Advances in Reliability, Safety and Security

ESREL 2024
Collection of Extended Abstracts

The Importance Of The Safety Case In The Nuclear And Fusion Industry

Hector Diego Estrada-Lugo, Jill Garner, Susan Wright, Omar Afify

Safety Case Engineering Group,UK Atomic Energy Authority, United Kingdom

Keywords: Safety Case, fusion industry, reliability, safety-critical systems

Several significant accidents, including the Piper Alpha Off-shore Oil, Seveso disaster, and the Clapham Rail Disaster, among others, have highlighted the need for re-evaluation of safety management practices in safety-critical sectors. In each of the mentioned events, safety concerns were not entirely ignored, nor were safety standards completely absent. Rather, one of the potential root causes lay in the failure of designers and operators to systematically and thoroughly address safety considerations (Kelly, 2004). As a result of the acknowledgement of this gap, the introduction of safety standards such as the guide to the Offshore Installations (Safety Case) Regulations (HSE, 1992), and the Railway Safety Case-Railway (Safety Case Regulations) 1994 – Guidance on Regulations (HSE, 1994), represented a fundamental shift in safety regulation. Previous approaches primarily emphasized prescriptive safety requirements, such as construction codes. However, with the adoption of safety cases, operators now bear the responsibility to demonstrate a robust safety argument.

The continuously developing fusion industry holds promise as a cleaner and abundant source of energy, but like any complex technological endeavour, it presents hazards that must be carefully managed. Facilities such as JET (Joint European Torus), STEP (Spherical Tokamak for Energy Production), and ITER (International Thermonuclear Experimental Reactor) face several potential hazards. Radiation poses unique challenges when considering fusion systems. Fusion reactions produce energetic neutrons capable of penetrating materials, leading to activation of structural components and creating radioactive waste. Shielding and remote handling systems are necessary to protect workers from exposure. Other hazards are the extreme temperatures and pressures involved in plasma confinement. Mishaps could result in equipment failures or uncontrolled plasma releases, causing release of radiation, damage to the facility and non-radiological harm to personnel. Furthermore, the handling and use of deuterium and tritium, which are the radioactive isotopes of hydrogen crucial for fusion fuel, pose risks. As well as all the "conventional" hazards of Hydrogen e.g. flammable/explosive, Tritium is highly reactive and presents challenges in containment, as it can leak and contaminate the environment. To address these hazards, fusion facilities implement rigorous safety protocols, including robust engineering designs, remote handling technologies, and strict radiation monitoring. Additionally, continuous research and development efforts aim to improve safety measures and minimise risks associated with fusion energy production.

In the efforts to minimise risks in the fusion industry, a regulatory regime has been implemented. In the case of the United Kingdom, the regulation of the safety in nuclear facilities is traditionally through the Office for Nuclear Regulation (ONR) which is an agency of the Health and Safety Executive (HSE) since April 2011 (Harman et al., 2011). The ONR regulates the nuclear power industry in the UK and brings together safety and security regulations for civil nuclear and radioactive transport into a single location. The aspects related to the environmental impact from nuclear facilities is regulated by the Environment Agency. In the UK, the fusion industry is regulated only by the HSE and the EA. Developing a robust safety case is a key step in getting a fusion facility licenced.

A Safety Case is a tool to demonstrate to regulators and the public that, a facility or operational hazards are reduced to as low as is reasonably practicable (ALARP) before it is allowed to start. The term reasonable practicability is applied to risk reduction measures and means that they should be implemented unless the time, trouble, or cost of doing so is in gross disproportion to the level of benefit realised. Institutions such as the UK Atomic Energy Authority, in the case of the UK, has groups specialised in the methodologies to carry out safety case reports that meet the requirements of the country's case law. The requirement for Safety Cases originates from the Health and Safety at Work Act 1974 issued by the HSE, which mandates that employers must reasonably ensure the health and safety of their employees and others. Even when not stipulated by a regulator, safety cases can be seen as best practice and an effective and thorough means identifying, assessing, and managing risk.

The Safety Case Engineering Group (SCEG) oversees the development and upkeep of all Safety Cases for the UKAEA. These safety cases involve assessing risks related to high hazard nuclear fusion safety, like the Hydrogen-3 Advanced Technology (H3AT), the Lithium Breeding Tritium Innovation (LIBRTI) programme, or the Active Gas Handling System (AGHS) as well as unique or innovative non-nuclear plant and processes (such as JET Pulsed Power Supplies). UKAEA safety cases undergo through quality assurance processes, including independent peer reviews and evaluation by their nuclear safety committee, the Site Safety Working Party. The skill portfolio involves, but it is not limited to, Hazard Identification Techniques (e.g., HAZID, HAZAN, HAZOP), Design Basis Assessment, Probabilistic Safety Assessment (e.g., Event Tree Analysis, Fault Tree Analysis, Bayesian Belief Networks), and Reliability Assessment. Safety Cases result in the identification of safety measures, both procedural and engineered status of control, necessary for ensuring the safe operation of plants and processes. These safety cases have a lifespan of 10 years, after which they undergo a Periodic Review of Safety (PRS) to confirm their continued adequacy and appropriateness by reviewing all the modifications during that time.

References

Harman, N. F., Anderson, G. S., Lillington, J. N., Booler, R. V. 2011, January. Safety assessment principles applied to small modular reactors. In Small Modular Reactors Symposium 54730, 359-368.

Kelly, T. 2004. A systematic approach to safety case management. SAE transactions, 257-266.

U.K. Health and Safety Executive. 1992. A guide to the Offshore Installations (Safety Case) Regulations 1992. Health and Safety Executive, HSE Books.

U.K. Health and Safety Executive. 1994. Railway Safety Cases - Railway (Safety Case) Regulations 1994 - Guidance on Regulations. Health and Safety Executive, HSE Books.