Vysus Group

Whitepaper

The RASTEP Methodology - aiding decision making for accidents at nuclear power plants and wider markets

Nuclear power is a clean and efficient energy source with multiple uses, however, managing and analysing risk continues to be crucial. At the same time, there is a global demand to drive energy transition, meet ambitious 'net zero' targets and increase the use of cleaner sources of energy to help mitigate the global climate crisis.

We believe that nuclear power will continue to be a fundamental part of the world's energy mix, through utilising existing plants and the building of new ones with an increased focus upon all aspects of risk management.

This whitepaper addresses the significant steps organisations can take to prepare for fast and high-quality diagnosis and decision-making during an accident within nuclear power, where risk management is pivotal to the safety of personnel, the public and for the economic viability of the energy industry. Furthermore, it examines wider markets and industries, and points to where and why such risk and decision-making management should be integral.

Introduction

A full decade on from the Fukushima Daiichi nuclear accident, which released a significant amount of radionuclides and led to the subsequent evacuation of more than 100,000 residents in the surrounding areas, much has been done to both minimise and manage accidents at nuclear power plants. At Fukushima, many factors relating to the management of the external event protection design of the plant, together contributed to the severity of the accident. It also became clear that parts of the emergency response plan were built on faulty assumptions on crucial infrastructure being unaffected by the event.

Many lessons have been learnt. Not least that nuclear power plant operators, regulators and emergency responders must continually be able to take in new information regarding hazards that have the potential to impact safety, and act upon it.

Additionally, reducing and managing the risk of major accidents lies at the heart of public acceptance of nuclear power, which includes being prepared to respond with appropriate actions to protect the public in case of an accident. Such protective measures need to be based on well-informed but timely decisions in situations with potentially missing or contradictory information. This is echoed by the International Atomic Energy Agency[1] (IAEA), in that decisions on protective actions during a nuclear accident should be based on observed plant conditions and cannot wait for detailed calculations and analyses to be completed.

Technical and commercial challenges

No industry is immune to accidents, but at the core of safety all industries should learn from the accidents, near-misses as well as success experiences. For context, the nuclear industry has been proven to be a safe means of generating electricity given that over the past 60 years only three major accidents have occurred in more than 18,500 cumulative reactor-years of commercial nuclear power across 36 countries.

A key challenge faced by emergency preparedness teams working within the nuclear industry is that not all of the information required to accurately manage and evaluate an ongoing accident may be available in time. Therefore, it's crucial they create a technical, decision-support methodology for such a scenario, which will enable them to make as well-informed decisions as possible. Such a decision support methodology needs to consider a number of factors including plant design specifics, physical phenomena of relevance during an accident scenario, onsite and offsite accident management, weather conditions and the local population distribution.

Likewise, a nuclear accident may have cross-border consequences that impact neighbouring countries that don't have domestic nuclear power themselves. These countries would still require a level of emergency preparedness. As the PETI Committee study - Cross-border nuclear safety (February 2019)[2] highlights:

> "A variety of arrangements exist aiming at disaster risk management. On the one hand there are many tools aiming at emergency preparedness and response, also at EU level which do, however, not directly focus on the nuclear sector. Specifically for the nuclear, particular features have been put in place, such as ECURIE, organising information exchange, aiming at a rapid and coordinated response. However, even though there are arrangements to deal with transboundary disaster risk management, also in this domain sovereignty of the Member States remains important as a result of which it is still the Member States that take the basic decisions. Legally binding arrangements at the European level are lacking.

When it comes to emergency preparedness, some countries have large organisations with substantial resources in terms of manning, secure data channels and computational tools, while others rely on a few individuals with fewer resources at their disposal. This fact requires decision-support methodologies to be flexible and can be tailored to a range of different needs.

Solutions

All of the above scenarios carry different challenges across borders and countries dependent upon size, cultural, organisational and regulatory structures. These differences will manifest themselves depending upon the level of reliance on pre-analysed scenarios, versus online analysis with fast tools, the size and available resource of the emergency response organisations and the level of dependence on probabilistic reasoning to counter information deficiencies.

RASTEP, (Rapid Source Term Prediction) a Vysus Group methodology to aid decision-making in situations with scarce or contradictory information for accidents at nuclear power stations, uses Bayesian Belief Networks to build probabilistic models that can identify incident scenarios and likelihoods to predict the outcomes of events. RASTEP's two greatest assets are;

- that the mathematics of the Bayesian Belief Networks makes the models particularly robust to uncertain or missing information and
- that the tool can run on an ordinary laptop, without internet connection.

Our own research and client feedback has highlighted the need for a remote tool that doesn't need to rely upon any terrestrial connectivity which may become extremely compromised during an accident.

The RASTEP methodology also offers the needed flexible modelling solution to support decisions in a nuclear emergency. It is comprised of a structured method to model the accident progression in the Bayesian Belief Network, integrating the probabilistic safety assessment (PSA) with live observations of the ongoing situation. In addition, it supplies a database of post-processed source terms, tailored to the needs of the emergency response team and a simple yet efficient graphical user interface, in which observations and current predictions are combined with convenient results, export functionality and modelling tools. This framework can also easily be extended to other similar systems.

Conclusion

For nuclear emergency preparedness and response, international organisations such as the IAEA can provide both general guidance outside of nuclear accident situations, in addition to supplying information and support during an ongoing accident. The local hands-on implementation will, however, still require substantial work to be performed in planning, training and organising an effective and competent emergency response. The RASTEP solution offers a flexible and robust approach to deal with both diagnosis and prognosis of the situation, well aligned with the IAEA guidance.

In a wider perspective, RASTEP is a framework for assisting decision-making in situations with missing or uncertain information. Given Bayesian Belief Networks are already highly prevalent in other industries such as medicine and defence, it should not be limited just to emergency preparedness and accident management in the nuclear industry.

At Vysus Group, we want to explore wider markets where the RASTEP methodology, using the Bayesian Belief Networks, can aid decision making where predicted outcomes are key. An obvious extension of the RASTEP methodology as used for nuclear power plants today, concerns chemical or petrochemical facilities, where the risks of emissions of hazardous substances may also need to be evaluated at an early stage during accidents or incidents.

Furthermore, if we look at the COVID-19 pandemic, much has been written and studies conducted, using Bayesian Belief Networks to predict both sentiment and potential fatality rates. There is a strong argument for the use of methodologies like RASTEP to analyse measurements, influence factors and consequences.

A research paper by Frontiers in Psychology[3] examined data taken from Denmark, Italy, China and Japan, and used Bayesian Belief Networks to measure to the 'psychological tensions that inherently arise between opposing human factors such as free enjoyment versus self-restriction,' to be prepared for future, global pandemics.

Likewise, RASTEP can support general practice diagnosis where the methodology complements the decision-making process doctors already undertake, while it can also further enhance the current procedures being undertaken in civil aviation for managing runway overruns, where "49% of fatal accidents involving commercial jet aircraft occur during the final approach and landing phase."[4]

Another area that requires particular focus on, is our seas. Nuclear-powered naval ships regularly patrol the world's oceans, with visits to other ports away from their home country. The need for peacetime nuclear emergency preparedness measures for these ships is widely agreed between affected countries, looking ahead, there is real potential to see an increased number of civilian nuclear-powered vessels at sea, bringing further attention to the debate. The options are not limited, and the benefits can be realised across multiple industries and markets.

References:

1. IAEA: Preparedness and Response for a Nuclear or Radiological Emergency
2. Cross-border nuclear safety, liability and cooperation in the European Union
3. Frontiers in Psychology: Cross-Cultural Bayesian Network Analysis of Factors Affecting Residents' Concerns About the Spread of an Infectious Disease Caused by Tourism
4. Aerospace Research Central

Why Vysus Group?

Vysus Group has long-standing experience of nuclear power safety, including probabilistic and deterministic methods as well as of licensing and regulation. We also perform independent evaluations of existing emergency response plans and analyses and actively participate in ongoing research and development efforts on the topic.

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