Challenges in the UK Generic Design Assessment Process. – 17062

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ABSTRACT

In the UK, Generic Design Assessment (GDA) is a voluntary step-wise joint assessment process undertaken by the Office for Nuclear Regulation (ONR) and the Environment Agency (EA) of a generic reactor design. The process focuses purely on the reactor design and does not consider any site specific issues.

The key objective of GDA is for the regulators to consider the adequacy of claims, arguments and evidence (CAE) put forward by a requesting party (RP) to demonstrate the safety of its design in the UK context. This includes all CAE relating to management of spent fuel and radioactive waste. The CAE are generally applied to a reference design put forward by the RP that is substantially complete in terms of the overall concepts and functions of the major systems, having already been deployed elsewhere. GDA assessment encompasses a broad range of topic areas which include fuel and core design, management of spent fuel, radioactive waste management and decommissioning. Other technical disciplines also have valid interests in particular aspects of the management of spent fuel.

This paper summarises the UK GDA process and the types of issues raised; in particular aspects of the proposed operation of liquid waste management systems and Spent Fuel Interim Storage are presented and the instructive resolution of the RP's original limited design scope to allow the regulators to carry out a meaningful assessment. Some examples are presented and useful lessons learned for future GDAs are discussed.

INTRODUCTION

In the UK, the Office for Nuclear Regulation (ONR) is an independent statutory body formed in April 2014 on the commencement of the Energy Act 2013 which regulates safety & security in the civil nuclear sector plus some *aspects* of defence activity. Upon receiving instruction from Government, ONR is responsible for implementing the Generic Design Assessment (GDA) process. Despite being presented as a voluntary process, virtually all designers and vendors of proposed Nuclear Power Plants (NPPs) in the UK choose to go through GDA to obtain a Design Acceptance Confirmation (DAC) from ONR in order to minimise risk and secure financial investment. GDA has no legal vires and examines the reactor design and does not consider any site specific issues. The reactor building is normally presented as detailed design and the remaining facilities as concept design including the waste processing system and spent fuel storage. This presents challenges for GDA in having available sufficient details of the design to allow a meaningful assessment.

The following lines of enquiry illustrate the type of regulatory assessment typical of the GDA process:

- Comprehensive strategies and plans for management of spent fuel over the plant's entire lifetime, including the envisaged periods of on-site storage and plans to deal with failed fuel
- The anticipated type and inventory of spent fuel, rates of arising, throughput and operation of the spent fuel management processes and capacities of storage facilities
- A demonstration that the intended management of spent fuel and radioactive waste will be compatible with the UK infrastructure, policy and standards for transport and disposal
- Identification of the systems, structures and components (SSCs) that will be used in the management of spent fuel, including a demonstration that safe management of the spent fuel will be deliverable using pre-existing technology

Because of the limited design information initially available aspects of the above processes can prove very challenging, particularly assessing preparation operations for spent fuel interim storage and aspects of the liquid waste management system.

The nuclear regulator's priorities are:

- Ensuring a fit-for-purpose level of information is provided within GDA
- Demonstration that risks have been or are capable of being reduced As Low as Reasonably Practicable (ALARP), which is a legal requirement [1]
- Delivery of a holistic Safety Case that covers all the steps in the waste management and spent fuel process

WHAT IS GDA?

Embarking on GDA is a significant undertaking for both the RP and ONR [2]; for the RP the costs may run into tens of millions of dollars, while for ONR it entails the commitment of a team of specialists for a period of up to 4 years. Subject to satisfactory progress through all of the GDA steps, it is usual that once Step 1 begins the process will run through uninterrupted to the end of Step 4. It is appropriate, therefore, for ONR to seek certain information and assurances from the RP prior to the start of Step 1 to ensure the project appears viable from the outset, and that the risks of nugatory effort are minimised. A cost-recovery agreement with the intending RP is set up to ensure that ONR can recover all of the costs incurred in GDA from the start of Step 1 through to the end of Step 4.

TABLE 1: The GDA Process

Step	Process	Timescale
1	Preparation of the design, safety and security case submissions	RP is responsible
2	Fundamental design, safety and security case claims overview	~ 6 – 8 months
3	Overall design, safety and security case arguments review	~ 12 months
4	Detailed design, safety and security case assessment	~ 28 months

Typical matters for consideration with the RP prior to Step 1:

- Ownership structure of the RP
- RP organisational structure
- RP decision making authority including budgetary control
- RP resourcing strategy for duration of GDA
- Clarity on the design being proposed and its ownership
- Assurance on the timely availability to ONR of all necessary design and safety case related information, including proprietary information owned by third parties
- RP plans and proposals for a UK regulatory interface office

GDA Steps Description and Aims

Step 1 is the preparatory part of the design assessment process. Mostly this will involve the RP setting up its project management and technical teams and arrangements for GDA, and writing and preparing submissions for Step 2, including the Preliminary Safety and Security Reports. It also involves discussions between the RP and ONR to ensure a full understanding of the requirements and processes that will be applied.

Step 2 is primarily an overview of the acceptability, in accordance with the regulatory regime of the design fundamentals, including review of key safety and security claims (or ‘assertions’). The aim of this step is to assess the key claims and identify any fundamental safety or security shortfalls that could prevent ONR permitting the construction of a power station based on the design. A related aim is that the RP will come to understand the regulatory approach used in Great Britain and thus ensure that adequate safety and security documentation will be developed for Steps 3 and 4.

It will also introduce ONR inspectors to the fundamentals of the design and provide a basis for planning subsequent, more detailed, assessment. This step may take around 6 to 8 months, assuming the RP is able to provide quality and timely submissions and responses to regulatory concerns.

Step 3 is a review of the arguments (or 'reasoning') supporting the RP's claims regarding the safety and related security aspects of the proposed design. The intention in this Step is to move from the fundamentals of the previous step to an analysis of the design, primarily at the system level, and by analysis of the RP's arguments that support the safety and security claims.

The specific aims of this step are to:
- improve ONR knowledge of the design
- assesses the safety and security arguments
- progress the resolution of issues identified during Step 2
- identify whether any significant design or safety case changes may be needed
- identify major issues that may prevent ONR issuing a DAC and attempt to resolve them
- achieve a significant reduction in regulatory uncertainty.

The exact scope and focus of Step 3 will depend on the design and on the outcome of Step 2. This step may take around 12 months, assuming that the RP is able to provide quality and timely submissions and responses to regulatory concerns.

Step 4 is an in-depth assessment of the safety and security case evidence and the generic site envelope. The general intention of this step is to move from the safety and security arguments and system level assessment of Step 3 to a fully detailed examination of the available evidence, on a sampling basis, provided in the RP's submissions.

The aim of this step is to:
- confirm that the higher-level claims and arguments are properly justified
- progress the resolution of issues identified during Step 3
- complete sufficient detailed assessment to allow ONR to come to a judgment of whether a DAC can be issued.

The exact scope and focus of the step will depend on the design and the outcome of Step 3. This step may take about two years, assuming the ONR GDA assessment team is fully resourced.

GDA Conclusions and Close-out

There could be three potential outcomes at the end of Step 4:
1) Provision of a DAC, marking the end of GDA for that generic design
2) Provision of an iDAC identifying outstanding GDA Issues
3) No DAC issued

MEANINGFUL GDA

In order to be able to provide a DAC, ONR must have completed a 'meaningful assessment'. A meaningful GDA is one where:

- Sufficient information is received on the generic design to allow assessment in all relevant technical areas. The information provided must be of adequate detail and cover the full scope and depth necessary for ONR to carry out its technical assessments
- A sufficiently thorough and detailed assessment of that information can be completed and judged against the SAPs, including the need to demonstrate that risks are reduced, or are capable of being reduced, ALARP.

The assessment relates only to the information provided on the generic design and does not mean that ONR has received and assessed all the information necessary to permit construction and operation of a plant, based on that design. The depth and scope of ONR's assessment is unlikely to be the same across all technical areas, as this will depend on the relevance of each area to the safety and security case. However, ONR will need to be satisfied that the sampling assessments it has carried out of the RP's submissions, along with information provided by the RP to resolve technical issues arising during GDA, is sufficient to allow it to make a balanced judgement on the overall acceptability of the generic safety case. In order for ONR to be able to provide a DAC, it is vital that the RP provides submissions of high quality, to an agreed timetable.

Detailed Design versus Concept Design

A key issue in GDA for both the regulators and the RP is "what constitutes sufficient information?" Unlike existing nuclear sites subject to site licence conditions, GDA has no legal vires but instead is dependent on and set against a collection of principles, guidance and safety documentation such as:

- ONR's Safety Assessment Principles (SAPs) [3]
- Technical Assessment Guides (TAGs)
- Technical Inspection Guides
- Reducing Risks Protecting People (R2P2)
- The Tolerability of Risk from Nuclear Power Stations
- IAEA Safety Standards Series
- Western European Nuclear Regulators Association (WENRA) Reference Levels
- Relevant Good Practice
- Operating Experience (OPEX)
- As Low as Reasonably Practicable (ALARP)

Whilst, for example, ONR's SAPs and TAGs have relevance to all regulatory functions, they primarily support legal compliance with licence conditions and the content and development of licensees' safety cases. As such, much of the GDA process is determined by 'where the Inspector's nose takes them' as it is by official guidelines. This relative lack of a formal framework in GDA can give individual inspectors considerable latitude in the level of detail that they will accept from RPs to satisfy a meaningful assessment. To get around this uncertainty and to forestall potentially disproportionate scrutiny some RPs scope-out aspects of the design out-with the main nuclear island and use two levels of design definition – detailed and concept. Detailed design level is normally restricted to structures, systems and components (SSC) associated with the reactor building which then allows an adequate assessment to take place. All other facilities including the waste processing & storage system, turbine building and SFIS are concept design.

However, this graduation of design can lead to tension between the regulators and the RP where the regulator may decide that too little information about SSCs is being provided by the RP to enable a meaningful assessment. On the other hand the RP may declare that the regulator is being disproportionate in seeking a level of design detail inconsistent with the aims of GDA.

The following sections provide an illustrative discussion using aspects of the UK ABWR waste management and spent fuel storage systems as examples.

UK ABWR LIQUID WASTE MANAGEMENT SYSTEM (LWMS)

The UK ABWR design is a Generation III boiling water reactor based on sound international practices and over 40 years of experience in design, construction and maintenance of boiling water reactors (BWR) [4,5]. BWRs are the second most common form of light water reactor with a direct cycle design that uses fewer large steam supply components than the pressurised water reactor (PWR), which employs an indirect cycle.

The concept design of the UK ABWR LWMS comprises the following systems:

1. Low Chemical Impurities Waste (LCW) system in the Radioactive Waste Building (Rw/B) designed to treat relatively large volumes of effluent containing low levels of insoluble and soluble impurities. Filters are used to remove the insoluble impurities and when the differential pressure across the filter reaches a prescribed level, backwashing operations are triggered to remove insoluble impurities (crud) collected on the filter surface. The LCW System processes floor drain and equipment drain effluents that have a low concentration of chemical impurities. The main sources of LCW are the reactor primary coolant system, the fuel pool clean-up system and the plant make-up water system. The system is designed to treat effluent to enable it to be re-used within the plant.
2. High Chemical Impurities Waste (HCW) system in the Rw/B processes the radioactive effluent that typically has relatively high concentrations of chemical and small quantities of radioactive impurities from streams which contain comparatively high levels of Total Organic Carbon (TOC). The main sources of HCW are the Condensate Demineraliser (CD) bottom drain and the chemical analysis lab (hot lab) drains.
3. Laundry Drains (LD) system in the Service Building (S/B) processes effluent originating from the laundry facility and Hot Shower Drain (HSD). The Hot Shower Drain effluent is generated from the hand-wash stations and shower facilities in the controlled areas. These effluent streams contain detergent,

suspended solids and organic material, as well as potentially low levels of radioactive crud.

4. Controlled Area Drains (CAD) system in the Rw/B collects effluent from non-radioactive facilities in the controlled areas of the Reactor Building (R/B) and Turbine Building (T/B). This includes the drains of the local air-conditioning systems and also potentially contaminated drains from various equipment systems.
5. Spent Sludge (SS) system in the Rw/B collects and stores spent bead (ion exchange) resins from the CD demineralisers, LCW demineralisers and HCW demineralisers; Powder resin from the Reactor Water Clean-Up System (CUW) and Fuel Pool Cooling and Clean-up System (FPC) and Filter crud from Condensate Filter (CF) and LCW filter. These are collected in tanks before being transferred to the Solid Waste Management System (SWMS) for solidification.

In assessing this system difficulties can arise because the design is presented at the concept stage which constrains a proper appraisal and gives rise to inconsistencies in the documentation between the LWMS and SWMS and their interaction. Due to the immaturity of the design the following issues can arise:

- too much emphasis presented on process rather than practical application and safe operations
- incomplete hazard assessment of the HCW system
- the rationale for selecting and rejecting alternative design features is unclear
- insufficient evidence that all available OPEX has been gathered
- optioneering is largely notional and the conclusions reached do not provide convincing evidence that no further reasonable practicable improvements could be made
- lack of clarity or failure to optimise multiple interacting facilities

SPENT FUEL INTERIM STORAGE (SFIS)

The UK ABWR fuel route operations can be grouped into four major processes:

- New fuel handling
- Irradiated fuel handling
- Spent fuel pool storage
- Spent fuel interim storage

For the purposes of this discussion a short description of the relevant operations are given:

Irradiated Fuel Handling

During outage for refuelling approximately every 18 months, the fuel handling machine (FHM) transports the fuel assemblies between the spent fuel storage racks within the spent fuel pool (SFP) and the reactor core, and shuffles individual assemblies within the reactor core or SFP. Fuel route operations also includes the handling of reactor components and non-fuel items, opening and closing of the pool gates as well as the flooding and draining of the Reactor Well.

To enable irradiated fuel handling to take place the reactor building crane (RBC) is used to remove the following components of the reactor and to store them on the operations deck:

- Reactor shield plug and slot plugs
- Primary Containment Vessel Head
- Reactor Pressure Vessel Head

Spent Fuel Pool Storage

Spent fuel assemblies are stored in the spent fuel storage racks for some years in order to allow the decay heat of the fuel to decrease. The Fuel Pool Cooling and Clean-up System (FPC) is used to remove the decay heat and maintain the water quality. Water makeup systems are available to maintain the water level in the pool.

Spent Fuel Interim Storage

After storage of the spent fuel assemblies in the SFP for some years, the spent fuel assemblies are transferred from the SFP to the on-site SFIS facility. These operations are performed whilst the reactor is operating. The RBC is used to move a transfer cask into the cask pit for loading with spent fuel. A transfer cask is raised from the truck bay to the operations deck where it is placed in the cask preparation pit. The cask lid is removed from the transfer cask, prior to the RBC transferring the transfer cask to the cask pit which is a segregated area of the SFP. The FHM is used to load individual fuel assemblies from the spent fuel storage racks into the transfer cask inner container, called a canister. The RBC is then used to place the lid on top of the transfer cask and to transfer the cask back to the preparation pit. Within the preparation pit a lid is welded onto the canister inside the transfer cask, the water is then removed and replaced with an inert gas, usually helium. A drying process is used to ensure moisture is removed from the canister. Once the dried and sealed lid is attached to the transfer cask, the cask is decontaminated, and then the RBC transfers the cask to the truck bay entrance. The transfer cask is then moved from the reactor building to the on-site SFIS facility to be repackaged into a storage cask and interim storage.

Again due to lack of development of the design presented in GDA the following are examples of regulator concerns that may arise:

- Credibility of gross failure of the canister boundary – lack of definition of what is meant by a ‘gross failure’ of a canister and explanation of the unmitigated consequences in terms of safety, environmental protection and the practical logistics of fault recovery over the intended storage period.

- Over temperature protection system proof of concept - given the high safety significance of these systems, further information and 'proof of concept' should be presented to substantiate that it is technically feasible for the required nuclear safety functions to be delivered at the required reliability.
- Canister cooling system proof of concept - the CCS will remain at concept design during GDA and the final choice of canister will not be made until the site-specific phase of design. However given the importance of the CCS to maintain nuclear safety during both normal operations and fault conditions, further information and 'proof of concept' should be presented to substantiate that a system of this nature will be capable of delivering the required nuclear safety function at the required reliability.
- Protection of workers from fuel clad failures within unsealed canisters - in the event of a fuel clad failure occurring within the canister during movement of the unsealed canister between the SFP and pits, the fuel drying process, canister inerting or canister welding to demonstrate that the standby gas treatment system will protect workers within the vicinity of the unsealed canister.

RESOLUTION AND EXPECTATIONS OF GDA

The RP needs to demonstrate that the spent fuel and waste facilities can safely handle, store and dispose of the spent fuel and wastes generated during the whole lifecycle of the reactor. This will require sufficient levels of design to:

- credibly justify the processing, treatment, handling and storage options proposed
- understand how spent fuel and waste streams and their packaging might evolve over the storage period
- consider spent fuel and waste disposability
- produce robust estimates of the required capacity

The first bullet point is by far the most important and the one that most often gives cause for concern due to insufficient design details, lack of robust optioneering and failure to demonstrate that the chosen option has been or is capable of being reduced ALARP. This is the issue that affects the examples given above for LWMS and SFIS.

Spent fuel and waste processing facilities within an ABWR practically fall into four general areas:

- the fuel route including the spent fuel storage pond in the R/B used for loading and unloading fuel and for cooling spent fuel
- the LWMS and the SWMS including storage
- spent fuel interim storage facility
- off-gas treatment system

For each of these facilities different levels of design are likely to be acceptable during GDA. The ponds used for transfer of fuel & reactor components and storage are an integral part of the reactor building and are needed early in the plant life. Therefore, their development should be to the same level of design as the reactor. This may include aspects of the fuel route but not all of SFIS. Facilities for processing liquid and solid wastes are fundamental to the safe operation of waste storage and disposal. Where these facilities are an integral part of the reactor, their development should be at the same level of design as the reactor. Where the facility or process is not integral to the reactor building as is the case for the LWMS and SWMS then a concept level of design can be used in GDA.

The design of spent fuel and waste processing and storage facilities needs to demonstrate that risks have been reduced ALARP at this stage if possible. The main faults and fault groups need to be identified and to have been taken into consideration. This will mean that parts of the plant design even those at concept level will have to be considered in the regulatory assessment. For the assessment topics in LWMS and SFIS the RP and the operators should develop designs and processes to sufficient detail to understand the interface with the reactor and key equipment and the types of potential faults and accidents in the waste and spent fuel systems.

The spent fuel interim store will not be required until at least 10 years after the start of reactor operations due to the capacity available in the SFP. In the meantime more experience will be gained of fuel route activities, long-term storage and potentially disposal. To give the regulators enough confidence that the operators can safely handle, store and transfer spent fuel, viable options will have to be identified by the RP and a plan developed to demonstrate that one of these could eventually be implemented. This will allow a conclusion at the end of GDA that the management of spent fuel has been adequately addressed.

ILW stores will be required on a shorter timescale and there is OPEX of stores of at least 50 years. Potentially challenging issues include the size, location and timing of the store and that it is consistent with UK Government policy. RPs and operators should look at exploiting synergies with other NPP companies.

CONCLUSIONS

The regulators need to ensure that the provision of information on spent fuel and waste management issues in GDA is proportionate, compliant with regulations and consistent with public expectations. It is in the RP interest to provide adequate information to permit a meaningful GDA. For the SFP and waste processing facilities that are an integral part of the reactor their development should be to the same level of design as the reactor. There can be more flexibility for other waste processing and storage facilities.

For the spent fuel handling and storage operations, the RP needs to demonstrate that they can safely carry out these operations many times. This will require sufficient levels of design to justify the credibility of the storage options proposed such as:

- the types of facilities that could be used
- when facilities will be developed and constructed
- understanding the evolution of spent fuel, waste streams and their packaging over time
- radiological implications and shielding
- the ability to retrieve, inspect and repackage damaged fuel
- plans for record and data management
- robust estimates of the required capacity

These planning requirements are comparable to those encountered by nuclear utilities and operators in the UK (including the NDA) and throughout the world. Therefore the RP should adopt similar approaches in GDA. Clearly many decades will pass between the initial design, construction, start of operations and spent fuel interim storage which will see new technologies develop and the gain of much experience. In the case of facilities subject to concept design it is plainly impractical if not even foolhardy for the RP to identify specific equipment or technologies at a stage as early as GDA that will not enter operation for a further 20 years or more. It may be more beneficial for the RP to select an existing technology or operation as 'proof of concept' to demonstrate that the process is capable of being implemented on the understanding that it might not be the final version. By adopting this approach both regulators and RPs can engage in a meaningful and productive GDA.

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