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Editorial: Unique safety features and licensing requirements of small modular reactors

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Editorial on the Research Topic
Unique safety features and licensing requirements of small modular reactors

Understanding the unique safety features of today's small modular reactors (SMRs) cannot be accomplished without understanding the historical context why this kind of reactor design is experiencing a renaissance and without understanding current safety concerns about nuclear technology.

In the early stages of nuclear fission experimentation, all reactors, from today's perspective, were relatively small. Those developed between the 1940s and 1970s served mainly as learning platforms and prototypes for larger reactors. For example, under the US Army Nuclear Power Program (ANPP), eight small reactors were constructed, and two others were conceptualized. For instance, the ML-1 was a mobile reactor that could be transported via truck, railroad, or barges. These features are very similar of some of those of current concepts, like the Westinghouse eVinci reactor or X Energy Xe-Mobile reactor. Research of the early designs focused on finding suitable reactor configurations, fuel compositions and reactor materials. Today's research is mainly about reducing maintenance requirements, minimizing refueling needs, reduction of number of system interfaces and use of passive safety systems.

For example, in the 1960s the nuclear ship NS Otto Hahn featured one of the earliest integrated pressurized water reactor designs, now classified as a "small modular reactor". Interface reduction was achieved by placing the steam generators, coolant pumps, and pressurizer into the reactor pressure vessel. Approximately 50 years later NuScale adopted a very similar approach as Welter et al. describe in detail for the VOYGR plant. Number of interfaces in this case is further reduced by only relying on natural circulation and by using a passive decay heat removal system and a passive containment heat removal system. This makes the design unique compared to the current fleet of light water reactors by its ability to passively remove core decay heat for an unlimited duration. Almost all modern SMR designs follow a similar logic of enhancing the level of safety for rare transients by minimizing the use of active systems for long term decay heat removal.

Interface reductions can also reduce the number of accident scenarios. For example, the KSMR reactor is another integrated light water concept. Compared to NuScale's design it does not use soluble boron and consequently boron dilution transients need not be considered. This was also the case, for example, for the NS Otto Hahn and the MH-1A reactor from the ANPP program. The uniqueness of these designs is partly due to the challenges of achieving a homogenous power distribution only through burnable poisons and suitable control rod configurations. Consequently, Mercatali et al. analyze a control rod ejection accident for KSMR. Unsurprisingly the results show that classical nodal methods are not very well suited to describe strongly heterogeneous pin power distributions. Today, compute power is in sufficient supply to apply full core Monte Carlo methods coupled with subchannel codes to demonstrate sufficient safety margins.

One of the earliest circulating fuel reactor was operated under the US Aircraft Reactor Experiment Program (ARE) in the 1950s. Fast forward, new molten salt reactor designs are currently developed, such as Flibe Energy's LFTR design or Terrestrial Energy's IMSR design. They are unique in the sense that they require a completely different infrastructure and licensing regime compared to the current light water reactor fleet. For example, Benzoni et al. analyzed natural circulation with a distributed heat source and studied the natural circulation of coupled systems with the DYNASTY-eDYNASTY research facility.

Liu et al. analyze the deployment of a new generation of reactor technology from the licensing perspective. Specifically, they focus on the deployment of low-temperature nuclear heating reactors and take the Chinese nuclear legal system as an example. Since SMRs are often planned to be located close to highly populated areas not only probabilities of rare transients are relevant but also expectation values of their impact on surrounding communities.

On the one hand economies of scale and scope favors large reactors. The logic of SMR deployment is that economies of scale and scope can be achieved through large scale mass production of smaller units. SMRs must overcome a barrier of entry because they require a different infrastructure for construction, licensing, and operation. Current investor enthusiasm to finance removal of this barrier is partly due to the promise of 24/7 CO2 free electricity generation without the safety concerns surrounding the existing reactor fleet. It is impossible to predict how reactor technology will evolve. SMRs have the potential to initiate a new era of mass deployment of small units, serve as a preparatory phase for larger reactors in the future, or provide the groundwork for subsequent reactor generations following a pause of reflection and introspection. Such is the serendipitous nature of research and development.

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MS: Writing–original draft. XW: Writing–review and editing.

Conflict of interest

Author MS was employed by PreussenElektra GmbH.

The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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