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NUCLEAR POWER IN PAKISTAN

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Pakistan started its nuclear power program by installing a 137 MWe Canadian Deuterium Reactor (CANDU) at Karachi in 1971 which became operational in 1972. The post-contract technical support for the Karachi Nuclear Power Plant (KANUPP) was withdrawn by Canada in 1976 as a consequence of Indian nuclear device test in 1974. Inspite of various difficulties PAEC resolved to continue to operate KANUPP and started a process for the indigenous fabrication of spare parts and nuclear fuel. The first fuel bundle fabricated in Pakistan was loaded in the core in 1980. Since then KANUPP has been operating on the indigenously fabricated fuel. The plant computer systems and the most critical instrumentation and Control systems were also replaced with up-to date technology. In 2002 KANUPP completed its original design life of 30 year. A program for the life extension of the plant had already been started. The second nuclear power plant of 300 MWe pressurized water reactor purchased from China was installed at Chasma in 1997, which started commercial operations in 2001. Another unit of 300 MWe will be installed at Chashma in near future. These nuclear power plants have been operating under IAEA safeguards agreements. PAEC through the long-term performance of the two power plants has demonstrated its competence to safely and successfully operate and maintain nuclear power plants. Pakistan foresees an increasingly important and significant share of nuclear power in the energy sector. The Government has recently allocated a share of 8000 MW for nuclear energy in the total energy scenario of Pakistan by the year 2025.

Keywords: Nuclear power, KANUPP, Parts replacement, Indigenous fabrication, CHASNUPP

1. Introduction

The Islamic Republic of Pakistan is technologically one of the most advanced countries among the predominantly Muslim states in the world. Still, it is far from a technologically developed country. Its population is growing rather fast, which makes it very difficult to increase the Gross Domestic Product (GDP). Per capita consumption of power is among the lowest in the world; so there is a vast potential for development. The economy is just beginning to show signs of vitality. As fundamental input for continued growth and development, Pakistan needs secure and economic sources of energy. As a poor and developing country, Pakistan looked forward to exploiting the great potential of atomic energy and technology for giving an impetus to its progress.

Since the late 1930's, the release of energy from the fission of uranium nuclei is known to be a vast source of energy. The reserves of uranium seem to promise abundant energy for many centuries. But due to the very high amount of energy which can be released by a small amount of matter, uranium is also a very potent basis for weapons. Besides energy, such weapons induce great human sufferings due to the release of radioactivity. This was demonstrated at the end of World War II. Since then, this threat has remained at the centre of the defence strategies in the world's super powers. To retain their strategic advantage, countries which already have nuclear weapons wish to ensure that other countries should not get the technologies, which could be used for developing nuclear weapons, even though they may need it for peaceful uses such as nuclear power. The realization of the great potential of atomic energy for peaceful purposes has thus been overshadowed by this threat. So far, there is no technology for nuclear power which completely excludes the possibility of misuse for the development of nuclear weapons. An international system of safeguards and inspections has been developed through the International Atomic Energy Agency (IAEA) to verify that nuclear materials in nuclear power plants in the world are not diverted for other purposes.

Soon after its establishment in 1956, the

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Pakistan Atomic Energy Commission (PAEC) chalked out plans for the utilization of nuclear energy for socio-economic development of the country. Development of the nuclear power program for the generation of electricity received considerable attention. Various types of nuclear power reactors were considered for the nuclear power plant. Finally a Canadian deuterium reactor (CANDU) was selected. Approval for the purchase of this reactor was obtained from the Government of Pakistan in April 1963. A turn-key contract for the supply of a 137 MWe Karachi Nuclear Power Plant (KANUPP) at a cost of US$ 60 million was signed with the Canadian General Electric Company (CGE) on May 24, 1965, which became effective from January 1966. A memorandum of understanding on agreed safety policy and procedures was also signed.

The preliminary safety analysis report of the site and the plant design was reviewed by the Pakistan Nuclear Safety Committee (PNSC) and a construction permit was issued. The construction of KANUPP was started in the middle of 1967 and completed in 1971. First criticality of the reactor was achieved on August 1, 1971, and the plant was connected to the electricity grid on October 18, 1972. Commissioning of the plant was interrupted in 1971 due to hostilities with India resulting in the formation of Bangladesh. The work on commissioning was resumed in late 1971 and completed in 1972. The reactor attained full power on October 4, 1972, and KANUPP became the first commercial CANDU nuclear power plant operational outside Canada. Mr. Zulfiqar Ali Bhutto, the-then President of Pakistan, formally inaugurated the Karachi Nuclear Power Plant on November 28, 1972.

India affected KANUPP by testing a nuclear device in 1974, for which Canada was blamed for having provided the technology. Consequently Canada put an embargo on all types of technical support in nuclear technology to both India and Pakistan in 1976. Although about 40% of the original design, operation and maintenance team trained in Canada left for Bangladesh, and post-contract technical support was withdrawn by Canada, PAEC resolved to continue to operate KANUPP. Good academic background of the staff, relatively complete documentation provided by CGE, and the comprehensive inventory of spares purchased up to 1976, sustained the operation of KANUPP until facilities could be established for developing human resources, fuel management software, and fabrication of a majority of spare parts and CANDU fuel, and upgrading heavy water. Human resource development program was started by establishing the KANUPP Nuclear Power Training Centre (KNPTC) in 1973 and a process for indigenous fabrication of spare parts was initiated. Studies on the fabrication of nuclear fuel of CANDU specifications gained momentum and a facility for the fabrication and testing of fuel elements was established. The first fuel bundle fabricated in Pakistan was loaded in the reactor core in 1980, which performed very well. Since then KANUPP has been operating on the indigenously fabricated nuclear fuel. With these efforts PAEC achieved a high degree of self-reliance in the operation of the power plant. However, KANUPP could achieve a lifetime plant factor of only 23% by 1992, largely because it had to be operated on low load factor to avoid potential grid instability due to the relatively high frequency of unplanned trips of KANUPP, which was operating as a base load station, with large drop, in the smaller-than-projected Karachi Electric Supply Company (KESC) Grid. The lifetime best performance of 85.4% availability with 48.8% capacity factor was achieved in 1995.

Obsolescence, specially of electronics and computers, soon overtook KANUPP. The process of replacement of obsolete electronics and computers was adversely affected due to the embargo imposed on the supply of nuclear-related equipment and spare parts by developed countries. Intensive efforts were, therefore, made to develop some spares, or buy substitutes at increasing levels of replacement. At the same time capability for reverse engineering for this purpose, with facilities for fabrication, integration and testing of equipment and systems was developed. Ultimately the plant computer systems, and the most critical Instrumentation and Control Systems were replaced with up-to-date technology, using equipment purchased from ACEC in Belgium. The technological upgradation project (TUP) was completed in 2002.

In late 1980's the lack room for of thermal expansion in the free end of one of the reactor fuel channels caused concern regarding the safety of the reactor. Therefore, Canada was requested to help in this safety related problem. In response to our request Canada allowed a technical expert mission through the IAEA in 1991, which identified many other issues as well, requiring updating of the safety measures. The IAEA sponsored a long-term technical cooperation project for 'Safe Operation of KANUPP (SOK)' with technical support from Canada only for safety issues, resulting in many hardware and software modernizations and up-gradation. These and other conventional modernizations and rehabilitations, specially in computers, control and instrumentation, allowed KANUPP to improve its cumulative plant factor gradually to 29% in 2002. In 1992, the government invested only Rs.154 M in the SOK Project, and approved that KESC should pay KANUPP at the average generation cost of all its generating stations, which was then sufficient to cover the remaining expenditures on the necessary improvements. Strong technical cooperation from IAEA also played a significant role in these improvements.

In 2002, KANUPP completed its original design life of 30 years, but only about 12 full-power years of the reactor. A program for the life extension of the plant had already been started. After completing some remaining rehabilitations in a re-licensing outage in 2003, the regulatory body allowed KANUPP to operate at limited power, pending procurement of some valves needed to increase redundancy in the safety injection. Following this, KANUPP would be re-licensed for another 15 years.

After the establishment of KANUPP, PAEC had planned to install more nuclear power plants; but there were no willing suppliers until China agreed to supply a power reactor in 1990. A turnkey contract was signed with the China National Nuclear Corporation (CNNC) / China Zhongyuan Engineering Corporation (CZEC) on December 31, 1991, for the supply of a 300 MWe pressurized water Reactor (PWR) at a cost of US$ 560 million. This plant, based on the identical Qinshan NPP Phase I in Haiyan, China, was paid for entirely in cash by the Government of Pakistan. The construction of Chashma Nuclear Power Plant (CHASNUPP) was started in August 1992 and completed in 1997. After the first fuel loading in November 1999, the reactor achieved first criticality on May 3, 2000, and first grid connection on June 13, 2000. The reactor attained full power in August 2000, and commercial operation started on January 9, 2001.

This first venture of South-South cooperation in the world, started operating commercially in September, 2000, with a delay of about one year, (mainly to improve the lower core internals following some damaged fasteners found in the 4th refuelling outage of Qinshan). Teething problems were more than in KANUPP, largely because of the language barrier, and weaknesses in quality control and documentation practices during installation and commissioning. But these seem to have been largely resolved with thorough efforts of the plant personnel and continued support from China. The plant is operating reasonably well now, but susceptibility to a relatively high incidence of significant grid transients remains the largest source of unplanned outages.

The greatest challenges in this adventure so far have been the development and sustenance of sufficient human resources with the necessary technical expertise despite embargoes on it, and safety culture in a society generally weak in these traits. The PAEC has been supported strongly in these areas by the IAEA, and recently by the World Association of Nuclear Reactor Operators (WANO).

The PAEC started with its own internal nuclear safety regime by constituting the Pakistan nuclear safety committee in the early 1960's, which reviewed the safety analysis reports of the research reactor and the power reactor. A Directorate of Nuclear Safety and Radiation Protection (DNSRP) was established in 1985 to ensure mandatory safety requirements. The process of spawning an independent regulatory body in line with international norms was started by the formation of the Pakistan Nuclear Regulatory Board (PNRB) in October 1994. The fully independent Pakistan Nuclear Regulatory Authority (PNRA) was finally established in January 2001.

The regime for nuclear power plant safety has to go far beyond design safety. Although research efforts in this direction continue, so far there are no inherently safe designs, i.e. which would operate, or even shut down to an indefinitely safe condition, without human attention. In other words, even with the best designs, the safe and economic performance of nuclear power plants depends on human performance. This importance of human performance and ways to ensure and enhance it was realized after the serious incident in the Three Mile Island nuclear power plant in 1976 in the USA, followed by the most serious accident in Chernobyl in the USSR in 1986. These have led to concerted the efforts, initially in the USA, and then worldwide, resulting in great advances in 'operational safety', demonstrating that nuclear power plants, besides being benign for the environment compared to fossil fueled plants, are also very safe, as well as economically competitive. Therefore, the PAEC gave the highest importance to the development of knowledgeable and competent manpower for the safe operation of reactors.

The nuclear power plants in Pakistan operate under IAEA safeguards agreements, providing on-going demonstration that the nuclear materials in these plants are not used for making nuclear weapons. Pakistan has demonstrated its capability to produce and deploy nuclear weapons needed for its strategic objectives, independently of the nuclear power program. Still, Pakistan remains a target of non-proliferation concerns, creating great difficulties in the acquisition and operation of its nuclear power plants. For its present and near-future needs, Pakistan feels greatly indebted to China for understanding this anomalous situation. However, for our dire and increasing needs for energy which can best be met by nuclear power in the long run, like most of the world, we must continue efforts to reduce reliance on external sources for the materials and technology needed for a secure nuclear power program.

Despite many problems, Pakistan has managed to be the first country in the Muslim world to embark on a nuclear power program. The performance of CHASNUPP remains much better than of KANUPP so far, and Pakistan is now in a much more confident position to install and manage more nuclear power plants. Pakistan cannot deny what it owes to Canada, China and the IAEA for its progress on this path.

Around the turn of the century, the world has witnessed a resurgence in the confidence, need and expectation of a strong future for nuclear power, mainly due to the improvements in the industry induced by WANO, and the realization that it offers the only viable source for abundant clean energy in the decades to come.

With the fundamental ability to operate nuclear power plants demonstrated through the long term performance of KANUPP, and with Unit 1 of CHASNUPP performing much better than even in its own early years, the energy planners of Pakistan can also see the promise of a bright energy future that nuclear power promises, with the strong friendly support from China. The government of Pakistan has recently allocated a share of 8000 MW for nuclear energy in the total energy scenario of Pakistan by the year 2025. A contract for a second unit at Chashma site (C-2) was signed with CNNC in late 2004 at a cost of US$ 580 million. A second unit at Karachi is also foreseen. But even with these, the contribution of the nuclear sector in the entire energy capacity in Pakistan will remain inside 10 percent.

The availability of imported as well as indigenous uranium for reactor fuel seems to be abundant; but so far, the technology for nuclear power plants has had to be imported. KANUPP was entirely a turnkey project, and further import of CANDUs seems unlikely. CHASNUPP Unit 1 was also a turnkey project; but about 25% of the total money filtered back through sub-contracts to domestic organizations. In the near future, access to PWR technology from China seems to be the only option for Pakistan, and PWRs constitute the dominant technology in the world today. Overall responsibility for CHASNUPP Unit 2 still remains with CNNC; but the local contribution may increase somewhat, with strong local participation in commissioning. It is expected that after the first four nuclear power plants, the balance will tilt in favour of indigenous contribution, and the nuclear power program may become financially self-sustaining. Indigenization seems more feasible for series of similar plants, and with a view to export the technology. Formal ‘incorporation’ of the nuclear power program, to achieve the necessary expediency, is being studied.

Like many other countries of the world, Pakistan foresees the increasingly important and significant role that nuclear power can potentially contribute as a safe, environmentally clean, economically competitive and abundant source of energy in the future of a well-developed economy.

Pakistan started the nuclear power program by installing and operating one CANDU and one contemporary PWR nuclear power plant safely and successfully. During this process it gained confidence and has set up some of the necessary organizations to operate and maintain nuclear power plants to international standards of safety, but its capabilities for design, manufacturing and project management are still quite limited.

Pakistan is more advanced along this path than many other developing countries; still there is a long way to go before the potential of nuclear energy in future is fully secure. Such development can be economically competitive only for a nuclear power program based on a series of standardized plants. In that case the architect-engineering capability and heavy industrial expertise may also be exportable to other smaller or less developed countries.