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Requirements for quantitative risk assessment of hydrogen facilities: An Irish use case

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The present work summarises the requirements for a Quantitative Risk Assessment (QRA) of a hydrogen facility. This is done within a framework of the recently announced National Hydrogen Strategy in the Republic of Ireland. The proposed framework for risk assessment is based on a probabilistic method called Bayesian networks. This framework is expected to provide permitting authorities with a decision support system and guidance for QRA hydrogen facilities.

Keywords: Quantitative Risk assessment, Hydrogen safety, Bayesian Networks, Hydrogen Economy, Uncertainty Quantification.

1. The Hydrogen Strategy in Ireland

In the summer of 2023, a recently formulated National Hydrogen Strategy has been unveiled in Ireland. This strategy stands as a pivotal point of reference intended to facilitate the advancement of the nation's hydrogen economy, predicated upon key objectives encompassing decarbonisation, energy security and growing industrial opportunities, The Government of Ireland: Department of the Environment, Climate and Communications (2023). In effect, this strategic framework offers a viable trajectory, particularly for corporate entities like the Electricity Supply Board (ESB), which has already embarked on ventures geared towards establishing robust hydrogen infrastructure. This infrastructure plays a crucial role in the overarching endeavour to effectuate the decarbonisation agenda for the country ESB-press (2022); RTE news (2023). While the strategy is congruent with existing European legislative provisions, it is pointed out that standards and the hydrogen safety framework should be revised and further developed due to the early stage of the sector. Given this context, it is of paramount importance to devise methodological frameworks designed to underpin the decision-making process within the hydrogen safety sector.

Safety is a central concern in hydrogen production, often pivotal for securing regulatory approval and public acceptance. This challenge arises from hydrogen's physical traits, including high leakage susceptibility, broad flammability limits, elevated laminar burning velocity, and low minimum ignition energy (Cashdollar et al. (2000)). Consequently, ensuring safe large-scale hydrogen production needs adept risk management and trustworthy risk analysis methodologies.

Authorisation of hydrogen systems, akin to other energy production systems, hinges on adherence to safety codes and standards. Currently, several safety standards derive from established natural gas safety frameworks and, in the case of Ireland, this is regulated by the Commission for Regulation of Utilities. Emerging standards (e.g., ISO–15916, and ISO–22734:2019, ISO (International Organization of Standardization) (2015, 2019)), are informed by recent system experience and tailored to hydrogen safety. Incorporating Quantitative Risk Assessment (QRA) methodologies into safety codes and standards offers a consistent reference for designing and operating hydrogen facilities.

2. Quantitative Risk Assessment for hydrogen systems

QRA is a systematic tool to identify individual risk contributions and to calculate the overall risk of a system or a process. According to West et al. (2022), the standard process for a QRA starts with risk identification, then risk analysis, and finally, risk assessment. The first step, involves scope definition, system description and initiating event identification. The analysis consists of scenario identification, consequence analysis, and risk quantification. The final step of QRA is made of uncertainty analysis and risk evaluation.

The QRA for hydrogen systems involves various methods for modelling and computing the risks. However, the study of different scenarios is limited due to the lack of sources listing the failure modes for all hydrogen fuelling station components or related systems.

3. Proposed method for Quantitative Risk Assessment

Bayesian Networks (BN), have been proposed in recent years as a methodology for enhanced accuracy, transparency, and dynamism Estrada-Lugo et al. (2019). A BN is a probabilistic model that models events as random variables, each of them described by a probability distribution. BNs can accept a wide range of data, from expert knowledge, to experimental data and historical records. The proposed work will need to gather data and information specific to hazardous scenarios relevant to hydrogen installations and the human factors involved. The data required for this study will be collected from experts in the hydrogen industry (e.g., ESB), hydrogen safety, as well as international standards and technical reports (ISO/TR 15916:2015; ISO 16110-1:2007; ISO 22734-1:2008) using structured risk assessment techniques such as HAZID and HAZOP. The information gathered will be used as input for the Bayesian model to compute the likelihood of the study scenarios.

4. Remarks

The Irish National Hydrogen Strategy explicitly suggests: *it may be more appropriate to develop a hydrogen safety strategy or framework which could initially be applied on a voluntary basis, which would then be used as a test case for early projects to assess its suitability and identify where improvements can be made, before ultimately progressing to establish it as a legally binding regulatory framework.* The objective of this study is to enhance the advancement of this safety strategy by employing a rigorously formulated methodology supported by explainable artificial intelligence methods like Bayesian Belief Networks. The proposed approach will facilitate the aggregation of existing information and enable model updates as needed on an actual hydrogen facility case study.

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