Small Modular Reactor Staffing and Current Regulation

H.W.Hanke[1]
[1]Canadian Nuclear Laboratories, Deep River,Ontario, Canada
(286 Plant Rd. Chalk River, ON, 613-584-3311 Herb.Hanke@CNL.ca)

ABSTRACT –SMR designs currently under development are expected to experience lower probability of core damage and radioactive release than current reactors. The lower anticipated risk is attributed to a smaller core, simpler design (less complex systems), and a focus on passive rather than active safety systems. These characteristics may enable SMRs to operate with a smaller staffing complement than traditional reactors. Updated regulatory guidance is needed to support SMR license applications that are proposing further reductions in on-site staffing or complete remote operation.

Introduction

Small modular reactors (SMR) have been publicizedas safer than existing power reactors, with the potential to reduce staffing levels without compromising safety. In addition, some SMR designers have proposed the remote operation of SMRs. Discussions are required to engage SMR developers, regulatory bodies, the International Atomic Energy Agency (IAEA), etc., to develop guidelines for initial SMR staffing requirements and to understand how they may evolve over time.This paper examines the subject of on-site small modular reactor staffing and hopes to promote discussion,with the goal of updating guidelines which address SMR staffing requirements for operations and security. Some of the unique attributes of SMRsthat may impact operator and security staffing levels are examined, and the possible evolution of current regulation over time to address SMRs is also discussed.

Existing regulation in Canada is designed such that nuclear facility applicants must demonstrate to the Canadian Nuclear Safety Commission (CNSC) that they will ensure the presence of a sufficient number of qualified workers to carry on licensed activity safely and in accordance with the Nuclear Safety and Control Act.

Most SMR designs are First-Of-A-Kind (FOAK) and initially SMR vendors will need to conduct a systematic analysis of the tasks required to be performed by staff, in order to calculate a minimum staff complement to comply with regulations.Many unresolved questions exist:

- Are SMRs safer? If this can be substantiated to the regulator it would impact staffing requirements.

- Underground siting is another safety measure touted to reduce risk, making SMRsmore difficult to attack. What potential impacts to operation and access could natural phenomena such asfloods, wildfires, and extreme ice or snow present to an underground SMR?

- Could the Emergency Planning Zone (EPZ) be reduced due to enhanced safety attributes? This would ease siting requirements and potentially allow SMRs on military bases, near population centres, resource/mine sites, etc.

SMR designs currently under development are expected to experience lower probability of core damage and radioactive release than current reactors. The lower anticipated risk is attributed to a smaller core, simpler design (less complex systems), and a focus on passive rather than active safety systems. Detailed assessments of these risks could be used to establish requirements for SMR staffing.

1. Design Features for Many Potential SMRs with Staffing Implications

Serious accidents can be grouped to a large extent into two categories: loss of cooling and radiation release. If the advanced design attributes of SMRs can reduce the staffing needs associated with these accident scenarios, then a case could be made for reduced on-site staffing. The following features would factor into this argument:

- SMRs are significantly smaller and simpler than most reactors currently licensed.
- Potential radiological consequences associated with an accident are orders of magnitude smaller than existing designs.
- Passive systems maintain core cooling, active safety injection systems are not required, closed cooling water systems are eliminated along with HVAC (Heating Ventilation and Air Conditioning) systems for room cooling.
- Safety related pumps are not required and also reactor coolant pump seals are eliminated along with their costly maintenance and replacement.
- Passive design also means backup power/diesel generators are not required to maintain cooling.

SMR designs use various systemsto protect against loss of radiation during an accident, including double containments or operation at nearly atmospheric pressure. Maintaining the core coolant provides assurance that the fuel cladding will not overheat.

The use of passive systems in place of active systems improves reliability. In SMR designs,replacing active cooling systems from the reactor with passive systems eliminates the need for emergency cooling systems from the reactor building and results in a simpler and more reliable system.Consideration of these design features suggests that a smaller operating crew should be acceptable for normal monitoring and accident response.

The potential for very remote SMR sites also introduces a number of possible external events such as fire, flood, extreme cold, snow and ice which SMR safety designs must consider and accommodate with and without operator intervention. These external events are not specific to remote SMRs, however the fact that they are remote could impact access and emergency response to a greater extent than for an SMR that is not remote.

2. Operator Staffing and Regulation

Very limited operational experience is currently available to use as a scaling resource, since most advanced SMR designs are FOAK. Major challenges exist to identify operator tasks that can be simplified, omitted or modified due to the number of passive vs. active systems associated the SMR designs. Task requirements at sites with multiple SMRs will include operating multiple units in different modes of operation and as the number of modules increases.Demands on operators will change, as may the number of operators required.A multi-unit SMR installation may use some units to produce electricity and others to provide process heat creating a multi-purpose nuclear power plant. This mix of uses and technologies will increase the complexity of control room operations.

Ensuring the safe operation of SMRs will most likely require more extensive training and testing for operators to allow them to perform a wider range of duties since it is expected that the number of operators will decline. Experience from other industries suggests that staffing can be reduced as automation and simplicity increase. For example:

- airlines now routinely operate with two man flight deck crews, where in the past three man crews was the norm (for long haul flights), due to increased automation and reliability [1]; and

- the US Navy has significantly reduced staffing on frigate sized ships, as a result of a new cross training strategy that allows operators to perform additional duties [1].

Some SMR vendors plan to operate SMRs entirely remotely [2], eliminating the need for operators on-site. The General Nuclear Safety and Control Regulation [3] states: licensees shall “ensure the presence of a sufficient number of qualified workers to carry out the licensed activity safely”. The inclusion of the word “presence”seems to specify that these qualified workers must be on-site, however a case could be made that a virtual presence through a remote operator would be as effective. A regulatory guidance document from the CNSC provides further definition “that the minimum staff requirements are validated by the licensee to provide assurance that there is, at all times, a sufficient number of qualified workers is available to operate the facility safely and to respond to the most resource-intensive conditions under all operating states”[4].Given the existing regulation and the lack of any sort of records for operating FOAK SMRs to provide assurance, it is assumed a minimum of one on-site operator would be required at all times. Assuming 3 8-hour shifts per day, this requires five operators in total.

Some SMR designers who are expected to submit license applications in the near future may have based their calculations for projected operating costs, initial economics and business plans on the remote operation of their facilities.This appears to conflict with existing regulation. Lack of clarity on this subject could also impact the decision making process for potential SMR customers considering an SMR as an energy source.

Until a number of SMRs have been successfully deployed, safely operated and NOAK (Nth of a kind) status has been reached it will bechallenging to enable remote operation.

3. Security Staffing and Regulation

Many SMRs will use enriched (between 10%-20%^{235}U) uranium fuel and will require an initial fissile fuel quantity in the hundreds of kilograms.According to nuclear material category definitions in the Canadian Nuclear Security Regulation [5], this results in a Category II classification for an SMR facility. This regulation requires attendance in a security monitoring room by at least one nuclear security officer at all times. In addition, the regulation requires every licensee to maintain an on-site response force that is capable of making an effective intervention (sufficient nuclear security officers to control movement, conduct searches, respond to alarms, apprehend intruders, etc.). This would suggest a minimum of two security staff at all times, three shifts per day, five teams for a total of ten security staff. The number of teams could be reduced through the use of 12 hour vs. 8 hour shifts.

4. Conclusions

Design and operations features attributed to SMRs suggest that staffing requirements couldbe reduced compared to those of existing reactors. These SMR attributes include a passive safety design, reduced and simplified systems and a smaller energy source, which could all reduce potential consequences should an accident occur.

Existing regulations, coupled with the lack of operating experience for SMRs, suggest that, at least initially, all SMRs deployed in Canada will requiresome level of on-site staffing. Initially, it is estimated that to align with existing regulation SMR sites would require, at minimum, ten security personnel and five nuclear operators to support on-site operations. Updated regulatory guidance is needed to support SMR license applications that are proposing further reductions in on-site staffing or complete remote operation. Staffing requirements should be addressed early in the design review process since ongoing operations and security costs will have a substantial impact on SMR vendor business plans.

5. References

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