Modern Advanced Reactor Technologies – do we need to still worry about the human?

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Amentum

SUMMARY

Nuclear reactor technology is developing and changing the role of the human and interaction with the plant. Specifically, working as a HF consultant in the nuclear industry, the human contribution to risk and reliance on the human to ensure the safe and reliable operation of the plant is changing - we will rely less on human diagnosis of faults and fault mitigation actions and more on passive and automated safety systems. Despite this, working on new build projects I have found that these fundamental questions still need to be explored systematically early on in the design – is there anything the human could do that could compromise the integrity of the safety systems to fulfil their intended safety function and, in a fault situation, is there anything the human could do to make things worse? In this paper I will elaborate on why these questions remain important.

KEY WORDS

Advanced Nuclear Technology, Modular Reactors, Automatic and Passive Safety Features

Introduction

Advanced Nuclear Technology (ANT) includes the Micro Modular Reactor (MMR) or Small Modular Reactor (SMR) which are compact nuclear fission reactor with a smaller footprint compared with more traditional reactor designs. These designs are modular in the sense that units can be added to existing plant on an established site. The main differences between Micro Modular Reactors (MMRs) and Small Modular Reactors (SMRs) are their size, capacity, and deployment capabilities

ANTs such as MMRs and SMRs present numerous benefits including improved safety using passive safety systems that do not require human intervention during an incident and factory fabrication for small modular reactors which can improve quality control and reduce costs compared with onsite construction. Accordingly, the safety analysis underpinning these more modern reactors often cite no or minimal Human Based Safety Claims (HBSCs) in fault sequences and negligible contribution of human error to the initiating event frequencies. The minimal contribution of human error and removing the reliance on human intervention is often justified by the design and safety demonstration which are presented as “taking care of itself”. That the human is less or even not important in these more modern reactor designs can be a position upheld by the design and safety team even when many questions remain unanswered.

Method/Approach

The UK has seen a busy time over the past few years for new build reactors going through varying stages of Generic Design Assessment (GDA) . The objective of GDA is for the requesting party to demonstrate and justify the safe design to the nuclear regulator, the Office for Nuclear Regulation (ONR) in order to proceed to the next phase of GDA. The scope of HF work typically involves

development of a Safety Case chapter comprising Human Factors Engineering and identification of Human Actions (important to safety). I and my colleagues have been involved in several design development and GDA projects, working as/with the integrated HF team for several ANTs. For GDA, the work typically involves identifying and undertaking a systematic review of input data in order to demonstrate HF integration into the design and safety assessment and, a comparison against HF Relevant Good Practice, in particular the ONR Safety Assessment Principles (SAPs) and Technical Assessment Guides (TAGs). This enables any gaps in UK expectations to be identified and where appropriate, Forward Work Actions (FWAs) to be generated and addressed at a future date. Safety case submissions are then provided to the regulator and discussed in regulator (ONR) engagement meetings which provides an opportunity to agree updates to the submission. For other design development projects starting at concept, the HF work really involves working with the design team and supporting decisions around the operational philosophy and allocation of function.

Typical Findings & Results

Working across different projects (not just GDA but even earlier in the design), HF integration and collaboration with different teams remains an important activity. This can be challenging not least due to the early design stage but also because it is harder to work out what the human role is in a design that relies heavily on passive and automatic safety systems and where design and safety objectives remove the need for human interaction and involvement. Accordingly, it is true that SMRs and MMRs require the human (e.g. the operator) to do very little when things go wrong – automatic shutdowns and passive safety systems help to bring the reactor to a controlled state if there is a fault/accident scenario. Thus, for example in the Main Control Room there is a shift from the need to diagnose and implement actions towards more monitoring activities to check that safety systems are functioning as intended.

Notwithstanding this, it became clear that although the design/design philosophy and safety assessment would suggest little or no role for the human, there were more questions than answers regarding what the human role is. Below summarises some of the key questions HF have been working towards answering:

- **What is the role of the human in the safe and reliable operation of the plant?** This includes for example:
    - Consideration of maintenance activities of passive safety systems and through life replacement activities.
    - When, how and why the human may need to take control of the plant.
- **What is the interaction between the operator and the technology**? In particular:
    - How do levels of automation vary across different plant operating states
    - Does the design support the detection and response to automation system issues that may require human intervention? For example, we are often able to justify the tolerance of the Instrumentation and Control (I&C) system to human error but, the role of the human in detecting faults associated with the I&C system and how this is supported by the design is more complicated.
- **What is the human contribution to risk?** For example:
    - Where are we implicitly claiming the human/operator? At first look there may be few explicit post fault actions claimed, but on further exploration of the pre-fault deterministic safety analysis it is likely that humans take on a greater role in the safety demonstration than implied by the explicit claims. It is important that these additional implicit actions are identified and substantiated as these actions are needed to support the longevity and reliable operation of safety critical equipment.

- What happens if the operator tries to intervene or override the automatic safety system? Could this exacerbate the fault in any way or lead to entry into other fault conditions?

The assessment of new build projects of different ANT technologies highlight that, even for modern reactor designs, although it may appear that automatic and passive safety systems remove the human role, this is not the case, - these designs *change* the role and highlight different aspects of the design and underpinning safety analysis that require HF support and integration.

Conclusion and Next Steps

As outlined in the introduction, new reactor designs under the "ANT" umbrella such as MMRs and SMRs do offer many benefits in terms of ease of construction, enhanced safety and reliability. For highly automated and passive safety systems, there will certainly be less for the human to do in terms of fault detection and mitigation but - that doesn't remove the human entirely.

The new challenge we now face as HF practitioners is trying to understand and define what the human role is (e.g. operations, maintenance) and then justifying the need to still consider the human at all with the design and safety teams i.e. that human error is still possible and, that this could result in unexpected consequences. As history shows, when a culture develops that discounts this or believes the design and technology will simply take care of itself, accidents can occur.

So, regarding the question, "Modern advanced reactor technologies – do we need to still worry about the human?" my response is, most likely yes, so until we can prove otherwise, let's not discount the human and let's keep asking questions. To guide HF with these questions and support future engagements with design and safety teams, drawing on experience from new reactors overseas and research in this area will be helpful going forward. This includes for example:

- Operating Experience from overseas installations (e.g. MMR1 designs such as Chalk River in Canada)
- Research from the Sandia National Laboratories in New Mexico
- Documentation and guidance from the International Atomic Energy Agency (IAEA) including; Technology Roadmap for Small Modular Reactor Deployment (2021) and Instrumentation and Control Systems for Advance SMRs (2017)