Thorium fueled small PHWRs present near ready export opportunity

BARC Q&A

Dr. ANIL KAKODKAR
Former Chairman, AEC

Dr. A.K. Nayak, Associate Editor of current issue of BARC Newsletter interacts with Dr. Anil Kakodkar on some of the burning issues on Indian energy security in the context of growing environmental concerns due to climate changes

Dr. A.K. Nayak: ***The growing population and ambitious GDP growth rate in India would require tremendous demand on energy for electricity, transport, industry and domestic sectors. How much do you foresee the demand by 2050 from all these sectors?***

Dr. Anil Kakodkar: As per India Energy Outlook 2021, recently brought out by IEA, India will need to add a power system of the size of the European Union, to what it has now, over the next twenty years to meet the growth in electricity demand. India currently produces around 1600 TWh electricity through its utilities and non-utilities. Power system of European Union is ~ 2800 TWh. Extrapolating these numbers, one can expect India's power system in 2050 a little more than 6000 TWh. This is still short of the electricity consumption required to support a Human Development Index (HDI) comparable to developed countries which is around 8000 TWh.

Dr. A.K. Nayak: ***The world is talking about Clean and Green energy, deep de-carbonization, etc. Do you feel that it is possible to have a carbon free energy supply by 2050 or by the end of this century? If so how?***

Dr. Anil Kakodkar: Four of the top ten CO_2 emitting countries in the world have announced 2050 as the target year for reaching zero emission. China has announced 2060 as the target year for the same purpose. In USA, State of California has set the target year as 2045. Now that USA is back in the Paris process and there is a major traction towards clean energy technologies, it is only a matter of time that USA would be adopting a zero-emission target year. With six of the top ten emitter countries as well as the European Union becoming zero-emission countries by mid-century as recommended in the IPCC Special Report on Global Warming of 1.5°C,there is bound to be a strong push for India, the third largest CO_2 emitter country after China and USA, to define target year for reaching zero emission.

On the other hand, while the developed countries have reached a level of energy consumption far beyond what is necessary to sustain highest level of HDI and there is no need for them for any further increase in per capita electricity generation, India happens to be a developing country that needs to augment its per capita electricity generation around 4-5 folds to reach a HDI comparable to developed countries. As a matter of fact, India's need for additional energy to reach the desired HDI is the highest in the world.

> To my mind the goal of reaching carbon free energy supply by 2050 would not be affordable without a large contribution of nuclear energy

While reaching a carbon free energy supply by 2050 may be a very tall order, we should target reaching that goal as early as possible. While there is a major thrust to renewable energy in that context, to my mind the goal would not be affordable without a large contribution of nuclear energy.

Dr. A.K. Nayak: ***What is the role of nuclear power in the energy mix, and what types of technology would play major role in next 2-3 decades?***

Dr. Anil Kakodkar: Nuclear energy has a major role in India's electricity generation mix to support, in a sustainable way, the large growth in demand that is expected with assured energy security. In the recent times with climate crisis looming large, deep cuts in carbon emission in the current decade reaching to zero emission by middle of this century, have become of paramount importance. That has made rapid deployment of nuclear power, which is a base load clean energy, an urgent necessity. Studies have shown that without a sizeable role of nuclear, reaching zero emission would be unaffordable. Also, there could be significant vulnerability in terms of potential blackouts under extreme weather conditions which could become more frequent. Looking at the available time period one would need to utilize readily available technologies. Clean energy technologies like solar, wind, bio-energy, hydro and nuclear would need to play a major role.

Dr. A.K. Nayak: ***First stage of Indian nuclear power programme has already matured; second stage is still evolving, and technology for third stage has just been initiated. India targets to harness substantial power in second stage and then significantly larger in third stage of its nuclear power programme. What is your vision to accelerate and strengthen the power programme by 2050 and then by 2100?***

Dr. Anil Kakodkar: Three stage nuclear power programme is designed to unleash vast energy potential in our thorium resources. This is necessary for our long-term energy security. This involves development of a number of reactor and nuclear fuel cycle technologies on which work is in progress. We must accelerate this process. While the rationale for this development continues to remain strong since India's needs for additional energy to reach a quality of life comparable to developed countries are the largest; decarbonization of energy supply and use by middle of this century (which is just thirty years away) has become an urgent necessity to protect the earth and our existence on it.

So, there is a need to accelerate nuclear power deployment which is the only near zero carbon - base load electricity production option that can deliver at the necessary scale.

To do this in three decades with realization of deep emission cuts in next ten years as recommended by IPCC would need reliance on readily deployable proven technologies. This is where rapid expansion of PHWR and LWR technology becomes important.

Dr. A.K. Nayak: ***Worldwide, most of the nuclear reactors today require large investments, face delay in supply-chain, incur large civil construction costs, and added safety barriers Post-Fukushima have aggravated the economics of nuclear industry. How could we reduce the capital cost of nuclear plants?***

Dr. Anil Kakodkar: Long construction period and consequential increase in construction outlays

Kakrapar Atomic Power Station @ DAE Photo

> To realise deep emission cuts in next 10 years, rapid expansion of PHWR and LWR technology becomes important

due to added interest burden as well as and financial risks associated with this and other aspects is one major factor that challenges enthusiasm about nuclear power even when other merits of nuclear power are increasingly well recognized. Making the reactor design simple, safer and standardized with assured continuity for repetitive manufacture and construction in a competitive environment is the key to rapid deployment. I believe that fleet mode construction approach for our 700 MWe PHWRs is an important step in this direction. We must pay attention to other related aspects to facilitate their rapid deployment.

Dr. A.K. Nayak: ***SMRs are being talked about as the "Game Changer", what is your perception?***

Dr. Anil Kakodkar: Small Modular Reactors (SMRs) have been talked about for a long time with shifting drivers. Some of these are safety (small is beautiful), reduced financial risk through lower capital cost for a smaller unit and modular site construction to realize the required capacity, increasing work content in the factory as against at the construction site (modular construction/fully factory assembled units that can be transported to site), barge mounted plants that can be moved to a coastal site and connected to grid and such other logics. Such plants are also a good fit for countries which can accommodate only marginal capacity addition either due to smaller grid sizes as would be the case in many small emerging economy countries or to meet specific needs in advanced countries. However, at the moment their specific capital cost would be higher as compared to large plants unless benefit of mass production can be leveraged. That is a matter of market development requiring a massive policy push. In the Indian context, we need to understand that manufacturing costs of high-tech products in India is way lower as compared to developed countries and unless one is talking about SMR activity with factory assembled units manufactured in India, they are unlikely to be competitive. Having said that, if these units in addition are demonstrated to be so safe that off-site impact in an accident is a non-issue and exclusion radius requirements can be done away with (AHWR development experience can be leveraged here), then there exists an opportunity to rapidly ramp up nuclear capacity by making use of sites of retiring coal plants provided the design can be made site independent and reactors mass manufactured and fully assembled in Indian factories and transported to site. This would require a new approach involving credible Government commitment and policy support, mobilizing a consortium involving public private partnerships and co-working between NPCIL and NTPC.

AHWR development experience can be leveraged for ramping up of factory assembled SMRs in place of retiring coal plants in India

Dr. A.K. Nayak: ***What do you feel about the future of fission technology? Do you think ADSS and fusion technologies would drive the power generation by the end of this century?***

Dr. Anil Kakodkar: To my mind both ADSS as well as fusion technologies are important technologies for securing long term energy needs on earth. However, the first commercial unit in my assessment may be around fifty years away.

We should welcome these developments particularly in the context of abundant clean energy potential these technologies can unleash and transmutation of long-life nuclear waste products.

Dr. A.K. Nayak: ***Nuclear technology is yet to reach the transport sector including civil aviation; what is your vision towards that?***

Dr. Anil Kakodkar: I believe nuclear technology can play an effective role essentially for shipping including transportation under the ice cap and space transportation beyond low earth orbit.

Dr. A.K. Nayak: ***The Russian KLT-40 has created new avenue for floating nuclear reactors, what do you feel about relevance of this technology for India, considering its large population density and limited sites for nuclear expansion?***

Dr. Anil Kakodkar: I think, these units are too small and expensive to make a difference to our capacity addition needs when deployed as single or twin units. However, there may be special needs in specific cases.

Dr. A.K. Nayak: ***AHWR is your brain child. Substantial work has happened towards technology development, proof of concept of this reactor. What are your views for faster deployment of this reactor?***

Dr. Anil Kakodkar: AHWR was conceived with the twin objective of enlarging our experience on thorium utilization for power generation and evolving a safe design leveraging current knowledge and technologies that does not lead to public trauma as was being experienced following a severe accident like Chernobyl then and Fukushima later.

I do believe that we should set up one or two units early and offer the units for export market. This will also take us a bit closer to our third stage which is yet to evolve besides making a significant contribution to mitigating climate change.

Dr. A.K. Nayak: ***To expand the nuclear power from few GW today to several hundreds of GW tomorrow, non-Government funding would play major role. How could this be achieved?***

Artist's impression of AHWR Facility @ BARC Photo

AHWR serves the twin objective of enlarging our experience on thorium utilization for power generation and in evolving a safe design

Dr. Anil Kakodkar: This is the main challenge. Beyond what Govt. funding can achieve, we need to create conditions to be able to leverage internal resource generation of our energy PSUs (on the basis of clean energy transition for them) as well as market resources on the basis of BOT (Build, Operate and Transfer) model.

Dr. A.K. Nayak: ***Large business potential from radio isotopes are being talked about. What are the perspectives for India?***

Dr. Anil Kakodkar: With vibrant Pharma industry in the country and domestic capability in building large research reactors, we should really be world leaders in radio-isotopes and radio-pharmaceuticals. In past we missed opportunities when there was disruption in production in other countries. We should now leapfrog and at least become a net exporter to start with and then move on to become a global leader.

Dr. A.K. Nayak: ***You have been talking about exporting small sized PHWRs to new entrants using thorium fuel; what are the bottlenecks today?***

Dr. Anil Kakodkar: HALEU-Thorium fuel in PHWR enable some unique advantages. Long burn-up, safer and much reduced spent fuel storage needs, proliferation resistance and superior safety performance.

Qualification of high burn up fuel can be done in test reactors abroad in a couple of years. This should open export opportunity for our well proven and cost competitive 220 MWe PHWRs which is really the need of emerging economy markets.

Export of thorium fueled small PHWRs represents a near ready opportunity for India to make a significant contribution to mitigating climate change besides boosting our exports. As mentioned earlier AHWRs could expand this opportunity further.

Dr. A.K. Nayak: ***You are an ambassador of solar energy. Do you feel that the nuclear has to compete with solar for cost and safety?***

Dr. Anil Kakodkar: Cost competitiveness is always a key factor. Having said that, nuclear and solar energy are complimentary to each other. The energy basket must be diverse, also there is merit in promoting both decentralized as well as centralized generation. I thus see a lot of synergy and not conflict.

> With a vibrant pharma industry and domestic capability in building large research reactors, we should really be world leaders in radio-isotopes and radio-pharmaceuticals

Dr. A.K. Nayak: ***Public acceptance of nuclear power has been a growing concern over decades. What can change the mindset of common people, and how?***

Dr. Anil Kakodkar: Sustained familiarity, being a practical beneficiary and consistently good performance along with meaningful outreach would be the key to greater acceptance of nuclear power. I also believe that taking up holistic development of all people and villages within 5 KM radius under a special planning authority framework utilizing CSR funds and synergizing renewable (wind & solar) energy deployment in the area including in exclusion zone would change NIMBY (not in my backyard) syndrome to Nuclear4Climate syndrome.

The editorial board expresses its deep gratitude to Dr. Anil Kakodkar, Former Chairman, AEC for sparing his valuable time to be the Special Guest for the new year issue of BARC Newsletter-2021, and replying to some of the critical issues on energy front the country faces at present.

● **Dr. Anil Kakodkar** served as the chairman of the Atomic Energy Commission of India and the Secretary to the Government of India during 2000-2009, and was the Director of the BARC, Trombay during 1996–2000. He was awarded the Padma Vibhushan, India's second highest civilian honour, in the year 2009. Apart from playing a major role in India's nuclear tests in 1974 and 1998 asserting India's sovereignty, Dr. Kakodkar had done pioneering work towards India's self-reliance on thorium as a fuel for nuclear energy. Technology development for AHWR and High Temperature Reactors are some of his major contributions for thorium utilization. He led the indigenous development of India's Pressurised Heavy Water Reactor Technology, and designed and built the research reactor Dhruva at Trombay.

● **Dr. A. K. Nayak** joined Reactor Design and Development Group in BARC in 1990.In his career spanning across multiple decades, he made immense contributions on design aspects of Advanced Heavy Water Reactor and on development of innovative passive safety systems of the reactor; he is also popularly known as "severe accident expert". His developmental work on small and modular reactors for addressing growing carbon emissions culminated into an innovative water-cooled 'Passive Safe Integral Reactor'.He is currently Outstanding Scientist and Head, Thermal Hydraulics Section, BARC and Professor, Homi Bhabha National Institute.