RSIS S. RAJARATNAM SCHOOL OF INTERNATIONAL STUDIES
Nanyang Technological University, Singapore

RSIS COMMENTARY

www.rsis.edu.sg No. 074 – 10 May 2023

The Way Forward for Underground Nuclear Reactors

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SYNOPSIS

The war in Ukraine and the safety of the Zaporizhzhia Nuclear Power Plant have heightened the safety concerns of nuclear power plants surviving direct hits from enemy missiles. But if nuclear reactors are built underground, the risks of a catastrophic fallout arising from this can be reduced.

COMMENTARY

THE United Nations Review Conference of the Non-Proliferation Treaty (NPT) in 2022 did not produce a consensus document because Russia did not agree with the texts related to the occupied Zaporizhzhia Nuclear Power Plant (NPP) in Ukraine. Such is the weight of the matter that discussions on a treaty concerning nuclear weapons non-proliferation and disarmament had reached a stalemate, all because of the safety of a civilian nuclear facility.

Over the last year, officials from the International Atomic Energy Agency (IAEA) had been allowed onsite to monitor the safe operation of the Zaporizhzhia NPP. Although the agency expended enormous resources on the NPP, any compromise of its structural integrity owing to shelling by the warring forces could have resulted in a consequence far greater than the Chernobyl radioactive fallout in 1986. Even though the reactors had been shut down, the NPP still remained a sitting-duck in the conflict zone.

The Zaporizhzhia NPP episode has highlighted how civilian NPPs can become centres of gravity during a war, and this has enormous implications for the design and reinforcement of NPPs going forward.

Going Underground for Protection

Nuclear reactors around the world are built above ground and housed in a fortified containment building. In the US, the Defence-In-Depth safety philosophy, which aims to prevent and mitigate accidents through overlapping layers of protection, ensure that such buildings have been designed to withstand the impact of an aircraft crash. In 1988, Sandia National Laboratories carried out component testing that showed a containment building withstanding the impact of an F-4 fighter jet crash. Following the 9/11 attack, computer simulations also concluded that containment buildings in the US can withstand the crash of a Boeing 767 commercial aircraft.

However, the impact of missiles are different from that of air crashes. Firstly, the structural integrity of the nuclear facility would have already been weakened by artillery barrages during a battle. Furthermore, the pressure exerted on the NPP will be much greater given the higher velocity of advanced projectiles comprising sharper shaped charges. An NPP target will succumb to the penetrative and explosive effects of these missiles.

Although it is a war crime to attack a nuclear facility, international instruments and laws are inadequate to prevent attacks arising from miscalculations. The reality, therefore, is that NPPs built above ground are vulnerable in a war, and the only way to reduce the risk of NPPs being attacked is to build the reactors underground.

An underground reactor not only possesses superior protection in times of war, but it also has a smaller footprint, which is a huge factor in winning public acceptance. The advent of Small Modular Reactors (SMRs) will also offer more flexibility for these underground reactors to be sited in or closer to city centres. For densely populated countries like Singapore, it will certainly be a major policy consideration to have reactors built underground – both in consideration of nuclear safety as well as physical security.

Challenges in Emergency Response

Building reactors underground is however a “double-edged sword”. While it offers better protection, the nature of it is such that access to the reactors would be more challenging in an emergency. For example, during the Fukushima nuclear disaster in March 2011, the reactors were doused with seawater as a last resort to cool the reactor cores and prevent them from a complete meltdown. Had the reactors been built underground, it would have been more challenging to pump seawater into the reactors’ vessels.

Evacuating personnel from an underground reactor during an emergency will also be a challenge. Emergency plans for evacuation would need to be meticulously drawn up and rigorously exercised. The easy access to and exit from an underground reactor during an emergency has to be balanced against the requirement for fortified security.

Currently, there are no IAEA guidelines on emergency responses for underground reactors. Vendors developing such reactors will need to convince their regulators that not only will the entire plant remain safe during operation, but the safety of the operators are also assured. Building such a reactor is not simply about assembling a conventional SMR in the factory and placing it underground. An integration of safety,

security and safeguards (termed the 3Ss) has to be embedded into the design philosophy.

NuScale Power Corporation has done several iterations of design and component testing to qualify for the US National Regulatory Commission (NRC) licence to develop an SMR that will be sited underground. The growing preference for smaller reactors could reduce costs as having them underground could be cheaper than having them in containment buildings. Hence, we could potentially see other vendors venturing into the domain of underground reactors.

The Way Forward

The demand for underground reactors will increase, not only because they will be less vulnerable during a war. An underground design is also more robust against earthquakes or tsunamis. The fact that an underground nuclear reactor will not be in the public eye could greatly ameliorate the Not-In-My-Backyard (NIMBY) syndrome.

In Singapore, the population, being well-educated, will have no doubts about the role nuclear energy plays in combating global climate change. In 2008, Minister Mentor Lee Kuan Yew had said that nuclear energy was the solution to Singapore's energy security and climate change issues. With advances in nuclear safety technology, it is technically feasible for Singapore to build an NPP. The NIMBY syndrome will be easier to address if the reactor is built underground.

With new safety technologies and the feasibility of building nuclear reactors underground, the time has come for countries in Southeast Asia to curb their carbon emissions by adopting nuclear energy. The region has deliberated on the issue for far too long, and our climate clock is ticking away. What is needed are vendors with a proven SMR design, which is licensed by a credible regulator and is ready to be deployed. The entry barrier to this niche nuclear industry is very high as the safety of populations and the environment cannot be compromised.

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