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Centre for Air Power Studies (CAPS)
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By Manpreet Sethi

Assessing the Promise of Small Modular Reactors from an Indian Perspective

Distinguished Fellow, Centre for Air Power Studies

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There is a palpable sense of enthusiasm around the idea of 'Small Modular Reactors' (SMRs). These are being seen as a solution to some of the persistent challenges of long construction times and high economic costs associated with traditional nuclear reactors. A race is underway within the nuclear industry, backed considerably by governments, to work on new designs and manufacturing processes that are expected to prove their commercial viability and make them operational within a decade. How realistic is this estimate? What kind of advantages will SMRs offer? What challenges are they likely to face? This issue of the column undertakes an assessment of SMRs, especially in the context of India's energy mix.

What are SMRs?

As the name suggests, SMRs would have two main attributes– small and modular. In terms of size, they are to be fission reactors with a capacity of about 300 MWe or less. In terms of modularity, they are envisaged to be amenable to being centrally manufactured at a factory and then transportable to the desired site for assembly/installation. Much like a machine, and quite unlike the traditional nuclear reactors that are built on site, SMRs are expected to arrive at a site, be plugged in and start producing electricity. They would also offer the possibility of the addition of multiple similar reactors when desired. Also, these could be placed on land, on ships for off-shore deployment (which are known as floating nuclear power plants), or even in an underground or submerged environment.

Over 70 SMR designs are being developed in different countries around the world today. At different stages on the drawing board, these designs range from slightly modified versions of existing reactors to those involving completely new technologies. Staying abreast of the high level of activity around the new ideas, the International Atomic Energy Agency (IAEA) has set up the SMR Regulators' Forum to help countries share information on issues of common concern. It published a Technology Roadmap for Small Modular Reactor Deployment in 2021 that_identifies, evaluates and promotes collaboration and knowledge sharing amongst technology developers, industry, users and regulatory bodies.

Expected Advantages of SMRs

Speed of Installation and Cost Savings

One of the main advantages of SMRs is seen in their ability to be manufactured as pre-fabricated and pre-tested modules that can be easily assembled/installed on site after being transported conveniently. Modularity in manufacturing and assembly is expected to reduce construction time. The idea, in fact, is to compress a large technological project into a relatively easy installation of a pre-fabricated product of standardised quality. A study in this regard has suggested that SMRs can reduce construction time by 3.5 years in comparison to the average 6.5 years required as of now.[1] Reduced gestation periods are then expected to reduce capital costs too, thus increase the economic competitiveness of the reactors.

Enhanced Safety and Security Features

Given the new technologies being incorporated by SMRs, these are expected to include enhanced safety and security features. On the safety front, the reactors are being designed to incorporate modern passive safety systems that minimise the need for human intervention in case of emergencies. On nuclear security, they would incorporate the concept of "security by design" to address concerns of sabotage, theft, attacks and proliferation. Since many of these designs are expected to operate for prolonged periods without the need for refuelling, there would be related benefits of reduced risks of transportation of nuclear materials too.[2]

Flexibility of Installation and Siting

SMRs would provide flexibility in siting options, especially their placement in remote, isolated areas that are currently dependent on diesel generators. Given their compactness, they are envisaged to need less land, as well as concomitant emergency zone requirements. Addition or removal of new modules, as considered necessary, would add to the flexibility advantage.

Baseload Power in Support of Renewables

Nuclear power has a major advantage of being a baseload source of electricity. With the current trend favouring a rapid deployment of renewable energy, SMRs could complement these sources to address their disadvantage of intermittency. So, SMRs could supplement solar, wind, small hydroelectric and tidal generation to ensure a continuous supply of electricity and thus help stabilise the grid. This combination would help overcome the challenge of storage that the use of renewables still poses. It would also allow renewable energy to enjoy a low-carbon backup source instead of relying on thermal plants for handling the problem of intermittency.

Better Waste Management

Spent fuel management has been perceived as a major challenge of nuclear plants. SMRs are trying to address this by experimenting with new ideas for dealing with nuclear waste. These include fast reactor designs that would ensure higher fuel burnup and hence a lesser amount of nuclear waste generation or the travelling wave reactor design that could consume the fuel that it breeds, thereby minimising the need to remove spent fuel. Likewise, other SMR technologies have been trying to develop a thorium fuel cycle, which too could reduce nuclear waste.

Better Resource Efficiency

SMRs are also likely to offer better resource efficiency, given their comparatively smaller physical footprint. Requirement of land would be less as compared to a traditional nuclear power plant. The latter needs an emergency planning zone extending up to 16 kms around the plant. In comparison, SMRs would require just about two kms.[3] They are also expected to be time efficient in deployment as well as require lesser maintenance.

Challenges that Persist with SMRs

While SMRs seem promising in addressing the long-standing challenges of traditional nuclear reactors, it needs to be understood that all these promises are currently expectations. The true economic viability of SMRs will be available for appraisal only when some designs have matured, become standardised and gone into factory production. This currently appears on the distant horizon.

Supply Chain Maturity & Price Advantage– Long Way Off

Modularity is being touted as the biggest advantage of SMRs. It is expected that SMRs will reap the benefits of serial factory manufacturing, which would enable optimum standardisation of components. Pre-assembled modules will simplify on-site installation. The problem, however, remains that for factories to sink in substantive capital investment to create the infrastructure for such manufacturing, they would need assurance of a sufficient number of orders. Only then will economic efficiencies emerge. Such orders, as of now, appear distant. It will take time before one particular design from the plethora currently being experimented with is sufficiently field-proven and accepted by a large number of companies, operators and regulatory bodies. Therefore, the supply chain maturity of SMRs will take time, even a few decades, to emerge.

Tussle between Industry and Regulators

Given the novelty of the concept, the nuclear industry investing in SMRs is facing challenges ranging from licensing to liability. The current regulatory regimes are designed for traditional nuclear plants. As the industry seeks changes, they are being met with overly cautious regulators who are not only careful about the novel designs being experimented with but also wary of the reality that many players in the SMR space are new to the nuclear industry. Both sides, therefore, are yet to find a level of comfort with each other.

Another challenge in this space would emerge when reactors that have achieved design approval in one country are exported for installation in another country as a pre-fabricated product. As per Current patterns, design approval secured by the regulatory agency of one country does not automatically become acceptable in another, and since different regulators place emphasis on different issues, any demand for design changes would defeat the advantage of modularity and stability of supply chains with pre-fab SMRs. Demands for changes would also drive up the cost of reactors, thereby negating one of the purported advantages of SMRs.

Liability Issues

Liability in case of an accident at a nuclear plant is also a matter of great concern and contention. The maximum concerns in this regard have been raised in the context of Floating Nuclear Power Plants (FNPPs). The first of these pertains to the very definition of such reactors under the existing conventions. For instance, the Convention on Nuclear Safety (CNS) defines a "nuclear installation" as "any land-based civil nuclear power plant under its jurisdiction". Experts differ on whether a floating nuclear power plant at shore or off-shore could be considered a nuclear installation under the international third-party nuclear liability conventions. Questions have also been raised on what happens when the FNPP navigates through different maritime zones and high seas. The CNS only refers to the carriage of nuclear substances, i.e. nuclear fuel and radioactive products and waste, not a nuclear reactor. A discussion on the liability regime applicable during the carriage and operation of a nuclear reactor, therefore, becomes imperative. This is especially necessary to facilitate the insurance coverage of such installations and protect potential victims in case a nuclear incident occurs during the journey.

India: The Way Ahead with SMRs

Of the 23 nuclear reactors operational in India today, the majority of those indigenously built have a capacity rating of 220 MWe. India also has the experience of having built an 85 MWe reactor for its nuclear submarine. This shows that India has the capability to design, build and operate small reactors. While it has not utilised a modular factory process so far, the industry involved in manufacturing nuclear equipment can be expected to make this possible in case the nuclear establishment is keen to build such reactors.

Cognisant of the potential of SMRs, India's Department of Energy has design teams working on the technology.[4] Speaking of SMR prospects for the country, K N Vyas, former Secretary, Department of Atomic Energy (DAE) and Chairman of the Atomic Energy Commission, had stated in 2019, "Carrying out the design of new reactor systems and refinement in the already performed design is an ongoing process, which is always under focus to improve the designer's capability. SMRs also need some technology development to fill-up gap areas. The process of technology development also needs to be completed before tasks related to SMRs can be taken up in a more serious manner."[5]

While DAE is keeping abreast of SMR developments, its current priority is technological advances in the current stream of reactors. Having graduated from 220 MWe to 540 MWe to 700 MWe, India has striven to reach higher capacity reactors in order to ensure a rapid expansion of nuclear electricity generation. In fact, one of the primary motivations for the conclusion of the Indo-US agreement for peaceful nuclear cooperation was to enable the import of larger-capacity reactors. While these imports have remained embroiled in price negotiations and liability Issues, India's indigenous efforts have yielded 700 MWe reactors.

Can SMRs be attractive for a country like India, where the demand for electricity is expected to continue growing? Indeed, in such a situation, the rationale for large reactors is loud and clear. However, SMRs too could be useful in a few scenarios. One of these could be to replace old coal plants that need to be decommissioned. In this regard, Srikumar Banerjee, another former Chairman, Atomic Energy Commission, had rightly stated, "Some of the retiring thermal power plants can be replaced with small modular reactors."[6] This would also help combat air pollution problems plaguing the country and meet its Paris Agreement goals. In fact, given the high induction of renewable power in a thrust to move towards green technologies, SMRs could supplement this by being a dependable base load and clean source of power. They might also come in useful for providing electricity in remote areas or islands.

However, it still remains unclear whether SMRs will become the force of transformation they promise to be. The buzz around them is certainly strong and fuelled by the urgent need to find low-carbon electricity generation sources. Not surprisingly, this space is being seen as a huge investment opportunity by the nuclear industry. India, too, should find ways, especially through the private industry route, to keep its options open. The DAE/Nuclear Power Corporation of India (NPCIL) may offer to do some hand-holding for private players to help them build such reactors once a design has been created and proven through a prototype. Thereafter, private players can be incentivised by the government through, as has also been suggested, production linked incentive schemes for manufacturing such reactors. Some of the more recent nuclear cooperation agreements signed with countries such as France, USA, South Korea and Russia mention possibilities of collaboration on SMRs too.

However, it needs to be emphasised that given the country's electricity requirements, it need not feature at the top of the DAE's priority list. Developed countries that are engaged with SMRs are doing so at a stage where their electricity demand and population growth are mostly stable and, in some cases, even stagnant. The new technology development, then, is actually a way for the nuclear industry to keep itself gainfully occupied and with a view to popularise new nuclear build for countries where reactor construction has stagnated or where there is potential to export them to nuclear newcomers. For DAE/NPCIL to divert any large part of its nuclear resources towards such a technology would be a diversion from its focus, which should be on the quick construction of planned nuclear reactors in order to enhance the country's electricity supply with an environmentally friendly source. Long-term policy support is needed to bring the planned reactors of larger sizes to fruition and to do so within specified time schedules.

(Disclaimer: The views and opinions expressed in this article are those of the author and do not necessarily reflect the position of the Centre for Air Power Studies [CAPS])

Notes:

[1] Clara A Lloyd, "Modular Manufacture and Construction of Small Nuclear Power Generation Systems", Research Gate, May 2019, https://www.researchgate.net/publication/337937287_Modular_Manufacture_and_Construction_of_Small_Nuclear_Power_Generation_Systems. Accessed on October 03, 2021.

[2] The Department of Energy, USA, "Benefits of Small Modular Reactors (SMRs)", *ENERGY.GOV,* https://www.energy.gov/ne/benefits-small-modular-reactors-smrs#:~:text=SMRs%20provide%20simplicity%20of%20design,as%20demand%20for%20energy%20increasess. Accessed on October 02, 2021.

[3] "Small Modular Reactors: An Overview", ANSTO, April 16, 2024, https://www.ansto.gov.au/news/small-modular-reactors-an-overview.

[4] "DAE working on Small Modular Reactors: KN Vyas", *Nuclear Asia*, November 21, 2019, https://www.nuclearasia.com/news/dae-working-small-modular-reactors-kn-vyas/3307/. Accessed on October 16, 2021.

[5] Ibid.

[6] "Small modular nuclear reactors are now beautiful for plant makers", *Energyworld.com,*

February 25, 2021, https://energy.economictimes.indiatimes.com/news/power/small-modular-nuclear-reactors-are-now-beautiful-for-plant-makers/81209735. Accessed on August 16, 2021.