Nuclear Power Plants at the Crossroads

Teruhi Fukano

wonder-news.com

September 30, 2022

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INTRODUCTION

Nuclear reactors are an unprecedented power source with a unique dilemma—they must meet people's extreme expectations while being forced to adhere to stringent safety concerns. There is no end to the fighting in Ukraine in sight. Governments in Europe and Japan are leaning toward deployment of nuclear power plants more than ever. The governments of the United Kingdom and France are breaking away from dependence on Russia for energy resources and have revealed plans to build new nuclear power plants to secure long-term, stable energy supplies. In light of this movement in Europe, the Japanese government also announced that it would move ahead with the construction of new reactors for the first time since the Fukushima nuclear accident. Extreme expectations for nuclear power plants by policy makers will grow stronger under pressure to take measures against a soar in fuel prices and climate change.

A nuclear power plant (NPP) is visible physical equipment, but also an invisible, complex system. It is difficult to understand the invisible system and how it works. Furthermore, it is even more difficult to develop such a system. That is one of the reasons why the development and operation of an NPP is never easy. In short, each element is visible, but the principles that connect the elements are invisible. The integrity of the entire system could fail by adding or changing a part or function. Thus, an NPP requires constant vigilance to reduce safety risks.

In general terms, an NPP tends to be viewed as “a power source that will stably generate power once it starts operating.” This report will seek to answer whether that is a correct view. In addition, it also explores the significance of securing the independence of nuclear power regulators and the geopolitical risks of NPPs, which come to light in the wake of the Russian invasion of Ukraine.

NUCLEAR REGULATION AUTHORITY

“Nuclear safety must be at the heart of energy policies.”[7] The nuclear regulators around the globe share this common philosophy and determined attitude. They say that nuclear regulators in each country reaffirm this belief every year on March 11th, the anniversary of the Fukushima nuclear accident in 2011. Following this, the Nuclear Regulation Authority (NRA) was separated from the Ministry of Economy, Trade and Industry (METI), which pushes the use of nuclear power, and was established as an external agency of the Ministry of the Environment as a highly independent organization that ensures the regulation of the use of nuclear power. Confidence in Japan's nuclear power administration was lost overnight after the Fukushima nuclear disaster. More than 11 years after the accident, the NRA is still on the way to regaining public trust.

It is a well-known fact that “in principle, a nuclear power plant is not allowed to operate without a strict safety review by the NRA”. Some of the Japanese policy makers’ words and deeds twist this principle as power supply and demand become tighter and energy prices soar. The NRA must not be a lapdog, but a watchdog to safeguard the safety of nuclear power plants. If there are any signs that the NRA is making a U-turn to become a lapdog of the administration and METI, overseas nuclear reactor manufacturers may think twice about providing new, hard-to-develop reactors to Japan, which it diligently procures.

NUCLEAR POWER PLANT STABILITY

It is difficult to say that an NPP, where safety is the top priority, is a stable baseload power. Let's look at some cases that prove it.

In December 2021, French power giant Électricité de France (EDF) announced that it found stress corrosion close to the welds on the pipes of the safety injection system during preventive maintenance checks on the primary circuit of No.1 reactor of the Civaux Nuclear Power Plant. EDF informed ASN, the French

[7] ASN, See https://www.french-nuclear-safety.fr/asn-informs/publications/asn-s-annual-reports/asn-report-on-the-state-of-nuclear-safety-and-radiation-protection-in-france-in-2021 (as of 2022/9/15)

Nuclear Safety Authority, of this detection. Checks initiated for the same equipment on No.2 reactor of the Civaux Nuclear Power Plant revealed similar defects. The four reactors of the Chooz and Civaux nuclear power plants use the same technology and form the N4 reactor series of the French nuclear fleet. EDF, therefore, shut down all of these four reactors by the end of December 2021 as a precautionary measure[8].

Table 1 Reactors undergoing checks and investigation (EDF)

	Plant Name	Commercial operation	Unit Power Capacity (MW)	Reactor Type	Model	Stress Corrosion
	Checks and expertises carried out					
1	Chinon B3	1987/3/4	905	PWR	CP2	The absence of stress corrosion on the SIS circuit was confirmed. Evidence of stress corrosion was located on a weld of the RRA circuit.
2	Penly 1	1990/12/1	1330	PWR	P4 REP 1300	RIS, RRA
3	Chooz 1	2000/5/15	1455	PWR	N4 REP 1450	RIS, RRA
4	Civaux 1	2002/1/29	1495	PWR	N4 REP 1450	RIS, RRA
		Subtotal	4,280			
	Checks and investigations are ongoing					
1	Bugey 3	1979/3/1	910	PWR	CP0	
2	Bugey 4	1979/7/1	880	PWR	CP0	
3	Flamanville 1	1986/12/1	1330	PWR	P4 REP 1300	
4	Flamanville 2	1987/3/9	1330	PWR	P4 REP 1300	
5	Cattenom 3	1991/2/1	1300	PWR	P4 REP 1300	
6	Golfech 1	1991/2/1	1310	PWR	P4 REP 1300	
7	Chooz 2	2000/9/29	1500	PWR	N4 REP 1450	
8	Civaux 2	2002/4/23	1495	PWR	N4 REP 1450	
		Subtotal	10,055			
		Total	14,335			

NA = not available

RIS = safety injection circuit

RRA = shutdown reactor cooling circuit

Note: Data is as of 2022/5/19.

Source: EDF, IAEA and World Nuclear Association

[8] EDF, "Nuclear power plants: replacements and preventive checks on parts of the piping of a safety system", 2021/12/15 See https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/reactors-of-the-civaux-and-chooz-nuclear-power-plants-replacements-and-preventive-checks-on-parts-of-the-piping-of-a-safety-system (as of 2022/9/15)

Furthermore, in 2022, EDF expanded the scope of checks and investigations, adding eight new reactors (**Table 1**). The reactors Civaux 1, Chooz 1 and Penly 1 also have confirmed stress corrosion near the welds of the RIS (safety injection circuit) and RRA (shutdown reactor cooling circuit)[9]. The safety injection system is an important backup system for nuclear stations in the event of an accident. This triggers serious concern.

The NPPs involved in the investigation have some common features. They are less than design operating lifetime of 40 years for the NPP[10], except for the CP model, and large output and PWR-based models. The head of French nuclear regulator ASN said in a parliamentary hearing that the cause of the problem was still unknown. However, one possible cause for the defect could be the "Frenchifying of the design" of 900 MW reactors originally based on a Westinghouse design. The P4 and N4 models where corrosion was found in RIS and RRA this time are the nuclear reactors that have been modified from the CP model. Fixing corrosion problems at some of EDF's nuclear reactors would require "several years," as he warned of a risk that more reactors could be halted[11].

Of EDF's 56 domestic reactors, 32 were offline this summer due to planned maintenance or work to evaluate the corrosion risks, in which 12 reactors were included for investigation or repair. The French government announced that EDF would restart all its nuclear reactors that have undergone planned maintenance and repairs by this winter and asks EDF to report the progress of the 12 reactors under investigation. The shutdown of 12 nuclear reactors will be a big loss for the government and EDF since they were expecting to operate all reactors this winter. Domestic power generation alone cannot meet the electricity demand, so the government is compelled to import electricity from other European nations.

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9 EDF, "Update on the stress corrosion phenomenon and adjustment of 2022 French nuclear output estimate", 2022/05/19 See https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/update-on-the-stress-corrosion-phenomenon-and-adjustment-of-2022-french-nuclear-output-estimate (as of 2022/9/15)

10 Stanislav Novak and Milan Podest, "Nuclear power plant aging and life extension: Safety aspects", April 1987, See https://www.iaea.org/sites/default/files/29402043133.pdf (as of 2022/9/15)

11 Reuters, "Fixing EDF's reactors corrosion mystery to take several years, French regulator warns", 2022/5/18

NEW NUCLEAR RECTOR CONCERNS

It is obvious that stable operation of new nuclear reactors is difficult from both domestic and overseas cases. EDF's next-generation European Pressurized Reactors (EPRs) have a troubled history. EPRs in Finland and China, which have just started operation after significant construction delays and budget overruns, have been hit by technical issues. The China General Nuclear Power Group (CGN), which operates the Taishan plant with EDF, shut down one of its reactors in July 2021 to investigate fuel damage after examining a potential issue linked to a buildup of inert gases.

The Japan Atomic Energy Agency (JAEA), a national R&D agency, set disgraceful records in nuclear reactor developments in Japan. The Fast Breeder Reactor (FBR) "Monju" began performance tests in 1992, and three months after the first power generation in the summer of 1995, a sodium leak accident occurred in the primary cooling system. The reactor was then shut down. The NRA approved decommissioning of Monju in the spring of 2018. Over the past 23 years, the JAEA invested 1.13 trillion yen (US$7.9 billion) in Monju, but it operated only for three months[12].

The nuclear fuel cycle reprocessing plant is another disgraceful example, although it is not a nuclear reactor. Construction of the reprocessing plant began in 1993 and was originally scheduled to be completed in 1997, but even now, more than 29 years later, there is still no prospect of when it will be finished. The total project cost is expected to exceed 14 trillion yen (US$97.5 billion). When completed, the next concern is the aging of the buildings and equipment. When it comes to nuclear power projects, the Japanese government and electric utility firms tend to disregard return on investment and there seems to be no way out of this predicament.

[12] Japan Atomic Energy Agency See https://www.jaea.go.jp/04/monju/history/ (as of 2022/9/1)

GEOPOLITICAL RISK

The prerequisite for using nuclear power plants is that a “peaceful era will continue.” Shelling at the site of the Zaporizhye nuclear power plant in Ukraine[13] horrifies the world and could lead to a nuclear disaster, highlighting the difficulty of ensuring the safety of nuclear facilities during wartime. A large aircraft approaching an NPP has a chance to intercept a strike, but missile technology is rapidly evolving so that interception is difficult. Primarily, armed attacks on NPPs have not been accounted for during their architecture. NPPs are not designed to withstand military munitions that could directly penetrate the concrete reactor containment and steel pressure vessel, allowing a release of highly radioactive material like in Japan's Fukushima nuclear disaster in 2011. Nuclear-related facilities have been occupied by Russian forces one after another right after invading Ukraine. If such a situation were to occur in Japan, it would be impossible for private-sector electric utilities to ensure the safety of NPPs (and their employees) alone.

Japan cannot ignore geopolitical risks either. Military tensions around Japan may rise as China and Russia have rapidly strengthened a military tie, and North Korea repeatedly has launched missiles in recent years. It would be no exaggeration to say that it is time to weave national security into Japan’s energy policy. It is necessary to discuss a mix of energy sources suitable for Japan in view of its unique geological hazards[14] and geopolitical risks.

[13] Six Soviet-designed VVER-1000 reactors, all of which are light water reactors (cooled by ordinary water).
[14] One third of the world's trenches are concentrated around the Japanese archipelago. Henc, volcanoes and earthquakes are likely to occur in the deep underground around the trenches due to interactions between plates.

FUTURE OUTLOOK

We need to keep a watchful eye on the NRA and whether its independence will continue to be secured. It must never be forgotten that the safety of NPPs is no longer a concern solely for Japan and that a nuclear disaster in one country affects the energy policies of other countries.

An NPP is not a magic wand. Regarding existing and new reactors, NPPs are not power sources that operate exactly as people wish. Japanese policy makers cannot solve the electricity shortage by simply anticipating the resumption of NPPs and the construction of new reactors that could fail or be wartime targets. It is essential to continuously develop new power sources to increase various options. It is necessary for Japan to boost energy security more than ever before by facilitating the use of renewable energy and diversifying energy sources (e.g., green hydrogen) and supply.