# emergency preparedness and response: towards identifying synergies between fission and fusion power reactors

F. STEPHANI

International Atomic Energy Agency (IAEA)

Vienna, Austria

Email: [f.stephani@iaea.org](mailto:f.stephani@iaea.org)

The IAEA Safety Standards Series No. GSR Part 7 [1], endorsed in 2015 in a joint sponsorship of 13 international intergovernmental organizations, provides the safety requirements for an adequate level of preparedness and response for any nuclear or radiological emergency that could occur in relation to a facility, an activity or a source, irrespective of the cause. GSR Part 7 follows a graded approach to define these requirements and their application at the national level to ensure that the emergency arrangements are commensurate with the hazards associated with a facility, an activity or a source, and the related potential consequences. In this context, it calls for Member States to perform a hazard assessment to inform decision on the level of Emergency Preparedness and Response (EPR) needed, as well as the associated emergency arrangements to be implemented for the facilities, activities and sources on their national territory, or those located abroad that might have impacts within their national jurisdiction in case of an emergency.

Besides, GSR Part 7 defines five Emergency Preparedness Categories (EPCs) on the basis of the expected radiological consequences on-site and off-site, with EPC I to III associated with facilities. EPCs help determine the level of preparedness to be implemented for these facilities. GSR Part 7 is further supported by 5 safety guides in EPR (IAEA Safety Standards Series No. GSG-2 [2], IAEA Safety Standards Series No. GS-G-2.1 [3], IAEA Safety Standards Series No. GSG-11 [4], IAEA Safety Standards Series No. SSG-65 [5]) that provide further guidance and recommendations to help Member States apply the safety requirements in EPR at the national level.

In 2021, the IAEA’s Incident and Emergency Centre (IEC) reviewed IAEA Safety Standards in the area of EPR for their applicability to “next generation reactors”. The scope of this review did not include nuclear fusion reactors, but it was focused on small modular reactors and other non-water-cooled reactors. The outcome of the review was that the IAEA safety standards in EPR are technology neutral and thus applicable for these next generation reactors. However, to support their implementation in practice, further clarity needs to be brought on how specific EPR concepts apply for new technologies.

Based on this recent review, EPR safety standards are believed to be applicable for fusion reactors, but up to a certain extent. Further research is needed to understand the hazards associated with such new reactors and potential consequences in case of an emergency, before this can be confirmed fully.

Based on the existing EPR safety standards, appropriate emergency arrangements for fusion reactors need to be decided based on a hazard assessment, provided that this hazard assessment considers:

* Events of very low probability and events not considered in the design, including those triggered by a nuclear security event (e.g., sabotage);
* Events involving a combination of a nuclear or radiological emergency with a conventional emergency that could affect wider areas and/or could impair capabilities to provide support in the emergency response;
* Events at similar facilities located abroad.

Consequently, nuclear operators and Member States will need to perform such a hazard assessment and categorize fusion reactors to a specific EPC. Then, respective requirements from GSR Part 7 for that EPC will apply. They will help identify operational arrangements needed, such as the characteristics of emergency response facilities, their location, staffing, operational protocols with off-site emergency services, whether or not Emergency Planning Zones (EPZs) and Emergency Planning Distances (EPDs) are needed, and the comprehensiveness of emergency arrangements within those zones and distances.

Even if most of the requirements, guidance and recommendations of the IAEA safety standards in EPR may apply to preparedness and response for an emergency at fusion reactors, its practical implementation is expected to require further work and specific developments. Questions such as the following will need to be addressed:

* What are the hazards associated to fusion reactors, including radiation and non-radiation related hazards?
* Can radiological consequences be expected on-site and off-site that might result in radiation induced health effects among affected population and on-site staff? What inventory of radioactive release can be expected and what can be the pathways for such a release in the environment?
* What non-radiation related consequences associated e.g., with the use of novel materials and techniques, can be expected on-site and off-site? What will their impact be on EPR?
* What is the kinetics of potential emergency scenarios at fusion reactors? How does this relate to the time available for effective decision-making and timely implementation of public protective actions?
* What non-radiological consequences (e.g., economic) can be expected from an emergency at fusion reactors?
* What mitigatory and public protective actions would be effective in mitigating the consequences of an emergency at a fusion reactor?
* In which EPC(s) are fusion reactors to be categorized? If fusion rectors are categorized under EPC I or II, what should be the size of the associated EPZ and EPD?
* Which on-site conditions can be indicative of an emergency situation and the associated level of emergency response to be activated? How can these on-site observables fit into the existing emergency classification system applied for other reactors, under which emergency action levels? What associated emergency action levels will apply?

Answers to these questions will help provide more definite answers to the required level of EPR for fusion reactors in line with the IAEA safety standards in EPR. However, answering these questions requires expertise beyond the one of the EPR community. Therefore, it is essential that people involved in other areas, such as scientific research, development of the technology, operation, work closely with the EPR community as early as possible. This will enable having informed decisions on EPR along with the progress made in the development of fusion reactors, for the benefit of Member States wishing to embark on this new technology. IEC stands ready to contribute to this in a joint cooperation with experts from Member States and to identify analogies and discrepancies in EPR needs between fission and fusion reactors.

References

1. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE NUCLEAR-TESTBAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).
2. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).
3. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE CO-ORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-G-2.1, IAEA, Vienna (2007).
4. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Arrangements for the Termination of a Nuclear or Radiological Emergency, IAEA Safety Standards No. GSG-11, IAEA, Vienna (2018).
5. INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material, IAEA Safety Standards No. SSG-65, IAEA, Vienna (2022).