A snapshot on Rooppur Nuclear Power Plant Project

Introduction

Bangladesh is strongly involved in achieving three consecutive development milestones: (i) a middle income country by 2021, (ii) a zero poverty level nation by 2030 and (iii) a high-income nation by 2041.-We need to secure sufficient supply of electricity to derive the desired level of economic growth for the three targeted socioeconomic development of our nation.

Over the last several years Bangladesh has made a significant progress in the development of the power sector. Government has undertaken various projects to increase the generation of electricity to cope with the rapid increases in the demand to support the economic development. Presently, Bangladesh is implementing a master-plan to produce 24,000 MW, 40,000 MW and 60,000 MW in the year 2021, 2030 and 2041, respectively. The Power System Master Plan (PSMP), 2016 aims to ensure supply of electricity to all citizen and economic sectors at affordable costs at all times through a well-balanced power generation environment that maximizes the respective advantages of different types of power generation methods, including nuclear power, thermal power, hydropower generation and power imports from neighboring countries. About 70% power generation plan will be covered by coal and gas and the remaining 30% will be covering by nuclear power, hydropower generation, renewables and power imports from neighboring countries. Nuclear power is considered as the base load energy and the share of nuclear electricity generation beyond 2030 will be about 10% of the total power generation.

Nuclear power plants (NPPs) are capable of generating low cost electricity and meeting modern society's demand for reliable and affordable electricity. Nuclear energy is clean air energy, avoids polluting the air that we breathe. Nuclear energy is a part of a diverse and balanced generation mix; energy security is strengthened when a nation uses it. Nuclear construction projects are the growth engine for the region where they are constructed and the NPPs are valuable long-term national assets which help to support healthy economy by providing employment and revenues from taxes. As of 1 July 2017, 447 nuclear reactors are operational in 30 countries, 60 new reactors under construction worldwide out of which 39 are in the rapidly developing countries of Asia. China alone has 19 reactors under construction and 6 in India, 4 in United Arab Emirates, 3 in South Korea and 7 in Russia are under construction. In 2015 and 2016, 20 new reactors were connected to the grid across the world.

The Early Phase of National Nuclear Power Programme and Rooppur NPP Project

The history of nuclear power in Bangladesh dates back to early 1960s. The proposal for introduction of nuclear power plant (NPP) in our country was made in 1961. Among potential twenty sites, the Rooppur NPP site was selected based on the then international practices and the plant was approved in 1963. Rooppur NPP site is located in the People's Republic of Bangladesh, on the eastern)left (side of the river Padma)the local name for the lower reaches of the Ganges River(, 160 km north-west of the capital -the city Dhaka, 21 km north-west from the city of Pabna, at a distance of about 8 km from the center of the sub-district Ishurdi .Site territory is located between 89° 02' and 89° 03' East longitude and between 24° 03' and 24° 04' North latitude.

Before liberation war and after the independence of Bangladesh, several feasibility studies for implementation of Rooppur NPP project were conducted but none was successful. In the meantime, pre-project phase activities were initiated during the period 1997-2021. Bangladesh Nuclear Power Action Plan was adopted in 2000 but after that no real progress was achieved.

Bangladesh government has taken a practical step for implementation of nuclear power programme from the beginning of 2009. The early activities included a detailed road map addressing all infrastructure requirements. We adopted the IAEA's Milestones approach and followed the steps required for each of the 19 infrastructure issues to build Rooppur NPP. Bangladesh established its NEPIO (Nuclear Energy Programme Implementing Organization) in 2010 based on the IAEA concept to monitor progress of nuclear power programme and Rooppur NPP project and coordinate all the required activities among the various implementing organizations/ministries involved in nuclear infrastructure development.

The National Committee Chaired by the Honourable Prime Minister is providing necessary directives and oversees the development of national infrastructure; establishment of the ownership pattern, project execution approach, selection of reactor technology, funding mechanism and HRD for Rooppur NPP project; capacity building in NPP owner/operating organization, strengthening nuclear regulatory and legislative infrastructure and creation of nuclear security infrastructure. Besides, the National Committee, a Technical Committee headed by the Honourable Minister, Ministry of Science and Technology (MOST) and a Working Group and eight Sub-Groups headed by Secretary, MOST have been formed to monitor progress of the project activities and coordinate among various relevant organizations and stakeholders– regulatory authority, NPP owner-operator, grid operator, transport authority, power development board, relevant law enforcement agencies, academic, research and educational institutions.

The IAEA has been supporting Bangladesh from its early phase of nuclear power programme. The Agency (IAEA) has been organizing training courses, workshops, fellowship and scientific visit programmes, educational seminars and with access to accumulated expertise in nuclear power to develop human resource of our country. A PC-based generic VVER-1200 training simulator facility has been established with the help of IAEA. The Agency's Integrated Nuclear Infrastructure Review (INIR) mission conducted in 2011 recognized that Bangladesh has progressed in building its first NPP. The INIR mission team concluded that Bangladesh reached Milestone 1, having "made a knowledgeable decision" regarding its nuclear power program and the country had progressed into Phase 2, in the stage of preparation to negotiate the agreement(s)/contract(s) with the selected NPP vendor. The INIR mission provided recommendations and suggestions on how to make further improvements. An Integrated Work Plan (IWP) for Bangladesh infrastructure development was developed through collaboration of the IAEA for the period 2012-2015 that provided a framework for the IAEA assistance to Bangladesh. Bangladesh had initiated its actions responding to all recommendations and suggestions provided by the 2011 INIR mission.

A follow-up INIR mission was conducted during 10-14 May 2016, to assess the progress of Bangladesh in the requirements and suggestions provided previously by 2011 mission. The follow-up mission report concluded that Bangladesh had made a notable progress in the areas of Management, Funding and Financing, Legislative Framework, Safeguards, Regulatory Framework, Electrical Grid, Human Resource Development, Stakeholder Involvement, Site and Supporting Facility, Environmental Protection, Emergency Planning, Nuclear Fuel Cycle, Radioactive Waste, Industrial Involvement and Procurement. Based on the reports of the

follow-up mission and taking into account the progress of Rooppur NPP project, the IWP has been updated covering the period 2016 – 2019. We are implementing the IWP under the close cooperation of the Agency for developing national competency for successful construction and commissiong of Rooppur NPP.

Bangladesh has created the legislative framework through a comprehensive nuclear law "Bangladesh Atomic Energy Regulatory Authority Act" that empowers the authority with the power, independence and resources it needs to carry out its function and responsibilities. The regulatory framework is established through formation of "Bangladesh Atomic Energy Regulatory Authority (BAERA" in 2012. The authority has been developing its competency for developing licensing process and performing regulatory supervision of activities at different phases of the project. BAERA is committed for undertaking its responsibilities in ensuring the highest standards of safety and security for Rooppur NPP.

Bangladesh developed a robust human resources strategy that identifies the scale and expertise needed for successful implementation of the programme and the project. Bangladesh has developed the required key competency for infrastructure development and project management through cooperation of international partners and then started developing the new and necessary manpower required for Rooppur NPP under the provision of the General Contrcat so that trained manpower for the plant would be available from the commissioning phase of the plant. Our human resource development programme for Rooppur NPP includes education and on the job training and mentoring. The country has introduced nuclear engineering educations at undergraduate and graduate levels in the reputed academic institutions and also providing scholarships to Bangladeshi studuents for higher education in abroad.

Over the years, the NPP siting activities have been evolved. The IAEA developed the NPP siting criteria and site safety evaluation methodology. As Roopppur site was selected long time ago based on the then criterias, in order to examine the suitability of the site and to introduce the features of Rooppur site to the IAEA and the vendor country, BAEC conducted Site Resource Investigation to derive site related data and information based on site specific issues, namely demographic, geotechnical, meteorological, hydrological features through involvement of national organizations, namely BUET, University of Dhaka, Bangladesh Water Development Board, Bangladesh Meterological Department, Survey of Bangladesh, Geological Survey of Bangladesh, Institute of Water Modelling, etc. during the period 2009-2012.

The IAEA Preparatory Mission for Site Evaluation of Rooppur NPP site was conducted during the period 10 -14 July 2011 to review the site reports and siting activities. The site suitability was justified; the IAEA mission recommended for performance of site assessment activities focusing on the geotechnical aspects and geomorphology, hydrological hazards and river morphology based on the IAEA guidelines. After Fukushima NPP accident, the IAEA gave emphasis on the site safety aspects and engineering solutions to increase resistance of plants to extreme natural events and recommended that the vendors should revise the site safety features-into their designs with adequate features to increase robustness of their designs to extreme natural events. Bangladesh decided to conduct the detailed site assessment study as a component of the project of NPP construction through the involvement of a NPP design organization of the vendor country.

NPPs have long-life times and low running costs, but they require high up-front cost which was identified as one of the key issues and challenges in implementation of NPP projects. There

is no single approach that can be applied globally to meet the financing challenges. Government's robust commitment and consistent support, high degrees of involvement, viable business model and sovereign guarantee are essential prerequisites for financing of the NPP project. Experiences learnt from the past, Bangladesh recognized that a complete solution from the vendor sources for the implementation of the project along with financing will be a suitable option for Rooppur project. Bangladesh has adopted a policy to finance Rooppur NPP project under a bilateral arrangement with vendor country with low-cost-loans with a longer payback period in one hand and decided to go with an experienced vendor who agreed to a fixed price contract for construction of the country's first NPP on the other hand.

Bangladesh signed an Intergovernmental Agreement (IGA) with Russian Federation for cooperation concerning the construction of two VVER-type reactor power units at Rooppur NPP site on 2nd November, 2011. The scope of the IGA included design, construction, installation, start up and commissioning and warranty operation of the Rooppur NPP, financing, fuel supply during the entire operational period of the power units, take-back of spent fuel to Russian Federation, education and training of Rooppur NPP personnel, cooperation for operation and maintenance of the plant, management of radioactive waste and decommissioning of the plant and other services. Under the provision of the IGA, the governments of Bangladesh and Russian Federation signed an intergovernmental credit agreement (IGCA) of $ 500 million state export credit on 15 January 15, 2013 for financing the preparatory stage construction activities of Rooppur NPP. Bangladesh also signed another IGCA amounting $11.385 billion on 26 July 2016 for financing the construction of the 2,400MW nuclear power plant at Rooppur.

The key stakeholders of the NPP project are the government, politicians, officials, public, nuclear regulatory authority, business group, media, educational institutions, scientific community, IAEA, vendor country and neighbouring country. We assumed that public and stakeholder engagement is essential, not optional. Bangladesh developed a joint action plan, signed a Strategy for Promoting Communication in Bangladesh Nuclear Power with Russian party for 2015–2021, which stipulates promotion of public awareness of the basic principles of nuclear energy, its benefits, safety and environmental sustainability among the society. Different media personnel, professionals, government senior officials, national and local political leaders, IAEA experts, university students and other stakeholders are being informed about Rooppur NPP technology by visiting the reference plant in Russia as well as our construction site.

Development of Rooppur NPP Construction Project

The construction of a NPP requires huge preparation and years of preparatory work. One of the biggest challenge is completion of the preparatory construction activity and another challenge is to meet the requirements of the licensing obligations for the *Siting Licence* and the *Design and Construction Licence.* The support of the experienced contractor or vendor has been inevitable for both the cases in case of first NPP build.

Bangladesh decided to make contractual obligations with contractor/vendor country that correlates between preparatory construction activities and licensing activities on one hand and implementation of main construction project on the other hand. Taking into account the domestic legal and regulatory conditions to obtain licenses, industrial base, availability and competence of human resources for managing the construction project, national resources and

economic and environmental condition to support NPP build, a Two-Stage Contracting Scheme has been adopted for Rooppur NPP. The first-stage contracts cover the detailed siting activities, engineering surveys and environmental studies, assessment and definition of the related design bases, preparation of documentation packages of the licensing activities, site development works and construction and erection of the facilities required for construction of NPP. The second-stage contract is the General Contract which covers all the activities starting from detailed design, procurement, construction, to commissioning and handover of the plant to the customer.

BAEC and the General Contractor, JSC Atomstroyexport signed four contracts for completion of the preparatory stage activities. Under the provisions of the first contract, detailed and comprehensive site characterization and environmental studies of site has been performed through involvement of Russian NPP design organizations based on regulatory requirements in agreement with IAEA Safety Standards, techno-normative requirements of Russian Federation and the applicable relevant rules and regulations of Bangladesh. These studies covered the areas of geodesic, geology, seismic and geotechnical, hydrology and flooding, meteorology, anthropogenic conditions and human induced events, ecological study, etc. has been carried out. In addition, for preparation of the Environmental Assessment Report of Rooppur NPP, necessary studies on environmental impact assessment those include the effect of any potential impact on key environment component such as land use, water, meteorology and air quality, ecology, culture, socioeconomics, radiological impact, radioactive waste, water use and possible need for cooling towers and impact of construction activities on the local environment have been conducted on the basis of the requirements of the Department of Environment, Bangladesh which is in line of the guidelines of the IAEA. All these studies have been done to receipt materials for confirmation of site in terms minimizing all safety hazards. BAERA reviewed Site Safety Reports and other documentations developed based studies mentioned above-mentioned and granted the Siting License for Rooppur NPP on 22 July 2016.

The technical information of the Site Safety Reports is used as input for designing Rooppur NPP. Moreover, under the provision of the second contract, the General Contractor has performed site engineering and environmental studies for the design stage to evaluate the site specific seismic design basis parameter and other site specific parameters particularly, relating to floods, temperatures, winds and other meteorological parameters as well as man-induced hazards for developing design documentation and the first priority working documentations of Rooppur NPP. Based on these studies the design and technical documentations, namely Preliminary Safety Analysis Report (PSAR), Probabilistic Safety Analysis (PSA) Report, QA Programme, various technical and safety documentations and organization matters of Rooppur NPP have been prepared and after proper revision of the mentioned documents and engineering solutions adopted in Rooppur NPP design incorporating site specific features, BAERA has granted the Design and Construction License on November 4, 2017.

Under the third and fourth contracts mainly site development, civil and construction works at pioneer base and construction-assembly base-1, construction of embankment along the river and activities at industrial base for stabilizing the soil under buildings and structures at the Rooppur NPP Unit-1 and Unit 2 and at the depth of soil stabilization for main buildings and structures equaling 20m below the foundation plate through soil-cement mixture by fulfilling the design requirements and the regulatory requirements of the authority and all other preparatory works for the first concrete are being done. The physical works includes land

development and civil and erection works such as workshop, cement warehouse, chemical additive warehouse, construction laboratory, health center, general contractor building, aminity building, indoor warehouse, storage area for equipment and materials, development of pit for Unit 1 and Unit 2 and soil stabilization works and development of foundation of Unit-1 ready for FCD.

The General Contract for Construction of Rooppur NPP was signed on 25 December, 2015 which includes the detailed design, supply of equipment and materials up to the construction site, construction and erection works; supply of nuclear fuel for a few initial batches, education and training for Rooppur NPP personnel, commissioning of NPP units; comprehensive demonstration tests and guarantee tests and provisional take-over and final takeover of the plant.

Under the General Contract, the following major nuclear long term manufacturing equipment (LTME) have been ordered for manufacturing: Reactor Presssure Vessel, Steam Generator, Pressurizer, Reactor coolant pump, Steam Turbine, emergency Core cooling system, full scale simulator, molten core catcher, etc. In addition, more than two thousand five hundred normal industrial and office equipment for the year 2017 are ready for shipment from Russia. During time interval of 2017 to 2024 a total 72 numbers of packages (around 7000 books) of Documentation will be developed and supplied. In 2017 a total 12 numbers of packages (around 1232 books) of Documentation are received for execution of the following major civil construction works: Lighting protection grid of main buildingand structures, base concrete for building foundation, reactor building foundation plate, construction of breakwater dike along the boundary, foundation works of reactor portal building, temporary structures of potable and industrial water supply, reinforcement works of reactor building and portal buildings, office and production building with places for six vehicles and with a training tower, etc. Moreover, 1424 (License, key personnel Fuel-handling, Safety and Operational) will be trained by the Contractor (Russian Federation) in the frameworks of the General Contract wherein 116 personnel will obtain license in compliance with Regulatory body.

Techno-Economic and Safety Features of Rooppur Nuclear Power Plant

Rooppur NPP, the first NPP of Bangladesh, is one of the latest addition to the Russian VVER (Water-cooled Water-moderated Power Reactor) reactor plant of AES –2006)VVER –1200, V-392M) technology by adopting the site specific safety features. The design of Rooppur NPP reactor Unit 1 and Unit 2 is developed based on VVER-1200 reactor plant with elaboration of designing, equipment manufacturing, construction and commissioning experience of Novovoronezh NPP-II and experiences in operation of the most recent VVER reactors in Russia and abroad. The high quality of engineering solution and design documentation has been developed based on application of the modern Russian rules, regulations and standards, recommendations of the IAEA, EUR, INSAG, ICRP, IEC, ISO and other international recommendations and the domestic regulatory requirements and site specific seismic and climatic conditions of Rooppur NPP site.

Technical Features: The main feature of Rooppur NPP is its simple design. Each reactor unit comprises a reactor and four circulation loops, each of which includes circulation pipelines, reactor coolant pump and horizontal steam generator. The Rooppur NPP will have some special technical features with added capability that differentiates it from other VVER NPPs currently

in operation. One of the main advantages of Rooppur NPP is the increased service life of main equipment to 60 years without necessity of its replacement. The turbine plant major equipment also have a service life of 50 years.

The main equipment is accessible for carrying out in-service inspection that will allow to perform scheduled preventive maintenance of equipment in due time. Some of the key technical characteristics NPP are listed in Table 1.

Parameter	**Value**
Reactor nominal thermal power	3200 MW
Maximum Utilization Factor	Over 90%
Operation mode	Base load
Service life of irreplaceable equipment of Reactor Plant main equipment	At least 60 years
Maximum linear heat flux	420 W/cm
Time of fuel operation)cycle (in reactor	4 to 5 years
Period between refueling	12 months

Table 1: Technical Characteristics of Rooppur NPP reactor Unit 1 and Unit 2

Safety Features: The design of Rooppur NPP meets the high level of safety required worldwide for future NPP. The lessons learnt from the major nuclear accidents of Chernobyl, Three Miles Island and Fukushima accidents were incorporated in the design by defense in depth principle. Reliable five layers of barriers prevent the radiation exposure to people and environment even in the worst-case scenario as shown in Figure-1.

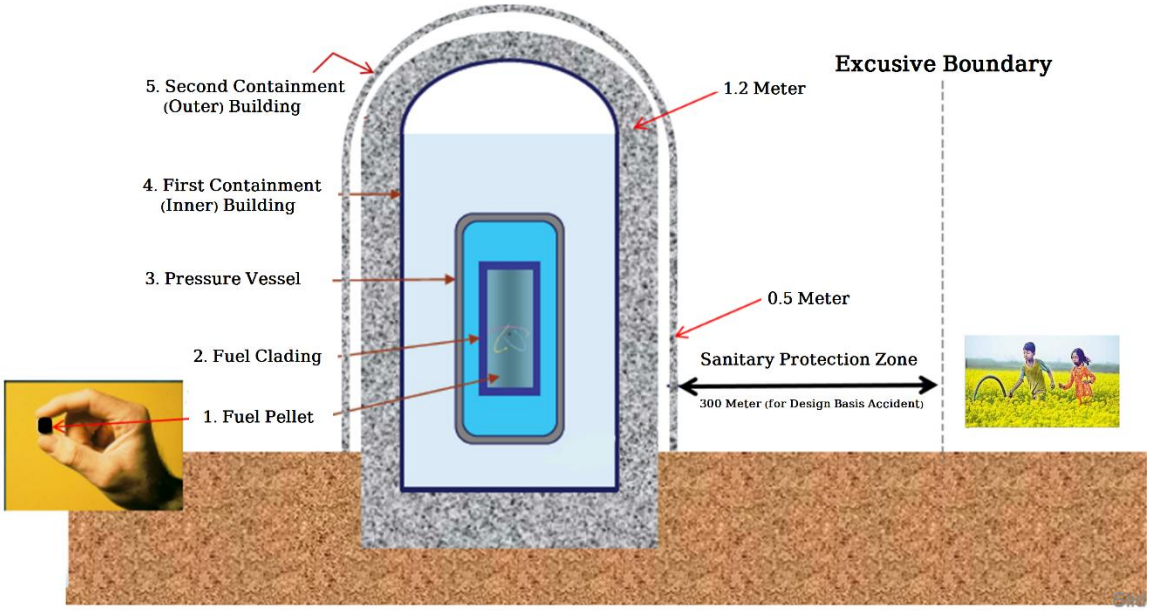

Figure 1: Five layers of barriers against the radiation exposure to people and environment

The safety system of Rooppur NPP is based on active safety systems with both normal and emergency power supply. To prevent severe accidents or mitigate their consequences, passive safety systems are envisaged which function without the involvement of the NPP personnel and do not require any power supply. In case of a severe accident with extreme power loss due to grid failure (like Fukushima NPP accident) the Rooppur NPP will remain safely shut-down for at-least 72 hours without the involvement of external assistance and off-site power supply.

The active and passive safety systems with 2 to 4 times redundancy and diversity will make this plant a real safe one. The active safety systems icludes emergency and planned cooldown protection system, high pressure emergency injection system, emergency boron injection system, emergency feed water system, emergency gas removal system, primary and secondary circuit overpressure protection system, spray system, containment isolation system, intermediate circuit and service water supply, ventilation, essential power supply, etc. The passive safety system of Rooppur NPP are: quick boron injection system, emergency core cooling system hydro-accumulators, passive containment heat removal system, passive steam generator heat removal system, hydrogen concentration monitoring and hydrogen passive recombination system inside containment system, molten corium trap and cooldown system, etc.

There will be also emergency power supply system and standby diesel power station etc.
The site specific features of Rooppur NPP are included into the design with due consideration that for both natural and man-made disasters and Rooppur NPP will remain safe in any disastrous situation. Site specific design parameters for natural and man-made impacts are shown in Figure 2.

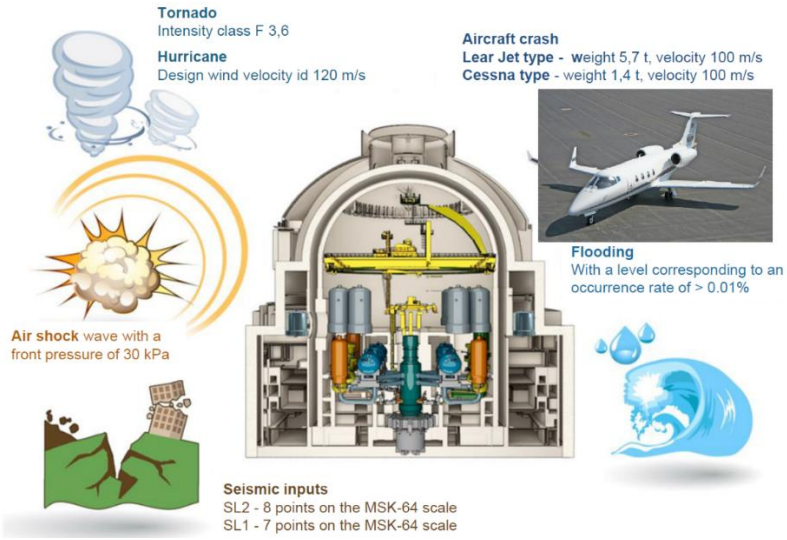

Figure 2: Design parameters of Rooppur NPP for Natural and Man-made Impacts

Techno-Economic Features: The Rooppur NPP have some special economic benefits due to very large generation capacity over a longer service life. Stable fuel and O&M cost also adds to the benefits from economic perspective. In spite of the huge capital investment during the construction period, Levelized Cost of Electricity was predicted less than 5 Tk / unit in the Feasibility Study report where as the average generation cost of electricity is much higher than this rate in the current power generation mix of Bangladesh. Some of the key technical & economic parameters is shown in Table 3:

Parameter	**Value**
Assigned service life: – power unit – reactor plant	50 years 60 years

Installed (nominal) capacity - Gross electrical power generation capacity at generator terminal	Not less than 1150 MWe
Electric power consumption for plant auxiliaries under the design conditions, % of the power unit nominal electrical capacity	not more than 10%
Net electric power measured on the HV side of the 400 kV transformer output lines at nominal conditions	Not less than 1030 MW
Utilization factor	Minimum 92%
Number of industrial production personnel (specific), men/MW	0.82
Annual generation of electrical energy at full utilization	Over 16 billion unit
Levelized Cost of Electricity (LCOE)	56.73 (USD/MWh)
Internal Rate of Return (IRR)	9.5 %
Real return on equity rate	7.84 %

Table 3: Key technical & economic parameters of Rooppur NPP Unit 1 and Unit 2

In addition to economic benefits, Rooppur NPP will bring ample opportunity to the locals and contribute to the overall GDP growth of the country by adding Financial benefits in multiple terms.

Radiation Safety Criteria and Rooppur NPP

Radiation safety is organized and implemented to prevent inadmissible effect of ionizing radiation sources on personnel, population and environment in the Rooppur NPP location area. The Rooppur NPP is designed in such a way that it will fulfill the fundamental principles and radiation safety norms, as well as to limit radiation impact on environment so as not to exceed the limits established by national and international organizations.

During normal operation, the exposure doses absorbed by the personnel and population, and the release of radioactive substances into the environment shall be kept below the established limits at reasonably achievable and socially and economically justified low level. The radiation consequences of design basis accident in the worst case would be limited within 300 meter at the border of sanitary protection zone maintaining the dose limits as per the regulatory documents. In case of Beyond Design-Basis Accidents, the exposure doses at the boundary of protective measures planning zone and outside will not exceed the permissible level .

Conclusion

The construction of this NPP is going to enhance the development of social and economic, scientific and technological potential of the country and promoting Bangladesh to become a member of the elite "nuclear club" of countries which have nuclear technologies. The Rooppur NPP project is the largest infrastructure project in Bangladesh. The Rooppur NPP will be equipped with two Russian VVER reactors, each with a capacity of 1,200 MW. The referential project for Rooppur NPP is Novovoronezh II NPP in Russia, which is a unique new Generation 3+ power unit with a VVER-1200 reactor. Bangladesh started preparatory construction activities in 2013. Now, the nation is celebrating the first concrete pouring of the unit 1 of

Rooppur NPP on 30 November. Hopefully, the two units of Rooppur NPP are expected to go into producing electricity in 2023 and in 2024. Rooppur NPP will play an important role in providing a stable base load and ensuring energy security of our nation. For 60 years, our country has had a dream of building its own NPP. We all are happy that we are proceeding steadily towards our dream.