Feasibility and Safety Study of Nuclear Power in Bangladesh: Perspective to Rooppur Nuclear Power Plant

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Abstract— **Electricity is the most demanding need of the present world. To fill this rapid demand a number of power generation methods have been invented and applied. Nuclear Power is one of the utmost ways in this race. Though there are a lot of questions of its sustainability and reliability but new latest and so called safer techniques are implemented for meeting the power demand. Bangladesh is one of the most densely populated countries of about 16 core people living on its area of 55 square-miles whose present peak power demand is around 9.5 GW and maximum served demand is about 6.5 GW. Though it has maximum power generation capacity of about 10 GW but due to aged plants and poor capacity factor its generation lowered very much when the country is planning to gain a generation capacity of 20GW by the year 2020. To fulfil this vision Nuclear Power Plant is considered as a vital factor which is not seemed feasible for such a country. At present the country mainly depends on fossil fuels for generating power, which amount is getting lowered. Though sometimes renewable energy is considered as a solution but for rapid demand, it is not sufficient to meet. Though Nuclear Power would not be a feasible option for Bangladesh, however if certain conditions are fulfilled some level of nuclear generation may be installed.**

Keywords— **Safety, Waste, Hazard, Radioactivity, Feasibility**

I. INTRODUCTION

Power demand of the world is increasing in a rapid way whereas the amount of fossil fuel is getting lowered day by day. So we need an extra eye to other power generation techniques than fossil fuel power harnessing. Nuclear power generation is one of the history making jobs in power generation system since 1951 [1]. Bangladesh is a country which power demand is very high in last few years & increasing at a rapid rate with the ongoing development of the country. But the country mainly dependent on natural gas to meet its high power demand which resource is not sufficient to present demand & is running out. So it is time for the country to look forward to other power generating options. Various renewable energy sources can be a solution but it needs an amount of time and huge investment which doesn't seem to a solution. Recently the government of the country is looking forward to nuclear power generation project named Rooppur Nuclear Power Plant to solve this power crisis. But safety is a very important factor in nuclear power generation. If we look into some recent nuclear disasters like Three Mile Island (USA) Chernobyl (USSR) & Fukushima Daiichi (Japan) where last two are the worst nuclear power plant accident & rated as seven on the seven-point International Nuclear Event Scale, so the main issue in nuclear power generation will be the safety. But at present safer reactors have been invented and used worldwide. The most recently invented nuclear reactors are called third generation reactor and referred to as simple and safe. On the other hand fuel of nuclear power plant is very available than conventional generations. Some years earlier the military misuse of nuclear techniques was a burning question but now recent technologies prevent that possibilities which makes the system more secured and reliable. Cost is one of the most important factors of power generation which is very low in nuclear though its initial cost is very much higher than any other systems but generation and maintenance cost is very much low that makes nuclear economically feasible. Nuclear waste management is one other important concern on the way to nuclear power. Although amount of this waste is very low comparing to the other fossil fuel used techniques [2]. But this waste can be technically disposed and not so hard to manage. Greenhouse gas emission is other important thing which is much lower in nuclear than other conventional power generation techniques that means it is quiet environmentally friendly to some points. As the density of population in Bangladesh is alarming so any unwanted situation may lead to serious loss of both life and property as well as environmental hazards. But to deal with the present as well as upcoming power crisis some scale of nuclear may be implemented while safety should be the priority most point. Again as lifecycle of a nuclear reactor is much higher than a conventional fossil fuel reactor so from this sense it may be called reliable also. Previously some studies have been done

where overall safety study and technological details were not discussed with key concern [3], [4]. Hence this paper mainly focused on technical details of nuclear power as well as RNPP and detailed safety study.

II. Nuclear Roadmap in Bangladesh

The plan for project Rooppur Nuclear Power Plant was first conceived by Pakistan govt. in 1960 under Pakistan Atomic Energy Commission (PAEC) to meet the future power crisis. Initial negotiation with USAID for a 70 MW nuclear power plant started in 1963. With the passing of time a number of feasibility study were done but due to the unwillingness of the ruling Pakistani govt. of that time, the project did not come out to light. In 1968 Russian company Technopromexport proposed to construct 400 MW Pressurized Water Reactor (PWR) while a Belgian firm also submitted a proposal of 200 MW PWR plant in 1969 which appeared more attractive and safer than Russian one [3]. The contract for supply, construction and erection of the plant was signed with WENESE in early 1971. But after liberation war the project had been postponed for some time. In 1977 a French consulting firm named Sofratome started a pre-feasibility study which ended in 1978 confirming the site as viable for 125 MW reactors [5]. Later during 1988-1989 another feasibility study were done by Lahmeyer International, Germany in association with Motor Columbus, Switzerland for Rooppur NPP (300 MW reactor). Then Bangladesh Nuclear Power Action Plan (BANPAP) was approved in 2000 by govt. The total nuclear roadmap is divided into three milestones [5]. They are – Milestone-1: Understanding the commitment, Milestone-2: Ready to invite bid/negotiation and Milestone-3: Ready to commission and operate the NPP. On 24th February, 2011 Bangladesh govt. have signed a primary deal with Russia for installing a 2000 MW nuclear power plant of two reactors each having capacity of 1000MW at Rooppur in Pabna. Responding to the request of Bangladesh, IAEA conducted the Integrated Nuclear Infrastructure Review (INIR) mission to review the Status of the National Nuclear Infrastructure in Bangladesh during 9-15 November, 2011 which led the country to Milestone-2. A Nuclear Industry Information Centre (NIIC) has been established in Bangladesh and inaugurated in Bangabandhu Sheikh Mujibur Rahman Novo Theatre, Dhaka on 2nd October, 2013 which main goal is to provide information to the local people on the planned RNPP Project. It is hoped that by 2021 one of the two reactors will be in operation and by 2030 second one will also come in operation. Recently, in June, 2014, the country has wished its desire of building another nuclear power plant with Japan's help in the southern region of the country.

III. Present Nuclear Technologies Comparison

There are two key factors in nuclear technologies which are generation of technology and type of technology.

A. Generation of Technologies

The There are some individual generations classified as Generation-I, II, III, III+ and IV [6].

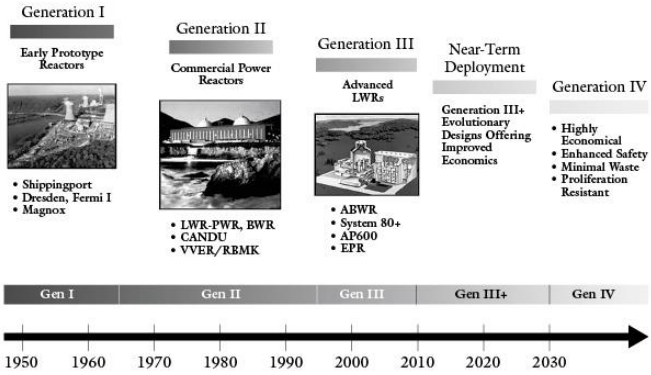

Fig. 1 The Evolution of Nuclear Power [7]

1) Generation-I: Early prototype and power reactors built in 1950's and 1960's are designated as Generation-1 Reactors. Most of the G-I reactors have already decommissioned.

2) *Generation-II:* Commercial power Reactors designed and built around 1970, 80 and 90 are Generation-II reactors. G-II reactors are considered having lifetime of around 40 years. These are mainly water cooled Light Water Reactors (LWR) and enriched Uranium fuel reactors. PWR, CANDU, BWR, AGR and VVER are some of the G-II reactors of which around 400+ reactors have been built worldwide [6].

3) *Generation-III:* These are basically the advanced design of LWRs. These advancements are in the fields of fuel technology, thermal efficiency, modularized construction, safety systems and standardized design. Typical life cycle of these reactors is around 60 years and considered more simple and safe [6].

4) *Generation-III+:* An evolutionary development of G-III reactors mainly in the field of safety are Generation-III+ reactors. These are the presently available safer reactors [6].

5) Generation-IV: These reactors are hoped to be the ultimate future of nuclear trend and come in light by 2030.

B. Different Types of Reactor Technologies

There are various types of nuclear reactors based on the cooling and moderating systems worldwide numbered around 436 [8]. Reactor manufacturers are looking for the cheapest and safest way to stay on the track of the competition of large and lucrative nuclear market.

1) Pressurized Water Reactor (PWR): Around 60% of total nuclear reactors of the world (over 230) are PWR type. Its thermal efficiency is 33-34%. In Russia these are known as Voda Voda Energo Reactor (VVER) [8].

2) Boiling Water Reactor (BWR): It's a moderated design of PWR. Around 20% of total nuclear reactors numbered 84 are BWR [8].

3) Pressurised Heavy Water Reactor 'CANDU' (PHWR): This reactor have been designed and developed in Canada. At present 48 CANDU reactors are in operation worldwide. It uses heavy water as coolant and moderator and natural

uranium (0.7% U-235) oxide as fuel that trades off the overall cost [9].

4) Gas-cooled Reactor (AGR & Magnox): Advanced Gas-cooled Reactor (AGR), developed form Magnox reactor are the second generation British Gas-cooled Reactor which uses natural U (metal) and UO_2 as fuel, CO_2 as coolant and graphite as moderator. Its thermal efficiency is 40% [10]. At present 17 reactors of this type are in operation.

5) Light Water Graphite Reactor (RBMK & EGP): Also known as Reaktor Bolshoy Moshchnosti Kanalniy (RBMK), designed and developed by Russia of which 16 reactors are in operation and developed from plutonium production reactors. There are no reactors of this type outside USSR [8].

6) Fast Neutron Reactor (FBR): There are two types of FNR – Fast Breeder Reactor (FBR) and Burner. Only one reactor has built in Russia. Its generated power is 60 times of conventional reactors but it is still in the research level [8].

IV. Rooppur Nuclear Power Plant Overview

Rooppur Nuclear Power Plant is the first ever nuclear project taken by Bangladesh govt. though there is a lot of delaying since 1961. But the project is going to be happened by estimated year of 2021. It includes project site area of 105 Hectare and residential area of 13 Hectare. It is situated beside the Ganges River from where required water for power plant is proposed to supply. The whole Rooppur project includes two reactor units. The first unit will be in operation by 2020 and second one by 2030. The cost for the first reactor is estimated about 2 billion US$ which 80% will be financed by Russia considered as soft term loan and other 20% will be country's self-financed. Bangladesh has signed agreement with Russia for cooperation in siting, design, construction and operation of power and research nuclear reactors, water desalination plants, and elementary particle accelerators. For fuel supply, waste management and decommissioning for two 1000 MW AES-92 type reactors to be built at Rooppur for the Bangladesh Atomic Energy Commission (BAEC) an agreement with Rosatom was signed. Another intergovernmental agreement was signed for the complete project to be built by Atomstroyexport [11]. For the regulation and safety another agreement was signed with Russia's Rostechnadzor to provide technical and other support to Bangladesh at Rooppur project.

V. Technical details of Rooppur Power Plant

A. Reactor

The reactor has finalized for Rooppur is AES-92 type 1000 MW reactor where AES stands for Russian Atomnaja Electrostancija that means Nuclear Power Plant. AES-92 is an updated version of VVER 1000/320[3] which is a Russian reactor and known as third generation VVER 1000 reactor (alias VVER 1000/V392). The first unit of this type of reactor went into operation in January 2007. This customized version of VVER 1000 reactor fulfils the conditions safety and reliability of IAEA and EUR. The operating life cycle of this customized reactor is longer than all other present reactors which is 60 years as claimed by Russia [11]. This reactor has more backup systems for safe shutdown and cooling in emergency than its older version. This newly designed reactor were developed by the Russian reactor design and construction company GIDROPRESS in cooperation with western institutions [12]. This design has higher efficiency (36.56 %), longer core life, lower per unit capital costs, shorter period of construction and enhanced safety against earthquakes with passive emergency core cooling system, double containment and core damage frequency of 1×10^{-7} per plant per year [13].

B. Fuel

The core of VVER 1000 G-III includes 163 fuel assemblies, identical in design, but different in fuel enrichment. It uses closed fuel cycle with MOX fuel. MOX fuel is the mixed oxide fuel that provides 2% of the new nuclear fuel used today [14]. Detailed information of fuel will be used has not yet published and still remained classified.

C. Cooling

The reactor AES-92 is a water-cooled water-moderated power reactor. There designed 4 loops in primary cooling circuit in AES 92. Flow rate of coolant through the reactor is 86000 m^3/h, pressure while operational is 15.7 MPa (max. 17.6 MPa). Temperature of coolant at inlet is 291ºC and at outlet is 321ºC [12].

D. Safety

It is stated that AES-92 has met European Utilities requirement for safety and reliability. It is declared by govt. that the safety will be three layered, though no details about safety systems have been published yet may be due to national classified issue. But it does satisfy EUR and IAEA recommendations which are.

1) European Utilities Requirement (EUR): Accidents with limited impact shall generate a maximum release of 0.1% of core inventory: I-131: 4000 TBq Cs-137~400 TBq, Sr-90~100 TBq. Probabilistic Safety Criteria (PSC) of European Utilities are more restrictive than the criteria of the IAEA. EUR declared some probabilistic safety targets- Core damage frequency: <10 E-5; Frequency of release > limited impact: 10 E-6; Early or large release frequency: 10 E-7 [13], [15].

2) IAEA Probabilistic Safety Targets: Core damage frequency (CDF): 1 E-4/reactor year for existing plants; CDF: 1 E-5/reactor year for future plants; Large release frequency (LRF): 1 E-5/reactor year for existing plants; LRF: 1 E-6/reactor year for future plants [13], [16].

VI. Safety and Hazard Analysis

To ensure overall safety some environmental, geographical and technical surveys and studies had to be done which includes Engineering and geological survey, Seismic and seism-tectonic studies, Engineering and hydro-meteorological survey, Engineering and environmental survey, Engineering & aero-meteorological survey and Anthropogenic conditions in the region and NPP site in accordance with the requirements

of Normative and Technical documentation of the Russian Federation, IAEA guidelines and National Normative and Technical Documentation of Bangladesh. AES-92 provides a unique combination of active and passive safety systems known as economically advantageous safety that guarantees maximum protection of the plant. Active: HPSI. LPSI, SS, EFWS: 4*100% Passive: (2 systems) 4*33% per system [13]. It is claimed that designers have anticipated worst possible scenarios like sudden de-energising of the plant, rupture of the reactor vessel, air-craft cashing into the plant etc. The reactor building will be double protective envelope, which will stay inside and heavy reinforced concrete outside. Some environmental and other hazardous situation should also be taken in concern.

A. Population Density

The first consideration of hazard study should be population of the surroundings. According to international law, the NPP surrounding has to be divided into 3 zones. Zone-1 (3.14 sq. km circular area) is the reactor area and entry has to be limited only to the people working with reactor. Zone-2 (5 km away from the centre) is security area. And zone-3 (30 km area) is for planning disaster and must be free of people. Hence if there is any explosion at RNPP almost 1000000 people have to be transferred to safe zone due to high density in the PP region [3]. There was an accident of this type at Three Mile Island Nuclear Power Plant in USA due to a cooling malfunction caused part of the core to melt in the reactor two.

B. Earthquake, Tsunami and Natural Disaster

The most recent nuclear accident is Fukushima Daiichi Nuclear Power Plant on 11 March 2011 at 14:46 JST due to the earthquake having Richter magnitude of 9.0 with epicentre near the island of Honshu [17]. Maximum ground accelerations due to earthquake were 0.56, 0.52 and 0.56g (gravity) (5.50, 5.07 and 5.48 m/s^2) respectively at unit 2, 3 and 5 while their designed tolerances were 0.45, 0.45 and 0.46g (4.38, 4.41 and 4.52 m/s^2) [3]. In the case Bangladesh, it's also in an active earthquake zone and already experienced four major earthquakes between 7-8.5 Richter magnitudes. According to seismic zoning map, Bangladesh is divided into three zones where zone-3 is most vulnerably active and zone-1 is most quiet [18]. And the good thing is Rooppur situated in zone-1 [4]. The peak ground acceleration (PGA) is estimated 0.18g for the return period of 2475 years which is very much lower than designed value. Tsunami precaution is another important thing in the case of Bangladesh and the site for RNPP is situated by a river which means there are possible tsunami treat. So considering Japan's condition during the accident this tsunami protective system should be developed around the site.

C. Waste Management

Unlike other conventional power generation systems, nuclear power generation takes full responsibility of the disposal of produced radioactive waste though the production of waste is not very high with respect to generated power. But this radioactive waste management is the most important factor of nuclear power generation. Radioactive wastes are classified into some categories depending on the rate of radiation.

1) Exempt Waste and Very Low Level Waste (VLLW): It mainly consists of demolished material (such as concrete, plaster, bricks, metal, valves, piping etc.) produced during rehabilitation or dismantling operations on nuclear industrial sites and not considered as harmful to the surroundings. The waste is normally disposed with domestic refuse, while some countries (i.e. France) are currently developing facilities to store VLLW in specifically designed VLLW disposal facilities [19].

2) Low Level Waste (LLW): It contains very small amount of radioactivity which doesn't require shielding while handling and transport. Comprising 90% volume about 1% of it is radioactive [19].

3) Intermediate Level Wastes (ILW): It consists higher amount of radioactivity than LLW and some of it requires shielding.

4) High Level Wastes (HLW): It contains the fission products and is highly radioactive (contains about 95% of total radioactivity). That's why it requires cooling and special shielding as well as long term disposal facility. There are some long term procedures to handle this kind of wastes like mining and milling, conversion, enrichment, fuel fabrication etc. From mining Yellowcake (U_3O_8) is found which is then converted to uranium hexafluoride gas (UF_6) which undergoes to increase the U-235 from 0.7-3.5% [19]. Then it's turned into a hard ceramic oxide (UO_2). Main by-product of enrichment is U-238 which can be reprocessed into plutonium and used in military projectiles. So it's also a serious point of concern. Again there is also use of these wastes and waste products in Breeder Reactor, which generates more fissile material in fuel than it consumes and hence this waste can be used as fuel [3].

D. Terrorism

It is a dangerous threat to the nuclear programme of a country as seen in Pakistan in recent few years. So there must be some options of emergency response of countries Defence agencies to prevent the possibility of nuclear terrorism.

VII. CONCLUSIONS

Nuclear sometimes is considered as a threat but this fear can be removed by taking adequate precautions against all kinds of probable disasters. Bangladesh is highly committed to build country's first nuclear power plant at Rooppur. Though there are many critiques against this project but to fulfil country's power crisis there is no alternative viable option found. But for sure safety should be the first and foremost concern in the way to make RNPP a success.

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