© May 2020 | IJIRT | Volume 6 Issue 12 | ISSN: 2349-6002

Review on Concepts of Nuclear Power Plant

Swapnil Namekar[1], Aman Singh[2]

[1]*Assistant Professor, Department of Electrical Electrical Engineering, Bharati Vidyapeeth Deemed University, College of Engineering PUNE, India*

[2]*Student, Department of Electrical Electrical Engineering, Bharati Vidyapeeth Deemed University, College of Engineering PUNE, India*

Abstract- **This Review paper states that the concept of a nuclear power plant. Nuclear power can solve the energy trilemma of supplying baseload, clean and affordable power. However, a review of nuclear power plant (NPP) builds show mixed results, with delays in Finland and the US offset by successes in China, South Korea and the UAE. In the West, financing for new builds has been difficult in the face of a deregulated energy market, billion-dollar upfront investments, long build times and in the case of the US historically low gas prices. We explore how the nuclear industry is innovating in facing these challenges through a review of nuclear power developments in the past, present and future. Early developments in nuclear power in the 1950s resulted in a variety of designs, out of which the pressurized water reactor (PWR) became dominant for its compactness and overall economy. Over the next 10 years, several PWR-based small modular reactor (SMR) designs are expected to come online within an eight-year timeframe. Their modular construction and fabrication in a controlled factory setting aims to shorten build times from 8 to 3 years. However, the lack of established regulatory approval pathways may be a time-limiting challenge that needs to be overcome by the first fleet of SMRs. The passive safety and a smaller fuel loading of SMRs will allow them to be deployed at more potential sites, including brownfield replacements of old coal-fired power plants or power unconventional, remote or islanded grids. Some SMRs are also designed to load follow which will allow them to work harmoniously with intermittent renewables sources with the promise of an affordable, truly carbon-neutral grid. In the longer term, advanced nuclear reactors in the form of sodium-cooled, molten salt cooled, and high-temperature gas-cooled reactors hold the promise of providing efficient electricity production, industrial heat for heavy industry as well as the generation of hydrogen for synthetic fuel.**

CURRENT NUCLEAR POWER

There are currently 454 nuclear power reactors supplying more than 10% of the world's electricity, operating at a high capacity factor of 81% (2017 world average). 31 countries operate nuclear power plants (NPP) with 70% of the world's nuclear electricity generated in five countries – USA, France, China, Russia and South Korea. Today, the average age of the operational power reactors stands at 30 years with over 60% of all NPPs having operated for more than 31 years.

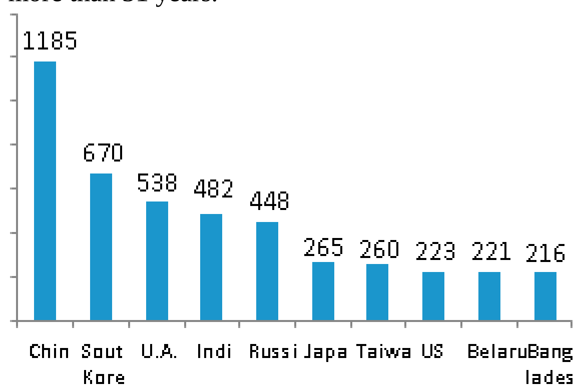

Fig. 1. Total net capacity of nuclear power under construction

Reactors (GCRs) at 3% with 14 units in the UK and two Sodium fast Neutron Reactors (SFRs) at 1% operating in Russia. Currently, 54 power reactors are under construction, the bulk of which is concentrated in Asia (figure 1) and one-third of all reactors under construction are in China. NPP builds are also underway in the West, but in more modest numbers as the industry revives its nuclear supply chain left dormant from the slow rate of build over the last 20 years

HISTORY OF NPP BUILDS

Nuclear energy production releases no CO_2, however the initial build out of NPPs was motivated by the desire for energy security. In reaction to the sharp rise in oil prices in 1973, France built 55 PWRs in the space of 16 years (1977–1993). In the US NPP numbers peaked at 111 units in 1991 with 95 GW coming online between 1970 and 1990. Currently there are 98 units (99 GWe capacity) in operation in the US, followed by France with 58 units (63 GWe capacity) then China with 46 units (43 GWe capacity, figure 3). China is quickly expanding its nuclear capacity, having overtaken Japan for third place in 2017. Taken as a whole, Europe operates more NPPs than the US with 130 units. NPP construction-starts in the US peaked at 44 units in 1976 and began to slow in late 1970s for a variety of factors "including slowing electric demand growth, high capital and construction costs, and public opposition. Costs, schedules, and public acceptance were all influenced by the accident at the Three Mile Island plant in 1979." This pattern was repeated with new reactor builds continuing to decline after Chernobyl (1986) before recovering briefly before the Fukushima accident in 2011.

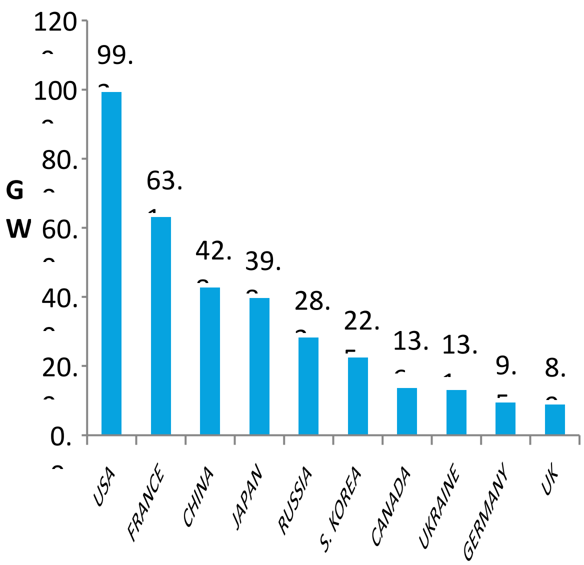

Fig.2 NPP installed capacity (PRIS, Oct. 2018)

After the Fukushima NPP accident, many governments initiated reviews of NPP operations, safety, management and procedures. All NPPs in Japan were shut down pending regulatory review. As of November 2018, 9 NPPs have restarted in Japan after satisfying new regulatory safety standards. In China, the 5-year build targets set by the State Council were slowed and new reactor build applications were suspended pending review. China's ban on new nuclear projects was lifted in Nov 2014, about three and a half years after the accident.

NPP BUILDS TODAY

Today, NPPs constructions have shifted from the West to the East with 4 out of 5 reactors under construction based in Asia and Eastern Europe. In the period 2016-2017, electricity generation from nuclear increased slightly by 1% to 2503 TWh. Most of the increase was attributed to three new NPPs commissioned in Chin lifting the country's nuclear power generation by 18% and expanding the share of nuclear electricity from 3.6% to 3.9% of total domestic production. Currently, there are 54 reactors under construction led by China with 11 reactors, India 7, Russia 6, South Korea 5 and the UAE with 4 units. Countries with 2 reactors under construction include Bangladesh, Belarus, Japan, Pakistan, Slovakia, Ukraine and the USA. Argentina, Brazil, Finland, France and Turkey all have 1 reactor under construction.

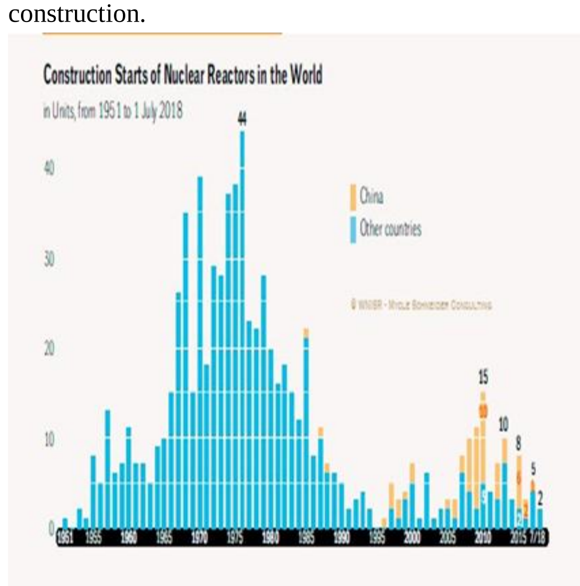

Fig.3 Construction starts of NPPs in the World and in China.

Today's global nuclear-installed capacity stands at 400 GWe. However, 169 GWe of that nuclear capacity will need replacing by 2030 to maintain the status quo in global nuclear capacity

This could be sustained by the continued build-out of NPPs in Asia, Eastern Europe and the Middle East but recent delays in nuclear builds in Olkiluoto (Finland), Flamanville (France) and Georgia (USA) makes large NPP build-outs in the West less likely. Instead, the West could diversify NPP builds with a small modular reactor (SMR) and now-LWR reactor (i.e. High-Temperature Gas Reactors - HTGRs, Molten Salt Reactors - MSRs etc.) deployments.

SMALL MODULAR REACTORS

In the face of delays in 1GW reactor builds in the West, it has become clear NPP vendors must innovate to build tomorrow's reactors faster, using safer, simplified designs. The general idea is to move construction away from the plant site and onto a factory mass-production line to decrease build costs and increase build quality.

Shortening build times are financially beneficial because 80% of the NPP life-cycle costs are incurred during the initial build phase. Thus, any year-long delay(s) in reactor construction could dramatically increase the reactor financing cost (i.e. interest repayments).

Small modular reactors are loosely classed as reactors with a power output of 300 MW electric or less and can encompass both LWR and non-LWR designs. The IRIS program, led by Westinghouse, sought to fit the separate parts of a reactor core, heat exchangers, control rods and pressurizer into a single, compact module. Findings from the IRIS program (1997 - 2009) led to the US DOE (Department of Energy) funding two competing i-PWR designs at USD 226 million each. BWXT received one grant to develop the m Power SMR (160 MWe) and Nu Scale the other to develop the Nu Scale Reactor (60 MWe) [9]. Today, the power project has been mothballed but Nu Scale is on track to build a first-of-a-kind (FOAK) 12-unit-plant supplying 720 MWe at Idaho National Laboratory (INL). The Nuclear Regulatory Commission (NRC) is currently reviewing Nu Scale's design certification which is scheduled to be completed in 2020. Construction will then start with a projected finish date of 2026.

THE FUTURE OF ADVANCED REACTORS

Research is underway on a variety of advanced reactors, including sodium-cooled fast neutron reactors (SFRs), lead-cooled fast reactors (LFRs), molten salt reactors (MSRs) and high-temperature gas reactors (HTGRs). As previously mentioned,. This versatility stems from sodium having an extremely low neutron capture cross-section resulting in a surplus of neutrons in the core that can be used to either burn actinide waste or bred more fissile fuel. Sodium is also a very good thermal conductor which enhances passive heat removal after reactor shutdown. China is constructing its pilot SFR (600MWe) that is scheduled for commissioning in 2023 in Xiapu. In contrast, the UK, USA, France and Japan have shut down their older experimental SFRs, though research in SFRs is continuing in France. Apart from the SFR, Russia is developing a lead cooled fast reactor (BREST-300). Using lead as a coolant is safer than using sodium (which is more chemically reactive) even though lead is not as neutron-efficient. To compensate for the higher neutron absorption of lead, uranium-nitride fuel with a higher uranium loading per unit volume is planned for use in LFRs.

Successful demonstration of the LF-1 demonstrator could pave the way for an MSR Breeder using thorium-232 as the fertile material for breeding uranium-233 fuel. Terrestrial Energy in Canada is pursuing a simplified design that uses denatured (i.e. low enrichment) uranium, and Terra power and Elysium Industries in the US are researching a molten chloride-salt fast reactor to burn the US spent-fuel inventory accumulated from LWR operation. Many other reactor-vendor startups are also working on MSR designs with much pre-licensing activity occurring in Canada.

ACKNOWLEDGEMENT

We would like to express our special thanks of gratefulness to De. DS Banker Head of department of electrical engineering for their able guidance and support for completing my research paper. I would like to also thanks the faculty members of the department of electrical engineering would help us extended support.

REFERENCES

[1] World Nuclear Industry Status Report [Internet]. 2018 Nov 1.
[2] Power Reactor Information System, IAEA, 2018 Nov 1.
[3] World Nuclear Association, Reactor Database. 2018 Nov 1.
[4] World Nuclear News 2018 Nov 1.

[5] US Energy Information Administration 2018 Nov 1.
[6] Ingersoll, Daniel, C. Colbert, Z. Houghton, R. Snuggerud, J. W. Gaston, and M. Empey. Integrating Nuclear and Renewables. 61 (2016).
[7] Lessons learned from the Fukushima Nuclear Accident 2018 Nov 1.