow more efficient work organization in the field and improve the economical competitiveness and safety of the NHPs.

REFERENCES

1. "Nuclear District Heating Plants AST-500. Present Status and Prospects to Future in Russia". O.B.Samoilov, A.V.Kurachenkov
2. "Technical Evaluation Report", prepared by US/Russian Study Team, Dec., 1995.
3. "Nuclear Heat Application in Russia". F.M.Mitenkov, E.V.Kusmartsev. IAEA, Advisory Group Meeting on Experience of Nuclear Heat Using", Dec. 1995.