Environment Agency

Office for Nuclear Regulation

An agency of HSE

Generic Design Assessment – New Civil Reactor Build

GDA Close-out for the EDF and AREVA UK EPR™ Reactor GDA Issue GI-UKEPR-CC-03 Revision 3 – Fukushima lessons learnt impact on UK EPR™

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EXECUTIVE SUMMARY

This report presents the close-out of part of the Office for Nuclear Regulation's (an agency of HSE) and Environment Agency's Generic Design Assessment (GDA) within the Cross-Cutting area. The report specifically addresses the GDA Issue GI-UKEPR-CC-03 Revision 3 generated to take account of the lessons learnt for the UK EPR™ following events at Fukushima. The assessment has focused on the deliverables identified within the EDF and AREVA Resolution Plan published in response to the GDA Issue.

On 11 March 2011 Japan suffered its worst recorded earthquake. Reactor Units 1, 2 and 3 on the Fukushima Dai-ichi (Fukushima-1) site were operating at power before the event and on detection of the earthquake shut down safely. Within an hour a massive tsunami from the earthquake inundated the site. This resulted in the loss of some Direct Current (DC) supplies, essential instrumentation, and all but one diesel generator, and created massive damage around the site. Despite the efforts of the operators, eventually back-up cooling was lost. With the loss of cooling systems, Reactor Units 1 to 3 overheated. This resulted in several explosions and what is predicted to be melting of the fuel in the reactors leading to major releases of radioactivity, initially to air, but later by leakage of contaminated water to sea.

The scope of the GDA Step 4 technical assessment reports did not include Fukushima as the accident occurred after the Step 4 submissions were provided to us. So, to ensure that the lessons learnt from the Fukushima accident were considered within GDA for the generic UK EPR™ reactor design, we raised GDA Issue **GI-UKEPR-CC-03** and in response to this EDF and AREVA submitted a Resolution Plan.

This GDA Issue and its two associated actions requested EDF and AREVA to demonstrate how they would take account of lessons learnt from the events at Fukushima, including those lessons arising out of EDF and AREVA's own internal reviews and the lessons and recommendations identified in HM Chief Inspector's (CI) final report.

The approach taken by EDF and AREVA was to review the robustness of the UK EPR™ design against severe external events and, where appropriate, to identify and develop potential design enhancements recognising developments in other EPR™ projects and wider international initiatives. EDF and AREVA provided reports covering:

- Review of UK EPR™ robustness against seismic and external flooding events;
- Review of UK EPR™ ability to withstand loss of power and cooling;
- Review of UK EPR™ severe accident management arrangements to mitigate the consequences of such events;
- Summary of how the recommendations from the CI's report have been addressed for the UK EPR™;
- A description of the enhancements identified from EDF and AREVA's post Fukushima reviews;
- Work undertaken to address other GDA issues that identified design changes which improve the robustness of EPR™ against extreme events; and
- A new PCSR sub-chapter dealing with post Fukushima reviews.

From their reviews EDF and AREVA identified five design change proposals for GDA that group together a series of resilience enhancements in areas such as the following:

- Improved flood protection for emergency electrical supplies (both AC and DC);
- Extension of the capability and autonomy of emergency electrical supplies (both AC and DC);
- Identified connection points for proposed mobile diesel generators;
- Addition of Spent Fuel Pool (SFP) instrumentation into the severe accident management Control and Instrumentation (C&I) systems; and
- Provision of connections to enable delivery of water via mobile pumps for SFP make-up and containment pressure control.

The regulators concluded that the additional information provided establishes that:

- EDF and AREVA have provided sufficient design reviews and supporting analysis to demonstrate the robustness of the UK EPR™ design. These reviews include normal operation and shutdown during extreme events such as earthquake and flooding (recognising that for flooding the reactor platform height is the critical determining parameter and this is a site specific matter).
- EDF and AREVA have provided appropriate evidence to demonstrate the ability of the plant to maintain a safe state following extreme events which result in loss of electrical power and / or cooling.
- The proposed resilience enhancements will improve the robustness of the UK EPR™ against extreme events.
- The development of EPR™ severe accident management arrangements will mitigate the consequences of severe accidents.
- The responses from EDF and AREVA to the Chief Inspector's (CI's) recommendations are considered to be suitable and sufficient.

From the assessment of other GDA Issues, in particular **GI-UKEPR-FS-03** relating to the Spent Fuel Pool (SFP) and **GI-UKEPR-FS-05** for reactor support systems, EDF and AREVA have identified plant and system enhancements agreed for inclusion in GDA which we judge will provide further improvements to the robustness of the UK EPR™ design against severe accidents.

We note that NNB GenCo, in their role as the licensee of Hinkley Point C and the company planning to build the first UK EPR™ at Hinkley Point C, have proposed their own list of site specific considerations and potential design improvements in response to the CI's report. These complement those now incorporated in the generic design.

Furthermore, from discussions with international regulators in the Multinational Design Evaluation Programme (MDEP) additional options are being considered in other EPR™ projects which have the potential to further improve the robustness of a UK EPR™. As these options are at an early stage of development we request future UK EPR™ licensees to consider their suitability for implementation into a UK site-specific design.

The regulators judge that the design changes proposed within GDA will provide improved resilience in the safety and robustness of the UK EPR™.

On the basis of our assessment of the information provided by EDF and AREVA we are satisfied that the lessons learnt from Fukushima and the requirements of GDA Issue **GI-UKEPR-CC-03** have been addressed.

ONR has raised several assessment findings in relation to this GDA Issue and these are identified in annex 2. The Environment Agency has not raised any assessment findings in relation to this GDA Issue.

LIST OF ABBREVIATIONS

ALARP	As low as is reasonably practicable
ATWS	Anticipated Trip without Scram
BDBA	Beyond Design Basis Analysis
C&I	Control and Instrumentation
CI	Chief Inspector
CHRS	Containment Heat Removal System
CMF	Change Management Form
CMSS	Core Melt Stabilisation System
DC	Direct Current
EDF and AREVA	Electricité de France SA and AREVA NP SAS
EDG	Emergency Diesel Generator
EA	Environment Agency
EFWS	Emergency Feed Water System
ENSREG	European Nuclear Safety Regulatory Group
ESWS	Essential Service Water Storage Tanks
FA3	Flamanville 3
GDA	Generic Design Assessment
HCLPF	High Confidence of Low Probability of Failure
HPC	Hinkley Point C
HSE	Health and Safety Executive
HVAC	Heating, Ventilation & Air Conditioning
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
IRWST	Incontainment refuelling water storage tanks
ISFS	Interim Spent Fuel Store
LHSI	Low Head Safety Injection
LOOP	Loss of off-site Power
MDEP	Multi-national Design Evaluation Programme
NAB	Nuclear Auxiliary Building
NI	Nuclear Island
ONR	Office for Nuclear Regulation (an agency of HSE)
OSSA	Operating Strategies for Severe Accident

LIST OF ABBREVIATIONS

PAR	Passive Auto-catalytic Recombiners
PCER	Pre-Construction Environment Report
PCSR	Pre-construction Safety Report
PDS	Primary Depressurisation System
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Analysis
REP	Radiological Substances Regulation Environment Principle(s) (EA)
SAP	Safety Assessment Principle(s) (HSE)
SFP	Spent Fuel Pool
SG	Steam Generator
SMA	Seismic Margin Assessment
SSC	Structures, Systems and Components
TAG	Technical Assessment Guide(s) (ONR)
TQ	Technical Query
UCWS	Ultimate Cooling Water System
UDG	Ultimate Diesel Generator
UHS	Ultimate Heat Sink
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1.1 BACKGROUND

1 On 11 March 2011 Japan suffered its worst recorded earthquake. Reactor Units 1, 2 and 3 on the Fukushima Dai-ichi (Fukushima-1) site were operating at power before the event and on detection of the earthquake shut down safely. Within an hour a massive tsunami from the earthquake inundated the site. This resulted in the loss of some Direct Current (DC) supplies, essential instrumentation, and all but one diesel generator, and created massive damage around the site. Despite the efforts of the operators, eventually back-up cooling was lost. With the loss of cooling systems, Reactor Units 1 to 3 overheated. This resulted in several explosions and what is predicted to be melting of the fuel in the reactors leading to major releases of radioactivity, initially to air, but later by leakage of contaminated water to sea.

2 On 14 March 2011 the Secretary of State for Energy and Climate Change requested that HM Chief Inspector of Nuclear Installations examine the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. The Secretary of State requested HM Chief Inspector to provide an interim report by the middle of May 2011, with a final report six months later. The interim report (Ref. 39) was published on 18 May 2011 and the final report on 11 October 2011 (Ref. 25).

3 The key impact on GDA is that, as we were waiting for any lessons learnt from Fukushima to emerge in the final report, we did not believe it was appropriate to draw conclusions from our GDA assessment work in June 2011 as originally planned, nor publish our GDA technical assessment reports on that date. In effect, our assessment was extended to await the recommendations of HM Chief Inspector's reports.

4 The interim and final reports identify the implications for the UK nuclear Industry and set out a number of recommendations for the UK Government, the UK Nuclear Regulators and the UK nuclear industry to address. In total, there are 38 recommendations: one has been completed; four are relevant to the Regulators, 23 are relevant to the nuclear industry; and nine are relevant to the UK Government, the Regulators and the nuclear industry. The final recommendation required reports of progress made by the nuclear industry in responding to the recommendations, to be submitted to ONR by June 2012.

5 In an international context there are a number of ongoing initiatives:

- The European Nuclear Safety Regulatory Group (ENSREG) has defined a set of "Stress Tests" to be carried out in European member states for nuclear power plants in operation or being constructed. Each member state had to report the outcome of the "Stress Tests" by the end of December 2011, and these reports were peer reviewed in early 2012 by an expert panel drawn from European member states.
- IAEA has initiated a number of activities to draw lessons from the accident, assist the Japanese authorities and report to IAEA member states. These include:
  - A preliminary mission to find facts and identify initial lessons to be learnt, undertaken by a team of experts from across the world, conducted from 24 May to 2 June 2011.
  - An IAEA Action plan on nuclear safety, which is aimed at making nuclear safety post-Fukushima more robust and effective.
  - A meeting of the Convention on Nuclear Safety to share lessons learnt and actions taken in response to events at Fukushima, held in August 2012.

6 The scope of the Step 4 technical assessment reports did not include Fukushima as the accident occurred after the Step 4 submissions were provided to us. So, to ensure that the lessons learnt from the Fukushima accident are considered within GDA, ONR and the Environment Agency raised a joint GDA Issue to ensure that EDF and AREVA addressed any lessons to be learnt for the generic UK EPR™ reactor design.

7 This GDA Issue requested EDF and AREVA to demonstrate how they will take account of the lessons learnt from the events at Fukushima, both those arising out of EDF and AREVA's own internal reviews as well as those lessons and recommendations identified in HM Chief Inspector's interim and final reports (Ref. 25 and 39). These should also take account of the wider international initiatives.

8 In response to this GDA Issue, EDF and AREVA submitted a report summarising the initial evaluation of the EPR™ undertaken following the Fukushima event. The report presented claims on EPR™ robustness and identified the following areas where further analysis would be undertaken for GDA:

- Seismic robustness;
- Flooding robustness;
- Loss of cooling/power;
- Severe accident management; and
- Summary report to address the relevant recommendations from the CI's report.

9 The items above and the initial evaluation report were identified as the key deliverables in the Resolution Plan submitted by EDF and AREVA to address this GDA Issue.

10 The Regulators reviewed the Resolution Plan and judged it as credible.

11 This report presents the close-out of the Health and Safety Executive's (HSE) and the Environment Agency's Generic Design Assessment (GDA) within the area of Cross Cutting GDA Issue associated with lessons learnt from the Fukushima event. The report specifically addresses the GDA Issue **GI-UKEPR-CC-03** Revision 3 and associated GDA Issue actions (Ref. 6).

12 The assessment focused on the deliverables identified within the EDF and AREVA Resolution Plans (Ref. 8) published in response to this GDA Issue and on further assessment undertaken of those deliverables.

13 An Assessment Finding results from a lack of detailed information which has limited the extent of assessment and as a result the information is required to underpin the assessment. However, they are to be carried forward as part of normal regulatory business and will require to be closed as the site specific design develops. The Step 4 Fault Studies Containment and Severe Accident Assessment report (Ref. 7) identified a number of Assessment Findings as part of the assessment of the evidence associated with the UK EPR™ reactor design.

14 The purpose of this report is to provide details of the assessment which underpins the judgement made in closing GDA Issue **GI-UKEPR-CC-03**.

1.2 SCOPE

15 This report presents only the assessment undertaken as part of the resolution of this GDA Issue and it is recommended that this report be read in conjunction with the Step 4 Fault Studies Containment and Severe Accident Assessment of the EDF and AREVA UK

EPR™ in order to appreciate the totality of the assessment of the evidence undertaken as part of the GDA process.

16 This assessment report is not intended to revisit aspects of assessment already undertaken and confirmed as being adequate during previous stages of GDA. However, should evidence from the assessment of EDF and AREVA's responses to GDA Issues highlight shortfalls not previously identified during Step 4, there will be a need for these aspects of the assessment to be highlighted and addressed as part of the close-out phase or be identified as Assessment Findings to be taken forward to the site-specific phase.

1.3 METHODOLOGY

17 ONR's methodology applied to this assessment is identical to the approach taken during Step 4 which followed the ONR HOW2 document PI/FWD, "Permissioning – Purpose and Scope of Permissioning" (Ref. 1), in relation to the mechanics of assessment within ONR. The Environment Agency's methodology applied to this assessment is identical to the approach taken during the detailed assessment stage.

18 This assessment has been focused primarily on the submissions relating to resolution of the GDA Issues as well as any further requests for information or justification derived from assessment of those specific deliverables.

19 The aim of this assessment is to provide a comprehensive assessment of the submissions provided in response to the GDA Issue to enable the Regulators to gain confidence that the concerns raised have been resolved sufficiently so that they can be closed with lesser safety significant aspects being carried forward as Assessment Findings.

1.4 STRUCTURE

20 This close-out report is a joint report between ONR and EA. The structure of this close-out report differs slightly from the structure adopted for the previous assessment reports produced within GDA, most notably the ONR Step 4 Fault Studies Containment and Severe Accident Assessment Report (Ref. 7). This report has been structured to reflect the assessment of this individual GDA Issue which concerns addressing the lessons learnt from Fukushima and the recommendations from the ONR Chief Inspector's report (Ref. 25).

2 THE ASSESSMENT STRATEGY FOR CROSS CUTTING GDA ISSUES

21 The intended assessment strategy for GDA Close-out of the three Cross Cutting Issues was set out in an assessment plan that identified the intended scope of the assessment and the standards and criteria that would be applied.

22 The overall basis for the assessment of this Cross Cutting GDA Issue are the following:

- Submissions made to the Regulators in accordance with the resolution plans (Ref. 8).
- Update to the Submission / Pre-Construction Safety Report (PCSR) / Pre-Construction Environment Report (PCER) / Supporting Documentation.
- Design Change Submissions – which are proposed by EDF and AREVA and submitted in accordance with UK-EPR GDA Project Instruction UKEPR-I-003 (Ref. 10).

2.1 The Approach to Assessment for GDA Close-out

23 The approach to the closure of GDA Issues for the UK EPR™ Project involved the assessment of submissions made by EDF and AREVA in response to GDA Issues identified through the GDA process. These submissions are detailed within the EDF and AREVA Resolution Plan for the GDA Issue.

24 In the event of requiring further supporting evidence for the assessment, Technical Queries (TQ) could have been generated. However, none were generated in the resolution of this GDA Issue.

25 Formal feedback on some draft documentation and our expectations for GDA deliverables was provided as appropriate throughout the assessment.

26 The objective of the Cross Cutting assessment has been to assess submissions made by EDF and AREVA in response to the GDA Issue and the design changes requested by EDF and AREVA and, if judged acceptable to close the GDA Issue.

2.2 Standards and Criteria

27 The relevant standards and criteria adopted within this assessment are principally the ONR Safety Assessment Principles (SAPs), the Environment Agency's Radioactive Substances Regulation Environmental Principles (REPs), internal ONR Technical Assessment Guides (TAGs), relevant national and international standards and relevant good practice informed from existing practices adopted on UK nuclear licensed sites. The key SAPs, REPs and relevant TAGs have been detailed within this section. National and international standards and guidance have been referenced where appropriate within the assessment report. Relevant good practice, where applicable, has also been cited within the body of the assessment.

2.3 Safety Assessment Principles/Radioactive Substances Regulation Environmental Principles

28 The key SAPs and REPs applied within the Cross Cutting assessment of the EDF and AREVA UK EPR™ are included within Table 1 of this report.

2.3.1 Technical Assessment Guides

29 The following Technical Assessment Guides have been used as part of this assessment (Ref. 3):

- T/AST/007 – Severe Accident Analysis

- T/AST/051 –Purpose, Scope and Content of Nuclear Safety Cases
- T/AST/057 - Design safety assurance

2.3.2 National and International Standards and Guidance

30 The following international standards and guidance have been used as part of this assessment

- Safety of Nuclear Power Plants: Design. Safety Requirements. International Atomic Energy Agency (IAEA). Safety Standards Series No. NS-R-1 (Ref. 5).
- Western European Nuclear Regulators' Association (WENRA) Reactor Reference Safety Levels (Ref. 4).
- European Nuclear Safety Regulators Group (ENSREG) "stress test" specifications, May 2011 (Ref. 23).
- Western European Regulators Association (WENRA) "stress test" specifications proposed by the WENRA test force. April 2011 (Ref. 24).

2.4 Use of Technical Support Contractors

31 No Technical Support Contractors have been used.

2.5 Out-of-scope Items

32 This GDA Issue applies across the UK EPR™ GDA design and there are no defined out-of-scope items.

3 EDF AND AREVA DELIVERABLES IN RESPONSE TO THE GDA ISSUE

33 The information provided by EDF and AREVA in response to this GDA Issue, as detailed within their Resolution Plan (Ref. 8), was broken down into the component GDA Issue Actions and then further broken down into specific deliverables for detailed assessment.

GDA Issue Action	Deliverable	Ref.
GI-UKEPR-CC-03.A1	Task 1 – Summary of the additional safety evaluation of the UK EPR™ design following Fukushima events, December 2011 - ECUK110959.	32
GI-UKEPR-CC-03.A1	Task 2.1 Seismic events -Summary of the Additional Safety Evaluation against Beyond Design Basis Earthquakes, PEPS-F DC 151, October 2012.	17
GI-UKEPR-CC-03.A1	Task 2.2 Flooding events- Design against Flooding Events, E.T.DPNN/120048 C, October 2012.	18
GI-UKEPR-CC-03.A1	Task 3 – Robustness of Power Sources/Long term Cooling, PEPS-F DC 133, November 2012.	19
GI-UKEPR-CC-03.A1	Task 4 -Severe Accident Management, ECESN120395, November 2012.	20
GI-UKEPR-CC-03.A2	Task 1 – Summary of Responses to actions in ONR Final Report on Lessons learned from the Fukushima Event, PEPS F DC 133, November 2012.	21
GI-UKEPR-CC-03.A2	Task 2 – 6. PCSR – Chapter 16.6 – Analysis of Extreme Beyond Design Basis Events carried out in Response to Fukushima, UKEPR-0002-168, Issue 0, November 2012.	22

34 An overview of each of the deliverables is provided within this section. It is important to note that this information is supplementary to the information provided within the Step 4 Consolidated SSER (Ref. 11) which has already been subject to assessment during earlier stages of GDA. In addition, it is important to note that the deliverables are not intended to provide the complete safety case. Rather they form further detailed arguments and evidence to supplement those already provided during earlier Steps within the GDA Process.

35 The documents described below have been produced in response to the ENSREG and WENRA stress tests (Ref. 23 and 24) in which sequential loss of the lines of defence was modelled deterministically, irrespective of the sequence frequency to confirm the validity of the design basis for certain extreme events. They have also been produced in response to the recommendations of the HM Chief Inspector of Nuclear Installations report on the Fukushima event (Ref. 25). The stated aim of EDF and AREVA submissions was to perform a comprehensive analysis of the response of the UK EPR™ to extreme events, to quantify design margins, identify cliff-edge effects and propose reasonably practicable enhancements to further improve robustness.

3.1 Summary of the additional safety evaluation of the UK EPR™ design following Fukushima events, December 2011 - ECUK110959

36 This report (Ref. 32) provides a summary of the results of the safety and environment reviews of the FA3 EPR performed by EDF and AREVA immediately following the

Fukushima events and was produced in response to ENSREG and WENRA stress tests (Ref. 23 and, 24) and as the FA3 design forms the basis for the UK EPR™ design in GDA, the report was submitted to the UK regulators as the initial response to **GI-UKEPR-CC-03. A1**.

37 The report concludes that the EPR™ has good resistance to extreme events such as Fukushima and identifies a number of potential plant enhancements to eliminate possible cliff edge effects. Additionally the report provides the commitment to provide further reports to further substantiate claims made on EPR™ robustness, to further develop proposed design enhancements and to address the recommendations in the ONR Chief Inspector's report.

3.2 Summary of the Additional Safety Evaluation against Beyond Design Basis Earthquakes, PEPS-F DC 151, October 2012

38 This report (Ref. 17) provides a summary of the analysis of robustness of the UK EPR™ against a beyond design basis earthquake which relies upon the seismic margin assessment (SMA) (Ref. 26) reported in the PCSR. SMA uses the PSA to identify safety classified systems, structures and components (SSC) necessary to ensure that a minimum set of key safety functions on the reactor are maintained following a seismic event.

39 Although the application of SMA has been applied to a limited number of SSCs for GDA, the report concludes that the UK EPR™ could tolerate a seismic event with a maximum peak ground acceleration (PGA) of 0.61 g, which is considerably in excess of the design basis earthquake corresponding to a 0.25 g PGA. Therefore no further enhancements are proposed.

3.3 Design against Flooding Events, E.T.DPNN/120048 C, October 2012

40 This report (Ref. 18) provides a summary of the analysis of the UK EPR™ against a beyond design basis flooding event. This is predominately a site-specific matter that relies upon a number of means including; platform height, site drainage, ground floor slabs above platform height, sea protection (sea walls etc) and volumetric protection. Nevertheless, the report does identify several enhancements to improve leak tightness of access doors to buildings housing essential SSCs.

3.4 Robustness of Power Sources/Long term Cooling, PEPS-F DC 133, November 2012

41 This report (Ref. 19) summarises the analysis undertaken by EDF and AREVA for the UK EPR™ for extended loss of power and / or cooling events and estimates the grace times available for the plant to withstand these losses of services before there could be a significant increase in the off-site radiological consequences. The report also identifies potential plant enhancements intended to extend grace times.

3.5 Severe Accident Management, ECESN120395, November 2012

42 This report (Ref. 20) provides a review of progression of a severe accident in extreme conditions of simultaneous loss of power and / or cooling and identifies potential plant enhancements.

3.6 Summary of Responses to actions in ONR Final Report on Lessons learned from the Fukushima Event, PTS DC 9, November 2012

43 This report (Ref. 21) summarises the responses from EDF and AREVA for the UK EPR™ to the actions in the ONR Chief Inspectors report (Ref. 28) and provides a summary of potential design enhancements identified from EPR™ reviews quoted above.

44 The design changes related to this GDA Issue are presented in Table 2 and summarised in Annex 3. The recommendations from the CI's report relevant to GDA are presented in Table 3.

3.7 PCSR – Chapter 16.6 – Analysis of Extreme Beyond Design Basis Events Carried Out in Response to Fukushima, UKEPR-0002-168, Issue 0, November 2012

45 This new sub chapter to the UK EPR™ PCSR (Ref. 22) provides a high level summary and references to the reviews undertaken by EDF and AREVA to demonstrate the robustness of the UK EPR™ against extreme events and summarised potential design enhancements arising from these reviews and other potential enhancements related to other GDA Issues such as **GI-UKEPR-FS-03** and **GI-UKEPR-FS-05.**

4 THE REGULATORS' ASSESSMENT

46 This assessment focused on the deliverables from EDF and AREVA provided in response to this GDA issue and also documents describing the inclusion of enhancements to the EPR™ design from work undertaken on FA3.

47 This assessment has been carried out in accordance with the ONR HOW2 Assessment Process (Ref. 1).

48 We have utilised ONR specialist assessment resource in completing our review of the deliverables provided by EDF and AREVA in response to this GDA Issue and these inputs are summarised in the assessment notes referenced from this close-out report (Ref. 29, 30, and 31).

4.1 Scope of Assessment Undertaken

49 The scope of the assessment has been to consider the expectations within the GDA Issue, **GI-UKEPR-CC-03**, and the associated GDA Issue Actions. These are detailed within Annex 3 of this report. Evidence was sought on:

- Analysis and reviews to demonstrate the robustness of the UK EPR™ design against extreme events.
- Identification of potential enhancements to UK EPR™ design.
- Adequacy of responses to the recommendations in the Chief Inspector's report (Ref. 25).

50 The scope of this assessment was not to undertake further assessment of the information already provided in the Step 4 consolidated SSER, nor was it intended to extend the assessment beyond the expectations stated within the GDA Issue Actions.

51 For each of the deliverables described in the following assessment, the Regulators provided feedback to EDF and AREVA on the draft deliverables and through a process of iteration, these deliverables were reviewed, revised, reassessed and finalised.

52 Any design changes arising from this GDA Issue that have been agreed for inclusion in GDA are summarised in section 4.2.2 and listed in Table 2 of this report.

4.2 Assessment

53 The seven deliverables provided to support closure of this GDA Issue Actions have been summarised within Section 3 of this report.

4.2.1 Lessons learnt from EDF and AREVA internal reviews following Fukushima

54 This section of the report covers the Regulators assessments of the internal reviews of the UK EPR™ robustness undertaken by EDF and AREVA following Fukushima under the following sub-section headings:

- 4.2.1.1 Review of UK EPR™ against Beyond Design Basis (BDB) seismic event
- 4.2.1.2 Review of UK EPR™ against BDB flooding event
- 4.2.1.3 Review UK EPR™ against loss of power and or ultimate heat sink events
- 4.2.1.4 Review of UK EPR™ severe accident management arrangements

4.2.1.1 Review of UK EPR™ against BDB seismic event

55 The analysis of robustness (Ref. 17) of the UK EPR™ against a beyond design basis earthquake essentially relies upon the seismic margin analysis (SMA) reported in the

PCSR (Ref. 26), primarily for structures. The analysis uses the PSA to identify those safety classified systems, structures and components (SCC) necessary to ensure that a minimum set of key safety functions on the reactor are maintained following a seismic event.

56 For each SCC, a conservative fragility analysis of its seismic withstand capability is performed to determine the maximum Peak Ground Acceleration (PGA) for which there is a high confidence of low probability of failure (HCLPF) for the SCC. The confidence level is set at 95% for a probability of failure of 5%. It should be noted that in practice, for many SSCs the maximum PGA corresponding to the HCLPF is not actually identified since only a limited range of PGAs are analysed up to a maximum value of 0.64 g.

57 The robustness report (Ref. 17) presents the argument that for those components within the scope of the GDA assessment, the SMA demonstrates that, with the exception of the fuel spacer grids, the UK EPR™ could tolerate a seismic event with a maximum PGA of 0.61 g, which is considerably in excess of the design basis earthquake corresponding to a 0.25 g PGA. However, it should be noted that the seismic margin analysis was only performed for the 'at power' state.

58 In response to Regulators questions, EDF and AREVA revised the report to address shutdown states by including information on the HCLPF calculations for the US EPR™, and this was adequate to show that EDF and AREVA had investigated beyond design basis behaviour and justified there was sufficient margin for extreme events such as Fukushima. EDF and AREVA had also added an appraisal of load combinations in the revised report.

59 With respect to civil structures we are satisfied with the case made for C1 classified Main Structures. But for civil structures classified as C1 "Other Structures", which generally comprise internal removable structures within a C1 building, we questioned what more EDF and AREVA had done following Fukushima with respect to this. These other structures, which are normally classed as seismic class 2 (SC2), could potentially block access/egress within the building or affect services performing a safety function relied on for an extreme event.

60 Although we are satisfied with the current classification procedure which will identify the specific criteria for a SC2 structure when it could affect C1 systems or components if the new design change proposals (CMFs) for Fukushima rely on a C2 system or component, a future licensee will have to demonstrate that this classification is sufficient.

61 EDF and AREVA state that emergency plans will be produced during the site-specific stage and plant walkdowns will be carried out as a check to confirm the adequacy of the classification proposed for other structures. We judge these proposals as adequate, however, as they are to be carried out during the site specific stage this leads to the following ONR Assessment Finding:

> **AF-UKEPR-CC-12** *The licensee shall provide a review of emergency plans and building walkdowns that are to be carried out for the civil structures classified as C1 "other structures" as part of the robustness review in light of Fukushima. This review shall demonstrate that the structural performance specified for each structure following an extreme event, provides sufficient beyond design basis margin such that its post event condition does not adversely affect the emergency plans.*
>
> ***Required Timescale:*** *before non-active commissioning.*

62 The robustness report states that the PGA for the fuel spacer grids corresponding to the HCLPF criteria is 0.4 g but argues that not maintaining fuel grid geometry leads to an

Anticipated Trip without Scram (ATWS) sequence for which other diverse protection is provided such that a change in the fuel is not warranted given the large margin to the design basis earthquake. It also notes that the for US EPR™ plant, the fuel grid is being redesigned to improve its seismic robustness.

63 In summary, in our opinion, given the large margins and the fact that fuel spacer grid design is not a limiting factor in terms of identifying plant layout, sufficient demonstration of plant robustness has been provided for the purposes of GDA recognising that site-specific seismic analysis will be required under an ONR Assessment Finding for the detailed site-specific design which is described below.

64 Although we are satisfied that EDF and AREVA have provided sufficient information to demonstrate the robustness of the UK EPR™ design against a beyond design basis seismic event a future UK EPR™ licensee shall complete the seismic analysis on the detailed site specific UK EPR™ design to a level consistent with the SMA provided in GDA:

> ***AF-UKEPR-CC-13:*** *A future licensee shall analyse the detailed site specific UK EPR™ design to demonstrate its robustness against beyond design basis seismic events for all plant operating states to a level consistent with the Seismic Margin Assessment provided in GDA.*
>
> ***Required timescale:*** *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

4.2.1.2 Review of UK EPR™ against BDB flooding event

65 The analysis of robustness (Ref. 18) of the UK EPR™ against a beyond design basis external flooding event is predominately a site-specific matter and relies upon a number of means including; platform height, site drainage, ground floor slabs above platform height, sea protection (sea walls etc) and volumetric protection. It relies upon the argument that the buildings housing essential safety classified equipment (SSCs) will remain dry by setting the platform height on which they are constructed at a level at least as a high as the maximum design basis flood level. This is supplemented by the requirement to prevent as far as possible, any water present on the platform from entering the buildings housing essential safety classified equipment.

66 This latter requirement has resulted in a number of proposed design changes to improve the leak tightness of access doors to buildings housing safety functions, the rooms containing the Ultimate Diesel Generators (UDG) and severe accident batteries, and the openings and doors of the pumping station main slab. These design changes are discussed and summarised in section 4.2.2 of this report.

67 The robustness analysis report (Ref. 18) argues that the assessment of the flooding hazard and the design of the pump station are site-specific issues. Nevertheless, the report does acknowledge that loss of heat sink as well as loss of grid (off-site power), and total loss of electrical power, are potential consequences of external flooding. These aspects are explored further in a subsequent robustness report (Ref. 19) such that, taken together, in the Regulators' opinion they provide an adequate response with regard to the robustness of the generic EPR™ design to external flooding events recognising that further work will be performed during the site-specific design stage.

4.2.1.3 Review UK EPR™ against loss of power and or ultimate heat sink events

68 For the robustness analysis (Ref. 19) of the UK EPR™ against total loss of heat sink and the loss of AC power, the aim of EDF and AREVA was to determine the grace periods

that would be available before there was a significant increase in the off-site radiological consequences, or irrecoverable deterioration in the plant state and to identify possible counter measures to extend grace periods and avoid cliff edge effects.

69 The report first describes the overall architecture of the support systems and the key safety systems on the UK EPR™. It then describes the method for selecting sequences to be assessed. Both at power and shutdown states (when the Steam Generators may not be available) are considered, as well as the fuel pool cooling aspects. For each sequence the analysis provides the time line for how long plant autonomy can be maintained. The report concludes with a presentation of the proposed plant modifications intended to extend the grace periods.

70 The main sequences identified for consideration are:

- Loss of off-site power LOOP (long term)
- Loss of off-site power with loss of Emergency Diesel Generators (EDGs) (Station blackout)
- Loss of off-site power with loss of EDGs and Ultimate Diesel Generators (UDGs) (Total Loss of AC power)
- Loss of main heat sink
- Loss of main heat sink and back-up heat sink (Total Loss of Ultimate Heat Sink)
- Total Loss of Ultimate Heat Sink together with Station Blackout
- Total Loss of Ultimate Heat Sink together with Total Loss of AC Power

71 In the Regulators opinion, the identification of these sequences is appropriate. Four of these sequences (total loss of ultimate heat sink, total loss of ultimate heat sink with station blackout, total loss of AC power, and total loss of ultimate heat sink with total loss of AC power) are not currently analysed in the PCSR and so are discussed further below.

4.2.1.3.1 Total Loss of Ultimate Heat Sink

72 The robustness report (Ref. 19) claims that if the total loss of ultimate heat sink is due to blockage of the water intakes on the Essential Service Water Storage Tanks (ESWS) and Ultimate Cooling Water System (UCWS), then the UCWS can be realigned to a diverse intake in the outfall of the pumping station. Otherwise, the report opts for bounding this case with the more onerous total loss of ultimate heat sink together with station blackout discussed in the next section.

4.2.1.3.2 Total Loss of Ultimate Heat Sink with Station Blackout

73 The results for this sequence are summarised in Fig. 13 of the robustness report (Ref. 19). The ultimate diesel generators (UDGs) are started by the operator and provide AC power to operate the Emergency Feed Water System (EFWS) pumps to feed the steam generators. This ensures the decay heat removal function. EFWS feed can be extended from two days up to seven days by transferring water to the EFWS tanks from the fire-fighting system and other proposed sources. The UDG fuel tank would also need to be refilled after 24 hours. Loss of leak tightness of the stand-still seal system is assumed to result in a small loss of coolant accident.

74 The report claims that significant degradation of the primary circuit would not occur for five days for the assumed size of break. The operator is then expected to commence manual bleed and feed operations using a single Primary Depressurisation System (PDS) valve

and the Low Head Safety Injection (LHSI) system in divisions 1 and 4 taking suction from the Incontainment Refuelling Water Storage Tanks IRWST.

75 The report further claims that adequate High Volume Air Conditioning (HVAC) cooling would be available on these two divisions powered by the UDGs. This phase would end when the IRWST heats up to 120°C such that suction is lost to the LHSI unless cooling via the heat sink is restored. The figure indicates a period of 24 hours for this to occur. The report claims that a severe accident sequence would therefore not start for a period of 6.5 days with containment failure not predicted to occur until after 9 days.

76 The case of a shutdown reactor with unavailable steam generators is more onerous. The operator is expected to realign and restart the LHSI pumps in divisions 1 and 4 to take suction from the IRWST. This phase again ends when the IRWST temperature reaches 120°C. This is predicted to occur after 20 hours such that a severe accident sequence with core heat up and meltdown does not commence until after 50 hours.

77 Cooling to the spent fuel pool would also be lost in these circumstances. For the most onerous configuration immediately following core unloading without any cooling or emergency make-up, EDF and AREVA estimate that fuel would start to uncover after 24 hours. With the reactor at power (and so a lower decay heat in the pool), it is claimed that this grace period would be extended up to four days.

78 As the calculations and assumptions underpinning the estimate of the grace times quoted in the EDF and AREVA review report (Ref. 19) are critically important the following ONR Assessment Finding is raised:

> ***AF-UKEPR-CC-14:*** *A future licensee shall provide evidence to substantiate the grace times claimed in report PEPS-F DC 133 for a UK EPR™ following prolonged loss of power and / or cooling events for all operating states.*
>
> ***Required timescale:*** *Prior to fuel load*

79 In summary, the results of the analysis provided by EDF and AREVA in report (Ref. 19) results appear plausible and are extremely useful in placing the loss of cooling chain sequences being considered under **GI-UKEPR-FS-05** in context, indicating that a severe accident event would not occur for at least one day for even the most unlikely of sequences and not for a number of days for the remaining very low frequency sequences.

4.2.1.3.3 Total Loss of AC Power

80 The results for this sequence are summarised in Fig. 11 of the robustness report (Ref. 19). If the total loss of AC power occurs with the reactor at power, the result is a severe accident sequence commencing at approximately two hours following steam generator dry out. The core starts to heat up and meltdown commences. The report acknowledges that similar time scales also apply for a shutdown reactor with the vessel head open and the steam generators unavailable. The report estimates that containment failure will occur after two days.

81 In discussing the severe accident mitigation measures, the report notes a potential vulnerability of the two hour and 12 hour battery backed severe accident Control and Instrumentation (C&I) equipment due to failure of the HVAC system. It notes that room by room thermal analysis will be required to confirm that the temperature rise due to heating by consumers powered by the two hour and 12 hour batteries will not threaten the continued operation of these systems. An ONR Assessment Finding covering this issue is provided in the close-out report for **GI UKEPR-FS-05**.

82 In the Regulators opinion, and in contrast with the loss of ultimate heat sink sequences, there is clearly a significant cliff-edge effect associated with the total loss of AC power in that core melt starts to occur relatively early with little grace time.

83 In the case of the spent fuel pool the consequences will be similar to the fault sequence for the total loss of ultimate heat sink case with station blackout discussed above.

4.2.1.3.4 Total Loss of Heat Sink and Total Loss AC Power

84 The robustness analysis (Ref. 19) concludes that the combined loss of ultimate heat sink and loss of AC power event is effectively bounded by the loss of AC power event since this already causes the consequential loss of ultimate heat sink. The Regulators agree with this conclusion.

4.2.1.4 Review of UK EPR™ Severe Accident Management

85 The report of robustness analyses of severe accident management (Ref. 20) provides a review of the progression of a severe accident in extreme conditions of a simultaneous loss of all AC electrical power and/or ultimate heat sink. Although the scope of Operating Strategies for Severe Accident (OSSA) that covers management of a UK EPR™ plant in severe accident conditions was excluded from the GDA assessment, some aspects are discussed in the report (Ref. 20).

86 In discussing the severe accident management measures, the report notes that the UK EPR™ plant includes the following mitigation measures:

- Provision of Primary Depressurisation System (PDS) valves to mitigate High Pressure Melt Ejection that could potentially lead to early containment failure. These valves are remotely operated from the control room and are powered by the 12-hour severe accident dedicated batteries.
- The failure of fuel due to loss of cooling and subsequent degradation of the reactor core will lead to hydrogen generation that is released into the containment. The UK EPR™ design includes the CONVECT system that incorporates the mixing dampers that helps to mix the hydrogen within the containment volume, and Passive Auto-catalytic Recombiners (PARs).
- The design provision of the UK EPR™ is intended to mitigate the progression of an accident into a severe accident conditions. However, should an accident progress into a severe accident condition, design measures are incorporated to minimise the risk of its consequences such as corium and coolant interaction and re-criticality.
- Total failure of the fuel within the reactor core in a severe accident is likely to lead to the failure of the reactor pressure vessel releasing the molten core into the reactor pit. The molten material is collected within the pit where it ablates the sacrificial concrete and eventually fails the melt plug positioned at the bottom of the reactor pit. The ablation of the sacrificial concrete within the reactor pit should condition the retained corium to allow its transfer into the spreading compartment for long term cooling.
- Operational provisions are also incorporated to prevent over pressurisation of the containment in severe accident conditions. This is achieved by operation of the spray system to limit the pressure build-up within the containment as the accident progresses. The success of this approach depends on the availability of the Containment Heat Removal System (CHRS) which requires the availability of ultimate heat sink and power supplies in extreme conditions.

87 The PDS valves are under manual control and are sized to depressurise the primary circuit in a relatively short time period. These valves are powered by dedicated power supplies that are further discussed in (Ref. 20). The operation of the PDS is further discussed in GDA Step 4 Fault Studies – Containment and Severe Accident assessment report (Ref. 7) which has resulted in the ONR **AF-UKEPR-CSA-10**, requiring future licensees to provide a robust justification of the operational requirements of the PDS during fault conditions. The justification is expected to fully consider the PDS implementation and Operating Strategies for Severe Accident (OSSA) for the UK EPR™. This will be further considered during the detailed site specific design stage.

88 The Severe Accident C&I resilience has been improved by the proposal to provide additional stationary and/or mobile power sources to extend the duration of power supplies to essential functions from severe accident batteries and this is covered by design change proposal Change Management Form (CMF) 49 which is summarised in section 4.2.2 and Annex 3 and listed in Table 2 of this report. The Regulators consider that this design modification, which has been agreed for inclusion in GDA, is likely to increase the plant resilience in a severe accident condition.

89 The aspect of the design relating to hydrogen generation and the ability of the PARs were considered as part of the GDA Step 4 Fault Studies containment and severe accident assessment report (Ref. 7) and the Reactor Chemistry GDA Step 4 assessment report (Ref. 28) which resulted in GDA Issue **GI-UKEPR-RC-01** requiring EDF and AREVA to justify the claims made on the operation of the PARs in prolonged accident conditions. It is however noted that the CONVECT system does not require any operator intervention, and the PARs operate passively in the presence of hydrogen and do not require any power supplies and as such are not susceptible to external extreme events. In addition, the CONVECT system includes hydrogen mixing dampers positioned at the lower parts of the containment that are designed to fail open to allow mixing of the environment between the inner and outer containment volumes.

90 In addition, the temperature measurement subsystem within the Combustible Gas Control System includes six thermocouples, which are distributed over the containment and the polar crane. The output of these thermocouples would provide an indication of the PAR operations. These thermocouples are monitored by the severe accident C&I which are supplied by the severe accident batteries in the case of total loss of AC power.

91 The CHRS is expected to maintain the containment pressure within the design limit and its successful operation is dependent on availability of power supplies and ultimate heat sink that is further considered in (Ref. 20). To further improve the functionality of the CHRS and the resilience of the plant in extreme conditions, EDF and AREVA are proposing to provide a means by which raw water, sourced from an on-site storage facility, can be supplied to the containment. The detail of the proposed enhancement is covered in CMF 50 which is summarised in section 4.2.2 and Annex 2 and listed in Table 2 of this report. We consider that this design modification, which has been agreed for inclusion in GDA, will need to be further examined as part of the detailed site-specific design development stage. Although this design change provision is likely to improve the overall resilience of the plant, we consider that the injection of water should be supported by monitoring of the containment pressure to allow alternative mitigation measures to be deployed if required.

92 The containment over-pressurisation is considered within GDA Step 4 Fault Studies containment and severe accident assessment report (Ref. 7) which has resulted in two ONR Assessment Findings. These require the licensee to justify that the isolation systems and containment penetrations meet the site-specific loading requirements

(pressure, temperature, moisture and leakage) in accident conditions under **AF-UKEPR-CSA-06,** and provision of available measures to limit the containment pressure, in the event of a severe accident leading to the failure of the Core Melt Stabilisation System (CMSS), to prevent uncontrolled radiological releases from the primary containment under **AF-UKEPR-CSA-25**. ONR will therefore look for satisfactory resolution of these Assessment findings during the site-specific phase of activities.

93 The possibility of re-criticality post accident conditions is examined in (Ref. 20) and it is argued that the design includes features that are likely to prevent such an occurrence. This has been the subject of GDA Step 4 Fault Studies containment and severe accident assessment report (Ref. 7) which has resulted in an Assessment Finding AF **UKEPR-CSA-22** requiring the licensee to provide a comprehensive examination of re-criticality for all reasonably foreseeable conditions during the transient progression and within the CMSS, and determine whether any further reasonably practical measures can be taken to prevent this. We would therefore look to satisfactory resolution of this aspect of the safety case during the site specific design development stage.

94 There are also a number of design change proposals to improve the resilience of the spent fuel pool in accident conditions discussed in the next section. In addition, in response to **GI-UKEPR-FS-03**, EDF and AREVA have identified the following modifications to the spent fuel pool that we judge to have improved the resilience of the SFP design to severe events:

- The removal of personnel access doors within the SFP and fuel route to minimise the risk of coolant loss due their failure. (CMF 73 and CMF 74).
- Upgrading of the spent fuel pool cooling trains from Class 2 to Class 1 (CMF 38).
- Upgrading of the SFP make up water safety feature to Class 1 (CMF 71) see Annex 3.

95 Overall, the Regulators are content that reasonably practicable measures have been adopted to improve the resilience of the plant to extreme conditions that may lead to severe accident conditions. These plant enhancements summarised in section 4.2.2 and listed in Table 2 of this report cover the proposal to improve the containment leak tightness qualification, improvements to the power supply and measures to maintain the pressurisation of the containment within design limits by providing additional water to be used via the containment heat removal system and improved resilience of the spent fuel pool in severe accident conditions.

96 On this basis the Regulators are satisfied that EDF and AREVA have provided sufficient information for this GDA Issue action, **GI-UKEPR-CC-03 A1**, to be closed.

4.2.2 Responses to recommendations in ONR Chief Inspector's report

97 The GDA Issue action **GI-UKEPR-CC-03 A2** required EDF and AREVA to provide a report to respond to the recommendations in the ONR Chief Inspector's report (Ref. 25) and to capture the lessons learnt in the UK EPR™ safety case. For the latter EDF and AREVA provided a new PCSR subchapter.

98 The Regulators review of these deliverables is provided in sections 4.2.2.1 and 4.2.2.2 of this report.

4.2.2.1 Fukushima Summary Report

99 EDF and AREVA's summary report (Ref. 21) provides:

- Responses to the 25 recommendations from the ONR Chief Inspector's report (Ref. 25) that are applicable to the UK EPR™. These are presented in Table 3 of this report.
- A description of GDA design changes (CMFs) related to this GDA Issue which are listed in Table 2 and described in Annex 3 of this report. These design changes originate from the following:
  - EDF and AREVA post Fukushima reviews
  - Related GDA Issues and
  - Additional potential enhancements identified from other EPR™ projects.

100 The Regulators have reviewed the EDF and AREVA responses to the Chief Inspector's recommendations and judge that these are satisfactory. Reference is included in the table of recommendations (Table 3) to the relevant section of this close-out report associated with these and our comments on them.

101 The plant enhancements identified in the summary report have been agreed for inclusion in GDA and are listed in Table 2 and summarised in Annex 3 of this report and these are described below.

102 From the robustness analysis, EDF and AREVA have identified a number of generic and site-specific design changes. The generic design changes are:

- Provision of a mobile pump to transfer fuel from the EDGs to the UDGs;
- Addition of a motor-driven pump for re-supply of the spent fuel pool from the raw water storage tank;
- Addition of a motor-driven pump for re-supply of the EFWS tanks from the raw water storage tank;
- Provision of a mobile pump to provide make-up to the containment building from the raw water storage tank;
- Increasing the severe accident batteries capacity from 12 hours to 24 hours and implementation of a fast connection between the severe accident battery chargers and a mobile diesel generator set;
- Provision of devices and equipment used to provide a high-power supply from day three following a severe accident;
- Implementation of a seismically qualified facility for passively or automatically opening an outlet from the fuel pit to the nuclear auxiliary building chimney stack to improve overpressure protection for the fuel building;
- Implementation of a facility to prevent generation of an explosive hydrogen atmosphere in the fuel building;
- Back-up of essential data relating to conditions in the spent fuel pool following loss of cooling;
- Activation command added to severe accident C&I cabinets;
- Study into achieving safe position for fuel assemblies during accident conditions;
- Sealing the penetrations in the structures between the EDGs and the UDGs;
- Addition of a sound powered telephone network to the site communication system;

103 The modifications above have been grouped into five change proposals by EDF and AREVA, CMFs 47-51, and these (see Table 2 and Annex 3 for more details) were agreed by the regulators to be included in the GDA reference design (Ref. 9). Table 2 and Annex 3 also includes change proposals arising from other GDA issues, in particular **GI-UKEPR-FS-03** and **GI-UKEPR-FS-05**.

104 Although, the Regulators consider that these change proposals can make a contribution to improving robustness of the design to extreme events, further evidence is required to demonstrate the robustness of the proposal, outlined in CMF 49 (see Table 2 and Annex 3) associated with the transfer of fuel from the EDGs to the UDGs to extend UDG running time, particularly with respect to the potential to introduce a common mode failure into UDGs given that the EDGs have already failed to operate for some reason.

105 Additionally, CMF 50 (see Table 2 and Annex 3) associated with the proposed SFP venting will require further review as it is understood that the proposed outlet will not be filtered. This matter will be addressed in more detail in the **GI-UKEPR-FS-03** close-out report which specifically covers the spent fuel pool.

106 This leads to an ONR Assessment Finding for future licensees to review design change proposal CMF 49 (see Table 2 and Annex 3) to consider the feasibility of enlarging the capacity of the UDG fuel storage tank.

> ***AF-UKEPR-CC-15:*** *A future licensee shall use relevant arrangements under the licence to review the agreed GDA design change described in CMF 49 to consider the feasibility of enlarging the capacity of the UDG fuel storage to avoid the introduction of a potential common cause failure.*
>
> ***Required timescale:*** *Prior to fuel load*

107 The site-specific modifications are:

- To ensure the seismic resistance of piping, valves and pumps involved with the raw water storage system;
- A means to limit the ingress of water to the pumping station slab;
- Limitation of ingress of water to the outfall slab (reinforced leak tightness of the access doors to rooms housing the fire fighting system);
- Seismic resistance of the sealing elements of structures that house equipment used to mitigate severe accident scenarios;
- Leak tightness of security access doors to nuclear island buildings housing safety functions will be checked and improvements implemented as necessary; and
- Analysis of the performance of equipment needed in extreme accident scenarios including containment instrumentation.

108 These modifications are also welcomed as making a contribution to improving robustness of the UK EPR™ design to extreme events.

109 Reviewing the modifications being proposed, it is noticeable that the generic modifications tend to be associated with extending the mission times of existing safety systems or improving the infrastructural support for severe accidents counter measures. In particular, the proposed modifications do not improve the cliff-edge effect identified with the total loss of AC power fault sequence.

110 However, in addition to generic and site specific proposals identified above, the report (Ref. 21) notes that a future potential UK EPR™ operator, NNBGenco, has as a new

holder of a Nuclear License, carried out its own post-Fukushima reviews and identified six potential additional resilience enhancements or studies for the UK. These are:

- A diverse means of providing emergency feedwater to the steam generators (without the use of the existing electrical distribution system);
- Installed diesel-driven fire pump capability;
- Investigate options for further systems or equipment to control containment over-pressure;
- Cross-connection between individual trains of safety systems (electrical and fluid);
- Adaptation of Severe Accident Management Guidelines to incorporate Fukushima lessons learnt;
- Further measures on the management of hydrogen accumulation in the fuel building;

111 The Regulators note that the option to provide further systems or equipment to control containment over-pressure is already covered by an existing ONR Assessment Finding **AF-UKEPR-CSA-25** in the GDA Step 4 Containment and Severe Accident report (Ref. 7). We also note that the option to consider cross-connection between individual trains of safety systems (electrical and fluid) needs to be considered very carefully since it is important to ensure that this will not cut across plant segregation requirements for diverse systems.

112 These proposals represent potentially important design changes which the Regulators consider need to be evaluated for possible inclusion within any site specific UK EPR™ design For this reason, the following ONR Assessment Finding has been raised requiring the future licensee to review the feasibility of providing these enhancements.

> ***AF-UKEPR-CC-16:*** *A future UK EPR*™ Licensee shall review the potential plant enhancements identified in report PTS DC 9 and develop and implement these as appropriate within a UK EPR™ design
>
> ***Required timescale:*** *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

113 The regulators note that no explicit consideration is given in PTS DC 9 to the possibility of using steam turbines to provide a diverse means (from AC supply) of introducing Steam Generator (SG) feedwater. Although arguments were provided by EDF and AREVA in Step 4 (pre-Fukushima event) in their response to TQ-EPR-390 justifying why this option had been rejected in favour of electrically powered feedwater pumps in the UK EPR™ design in the light of the Fukushima event the following ONR Assessment Finding has been raised requiring the future licensee to reconsider this option.

> ***AF-UKEPR-CC-17:*** *A future UK EPR*™ Licensee shall consider the provision of steam turbines as a diverse means of introducing SG feedwater.
>
> ***Required timescale:*** *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

114 In addition to the need to provide a diverse means of SG feedwater, there is also a need to demonstrate how the long-term control of reactivity will be ensured following the total loss of AC power. For this reason, the following Assessment Finding has been raised requiring the future licensee to provide such a demonstration.

AF-UKEPR-CC-18: *A future UK EPR™* Licensee shall demonstrate how the long-term control of reactivity will be ensured following the total loss of AC power.

Required timescale: *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

4.2.2.2 New PCSR subchapter – Analysis of Beyond Design Basis Extreme Events

115 The Regulators reviewed the final deliverable for this GDA Issue, the new PCSR subchapter 16.6 (Ref. 22): Analysis of Extreme Beyond Design Basis Events carried out in Response to Fukushima, UKEPR-0002-168, Issue 0, November 2012.

116 The sub-chapter is structured in five sections, with Sections 1- 3 providing a summary of the EDF and AREVA UK EPR™ Fukushima review reports, Section 4 describing design enhancements and Section 5 summarising overall conclusions on EPR™ robustness for Fukushima type event.

117 The summaries in Sections 1-3 of PCSR sub-chapter 16.6 align with the conclusions provided in the review reports identified above and the assessment of these is considered in section 4.2.1 of this report:

- Section 1 Summary of additional safety evaluation of the UK EPR™ against Beyond Design Basis Earthquake (Ref.17) and flooding events (Ref. 18).
- Section 2 Robustness of Power Sources/Long term Cooling (Ref. 19).
- Section 3 Severe accident management (Ref. 20).

118 Section 4 of the PCSR sub-chapter summarises the design changes identified in the severe accident management report (Ref. 20) and is considered in section 4.2.1.4 of this report.

119 The regulators judge that the new PCSR sub-chapter 16.6 provides a sufficient high level summary and reference to supporting documentation for the analysis of beyond design basis extreme events for the generic UK EPR™.

120 The Regulators are satisfied with the responses provided by EDF and AREVA to **GI-UKEPR-CC-03 A2** and this action is now closed. Overall the Regulators are satisfied that GDA Issue **GI-UKEPR-CC-03** can be closed.

4.3 Comparison with Standards, Guidance and Relevant Good Practice

121 Throughout GDA ONR met with other international nuclear regulators who are reviewing the EPR™ design through the Multi National Design Evaluation Programme (MDEP) of OECD. The group meetings have focused on sharing our assessment methodologies and findings and the group has an objective of achieving common position statements on key EPR™ topic areas.

122 Following Fukushima, ONR has shared with MDEP regulator colleagues the findings of our assessment and has worked with MDEP to develop a common Fukushima position statement for the EPR™. Although the Fukushima statement has not been finalised its conclusions are expected to be consistent with those we have drawn from the GDA assessment.

5 ASSESSMENT CONCLUSIONS

123 The Regulators concluded that :

- EDF and AREVA have provided sufficient design reviews and supporting analysis to demonstrate the robustness of the UK EPR™ design. These reviews include normal operation and shutdown during extreme events such as earthquake and flooding (recognising that for flooding the reactor platform height is the critical determining parameter and this is a site specific matter).
- EDF and AREVA have provided appropriate evidence to demonstrate the ability of the plant to maintain a safe state following extreme events which result in loss of electrical power and or cooling.
- The proposed resilience enhancements will improve the robustness of the UK EPR™ against extreme events.
- The development of EPR™ severe accident management arrangements are intended to mitigate the consequences of severe accidents.
- EDF and AREVA responses to the Chief Inspector's recommendations are considered to be suitable and sufficient.

124 From our assessment of other GDA Issues, in particular **GI-UKEPR-FS-03** relating to the spent fuel pool (SFP) and **GI-UKEPR-FS-05** for reactor support systems, the Regulators have identified plant and system enhancements which will provide further improvements to the robustness of the UK EPR™ design against severe accidents.

125 In addition, the Regulators note that NNB GenCo, in their role as the licensee of Hinkley Point C and the company planning to build the first UK EPR™ at Hinkley Point C, have proposed their own list of site specific considerations and potential design improvements in response to the Chief Inspector's report. These complement those now incorporated in the generic design.

126 Furthermore, from discussions with international regulators in the Multinational Design Evaluation Programme (MDEP) additional options are being considered in other EPR™ projects which have the potential to further improve the robustness of a UK EPR™. As these options are at early stage of development we will request future UK EPR™ licensees to consider their suitability for implementation into a UK site specific design.

127 The Regulators judge that these design changes offer improved resilience in the safety and robustness of the UK EPR™.

5.1 Overall Conclusions

128 On the basis of the assessment of the information provided by EDF and AREVA, the Regulators are satisfied that the lessons learnt from Fukushima and the requirements of GDA Issue **GI-UKEPR-CC-03** have been addressed, and that the GDA Issue is now closed.

5.2 Review of the Update to the PCSR

5.2.1 New PCSR sub-chapter 16.6

129 New PCSR sub chapter created to address this GDA Issue and this has been considered in section 4.2.2 of this report

6 ASSESSMENT FINDINGS

130 ONR concludes that the following Assessment Findings that are identified in this report and listed in Annex 1 should be addressed during the forward programme of this reactor as normal regulatory business. The Environment Agency has not raised any AFs as a result of resolution of this GDA Issue, but notes that any future operator will need to take account of design changes raised in response to the Fukushima GDA Issue and accepted in GDA as part of the reference design (see joint assessment findings **AF-UKEPR-CC-09** and **AF-UKEPR-CC-11** raised for GDA Issue **GI-UKEPR-CC-02** Ref: 40).

6.1 Additional Assessment Findings

AF-UKEPR-CC-12: *The licensee shall provide a review of emergency plans and building walkdowns that are to be carried out for the civil structures classified as C1 "other structures" as part of the robustness review in light of Fukushima. This review shall demonstrate that the structural performance specified for each structure following an extreme event, provides sufficient beyond design basis margin such that its post event condition does not adversely affect the emergency plans.*

Required Timescale: *Before non-active commissioning.*

AF-UKEPR-CC-13: *A future licensee shall analyse the detailed site specific UK EPR™ design to demonstrate its robustness against beyond design basis seismic events for all plant operating states to a level consistent with the Seismic Margin Assessment provided in GDA.*

Required timescale: *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

AF-UKEPR-CC-14: *A future licensee shall provide evidence to substantiate the grace times claimed in report PEPS-F DC 133 for a UK EPR™ following prolonged loss of power and / or cooling events for all operating states.*

Required timescale: *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

AF-UKEPR-CC-15: *A future licensee shall use relevant arrangements under the licence to review the agreed GDA design change described in CMF 49 to consider the feasibility of enlarging the capacity of the UDG fuel storage to avoid the introduction of a potential common cause failure.*

Required timescale: *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

AF-UKEPR-CC-16: *A future UK EPR™ Licensee shall review potential plant enhancements identified in report PTS DC 9 and develop and implement these as appropriate within a UK EPR™ design.*

Required timescale: *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

AF-UKEPR-CC-17: *A future UK EPR™* Licensee shall consider the provision of steam turbines as a diverse means of introducing SG feedwater.

Required timescale: *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

AF-UKEPR-CC-18: *A future UK EPR™ Licensee shall demonstrate how the long-term control of reactivity will be ensured following the total loss of AC power.*

Required timescale: *Mechanical. Electrical and C&I Safety Systems – Before delivery to Site*

6.1.1 Impacted Step 4 Assessment Findings

131 No Assessment Findings raised in Step 4 are affected by the Resolution of this GDA Issue.

7 REFERENCES

1 *ONR HOW2. Permissioning - Purpose and Scope of Permissioning.* PI/FWD, Issue 3. HSE. August 2011.

2 *Safety Assessment Principles for Nuclear Facilities.* 2006 Edition Revision 1. HSE. January 2008. www.hse.gov.uk/nuclear/SAP/SAP2006.pdf.

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39 *Japanese earthquake and Tsunami: Implications for the UK nuclear industry: Interim Report. HM Chief Inspector of Nuclear Installations. May 2011.*

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Table 1

Relevant Safety Assessment Principles (ONR) and Radioactive Substances Regulation Environmental Principles (EA) Considered for Close-out of *GI-UKEPR-CC-03* Revision 3

SAP No.	SAP Title	Description
REP:MLDP5	Learning from Experience	Organisations should learn from their own and others' experience so as to continually improve their ability to protect the environment.
REP:EPRDP1	Facility Design	The design of a facility, in terms of layout, construction, communications and infrastructure, should be such that response arrangements can be enacted in the event of an emergency.

…

Table 2

List of Design Enhancements

CMF Ref.	Related CI's Recommendation's	Related GDA Issue	Title (see Annex 3 for detailed description)
CMF037		GI-UKEPR-CC01	Classification – UDG Diesel generators
CMF038		GI-UKEPR-CC01	Classification – Spent fuel pool cooling system
CMF041		GI-UKEPR-FS05	Fault studies – Loss of essential support systems – DVL/DEL [SBVSE/SCWS] modifications
CMF042		GI-UKEPR-FS05	FS05 – Design improvements linked with RRI [CCWS] cooling functions
CMF047	22	GI-UKEPR-CC03	FKA – Task 4 – Severe Accident Addition of a sound powered telephone network to the DTV system
CMF048	13,22,FR-2	GI-UKEPR-CC03	FKA – Task 2 – Flooding
CMF049	8,18,22,FR-3	GI-UKEPR-CC03	FKA – Task 3 &4 – Loss of Electrical power/ Heat Sink & Severe Accident - Robustness and management of Power Sources
CMF050	8,14,19,20,21	GI-UKEPR-CC03	FKA – Task 3 &4 – Loss of Electrical power/ Heat Sink & Severe Accident - Design Against Seismic Events
CMF051	22	GI-UKEPR-CC03	FKA – Task 3 &4 – Loss of Electrical power/ Heat Sink & Severe Accident - Fuel strategies
CMF056	10	GI-UKEPR-IH03	Internal Flooding – Design Modification of Fire-Fighting System (JPI) in the Annulus
CMF057	10	GI-UKEPR-IH03	Internal Flooding – Design Modification of Essential Service Water System (SEC) in the Safety Auxiliary Building
CMF058	10	GI-UKEPR-IH03	Internal Flooding – Design Modification of Distribution of Demineralised Reactor Water System (SED) in the Annulus
CMF070	14	GI-UKEPR-FS03	Addition of removable standpipes and covers on the penetrations at the bottom of the HR-HK pool compartments
CMF071	14,19	GI-UKEPR-FS03	Upgrade of the SFP emergency make up to Class 1

Table 2

List of Design Enhancements

CMF Ref.	Related CI's Recommendation's	Related GDA Issue	Title (see Annex 3 for detailed description)
CMF072	14	GI-UKEPR-FS03	Fuel transfer tube modification
CMF073	14	GI-UKEPR-FS03	Removal of personnel access doors located on the fuel path
CMF074	14	GI-UKEPR-FS03	Change of cask procedure
CMF076		GI-UKEPR-FS05	Connection of reactor coolant pump (RCP) thermal barrier cooling system
CMF078	18	GI-UKEPR-FS05	Solutions to manage common cause failures (CCF) on LJ and LV electrical switchboards
CMF079		GI-UKEPR-FS05	Modifications to manage the Total Loss Of Cooling Chain (TLOCC)

Table 3

Summary of Responses to Chief Inspector's Final Report Recommendations

No	Recommendation	Regulators comments and reference, where applicable, to relevant section of this assessment report
IR-4	Openness and Transparency	Communication with public and stakeholders. The GDA process has been open and transparent and includes publication of key GDA documentation by EDF and AREVA and the regulators have published all their technical assessment reports, including the report for this GDA Issue which concerns the reviews undertaken by EDF and AREVA for the GDA EPR™ following the Fukushima event.
IR-8	Off-site Infrastructure Resilience	Self Sufficiency in extreme conditions. Resolution is by enhancing on site supplies of fuel, oil and water and is considered in sections 4.2.1.3 of this report. EDF and AREVA proposals to enhance self sufficiency (Ref. 19 & 21) are provided through design change proposals CMF 49 and 50 which are described in Table 2 and considered in sections 4.2.1.3 and 4.2.2.1 of this report.
IR-9	Comparison of Events	Comparison of Events at Fukushima 1 and 2 sites. Ref. 21 compares the seismic response and tsunami at both sites. The report concludes that the UK EPR™ needs to sustain long term cooling following extreme events and detail on how this is to be achieved is given under IR-10 below.
IR-10	Impact of Natural Hazards - Flooding	Flooding – confirm flooding design basis and margins beyond This is considered in section 4.2.1.2 of this report EDF and AREVA provided a robustness report (Ref. 19) for this topic and summarised the conclusions in (Ref. 21) which refers to a flood study and concludes design basis of 1 in 10,000 years with margins to avoid cliff edge effects, which is sufficient. Supported by DEFRA 2005 study of predicted tsunami heights around the UK coastline. The GDA agreed design changes arising from GDA Issue **GI-UKEPR-IH-03**, CMFs 56-58 described in Table 2 and considered in sections 4.2.2.1 of this report are considered to improve the UK EPR™ robustness.
IR-11	Multi–reactor Sites	Multiple reactors – multiple serious concurrent events from external hazards. Although GDA is for a single UK EPR™, in Ref. 21, EDF and AREVA refer to a HPC report and state that the

Table 3

Summary of Responses to Chief Inspector's Final Report Recommendations

No	Recommendation	Regulators comments and reference, where applicable, to relevant section of this assessment report
		only connections between two adjacent UK EPR™ units would be electrical and the forebays. No safety drawbacks have been identified. EDF and AREVA commit to this being looked at again at the site specific stage.
IR-12	Spent Fuel Strategies	Ref. 20 states 10 years storage is provided in the SFP and then on site in an interim spent fuel store (ISFS) for 100 years. ISFS is outside GDA scope. Robustness of the SFP is considered in sections 4.2.1.1, 4.2.1.3 and 4.2.1.4 of this report. Design change proposals CMF 70-74 described in Table 2 and considered in sections 4.2.1.3 related to GDA Issue **GI-UKEPR-FS-03** are considered by the regulators to enhance the robustness of the SFP.
IR-13	Site and Plant Layout	Robustness – layouts with respect to severe flooding and other extreme events. Main protection is through platform height which is a site specific issue. EDF and AREVA report (Ref. 18) on flooding robustness was reviewed in section 4.2.1.2 of this assessment report.
IR-14	Fuel Pond Design	Current design – Although there are no bottom penetrations in the SFP for the UK EPR™ there are wall penetrations close to the bottom (Ref. 20). Consideration of these penetrations and consequences of their failure on pool drainage are presented in section 4.2.1.3 of this report. Through GDA Issue **GI-UKEPR-FS-03** which concerns the SFP and was raised prior to the Fukushima event ONR has secured the following SFP design enhancements: o CMF 70 – covers to floor drains in flooded compartments o CMF 71 - upgrade make up system o CMF 72 - leak-tight Fuel Transfer Tube o CMF 73 - remove personnel doors to reactor cavity and fuel transfer compartments o CMF 74 – modify cask loading procedure Through CMF 50 EDF and AREVA have identified a further enhancement to the SFP robustness which has

Table 3

Summary of Responses to Chief Inspector's Final Report Recommendations

No	Recommendation	Regulators comments and reference, where applicable, to relevant section of this assessment report
		been agreed in GDA and this concerns the addition of a motor driven pump to supply the SFP and a passive facility for venting the SFP building in the event of hydrogen build up. Further details of these CMFs are provided in Table 2 of this report.
IR-15	Concrete-Seismic Resilience	Seismic resistance is considered in sections 4.2.1.1 and 4.2.2.1 of this report. The EDF and AREVA summary report (Ref. 21) states that "*current information from the post-accident investigations at Fukushima-1 indicate that the damage to the plant was due to the failure of power sources and the nuclear island cooling systems due to the entry of floodwater into NI buildings. There is no evidence currently that failure of concrete or other structures due to seismic or other dynamic forces, contributed to worsening of the accident consequences….no requirements for structural improvements of the UK EPR™ design were identified.*" No requirements for structural improvements of the UK EPR™ design were identified. EDF and AREVA conclude that the seismic resilience of the civil structures in GDA scope is sufficiently robust.
IR-16	Extreme External Hazards – consider plant layout and design	The EDF and AREVA summary report (Ref. 21) and PCSR sub-chapter 13.1 for External hazards (Ref. 12) conclude that the UK EPR™ design is adequately protected against extreme hazards.
IR-17	Off-site Electrical Supplies - robustness	Loss of off-site supplies is considered in section 4.1.2.3 of this report. Additional measures have been put in place to improve the robustness of the design against beyond design basis events involving loss of off-site supply for greater than 24 hours. A demonstration of the bounding nature of GDA assumptions including a site specific assessment of Loss of Offsite Power frequencies will be provided for each site. We judge that these responses are acceptable.
IR-18	On-Site Electrical Supplies	The provision of additional, diverse means of providing electrical supplies on site to reflect the loss of off-site supplies under severe conditions is proposed in the following CMFs:

Table 3

Summary of Responses to Chief Inspector's Final Report Recommendations

No	Recommendation	Regulators comments and reference, where applicable, to relevant section of this assessment report
		• CMF 49 M1 – Extension of ultimate diesel generator running time • CMF 49 M2 – Modification of severe accident batteries capacity • CMF 49 M3 – Activation command added to severe accident I&C cabinets • CMF 49 M4 Provide a high power supply from day 3 after a severe accident • CMF 78 Modifications to address common cause failure of electrical systems We judge that this commitment is sufficient for GDA.
IR-19	Cooling Supplies	This concerns the long term provision of long term coolant supplies to a NPP. Ref. 20 considers the resilience of on-site supplies of water. Change modifications proposed under GDA for the UK EPR™ are as follows. CMF 50 – extra pumps to make up supplies from raw water storage. CMF 71 – upgrade SFP emergency make up water system. These design changes are considered in section 4.2.2.1 of this report and described in table 2. We judge this response as sufficient for GDA.
IR-20	Pond water make up under severe accidents	Ref. 20 considers this is covered by IR-19 above and we concur that this sufficient for GDA.
IR-21	Ventilation and venting – where combustible gases could accumulate	For hydrogen build up, Ref. 19 identifies the following design change proposal to enhance UK EPR™ robustness. CMF 50 which is described in section 4.2.2.1 of this report and Table 2 relates to a study of potential hydrogen build-up in the SFP building and if necessary to design a system to prevent this build-up. One element of this change proposal CMF 50 is to provide a passive vent route for hydrogen build up via the NAB

Table 3

Summary of Responses to Chief Inspector's Final Report Recommendations

No	Recommendation	Regulators comments and reference, where applicable, to relevant section of this assessment report
		stack. This is discussed further in section 4.2.2.1 of this report. Although we have agreed to the inclusion of this design change in GDA a future licensee will have to ensure that the stack utilised to vent the SFP is seismically qualified to the appropriate level. Our judgement is EDF and AREVA have provided sufficient information to address this recommendation for GDA.
IR-22	On Site Communication – emergency control, instruments and communications	In response to this recommendation EDF and AREVA proposed the following design change modifications to enhance robustness of essential control and communication systems following an extreme event. o CMF 49 - increase severe accident batteries from 12h to 24h, plus improve power supplies o CMF 47 – sound powered telephone o CMF 51 - essential data backup o CMF 48 - sealing of penetrations in ED and UDGs buildings These design changes are discussed in sections 4.2.1.3 and 4.2.2.1 of this report and have been agreed for inclusion in GDA. These are judged adequate to meet the intent of IR-23.
IR-24	Workers	This recommendation concerns training, instruction, procedures for workers involved in site operations for extreme events. Although the principals covering the development of emergency operating procedures are included in the GDA PCSR sub chapter 18.2 it is an activity for a future UK EPR™ licensee to develop appropriate procedures and assessments of tasks required from these.
IR-25	Accident sequences	This recommendation concerns the development of strategies to manage long term loss of power/cooling, and the robustness of the UK EPR™ against these is provided in Ref. 19 and this is considered in section 4.2.1.3 of this report. EDF and AREVA claim that the UK EPR™ enhancements identified in Ref. 21 improve UK EPR™ robustness against loss of power/cooling. We have agreed the inclusion of these enhancements in GDA.

Table 3

Summary of Responses to Chief Inspector's Final Report Recommendations

No	Recommendation	Regulators comments and reference, where applicable, to relevant section of this assessment report
FR-2	SSCs - Protection against hazards	EDF and AREVA provided UK EPR™ robustness reports for BDB seismic and flooding events (Ref. 17 and 18) and these are considered in sections 4.2.1.1 and 4.2.1.2 of this report. We judge the current design for aircraft crash, seismic and external flooding provides adequate design margin. The EDF and AREVA reviews identified in design change CMF 48 for sealing of penetrations in diesel building to prevent ingress of flood water and we have agreed to the inclusion of this change in GDA.
FR-3	SSCs - Capability of operation	EDF and AREVA claim key SSCs are protected by UK EPR™ features in FR-2. Additionally EDF and AREVA proposed design change CMF 49 to increase severe accident batteries from 12h to 24h, plus improve power supplies for SSCs and we agreed the inclusion of this design change in GDA.
FR-4	Level 2 PSA	A level 2 PSA was provided in GDA for the UK EPR™ and this was assessed in Step 4 and found to be adequate. A future licensee will have to update the level 2 PSA for the site specific case.
FR-6	Source Terms	This recommendation concerns ability and techniques for measuring source terms which are used to assess consequences of radioactive releases. EDF and AREVA claim that the UK EPR™ is designed to minimise source term and plant monitoring facilities allow for real time monitoring of releases.
FR-9	Development of International Standards	EDF and AREVA will contribute to IAEA initiative to review and develop nuclear safety standards in light of Fukushima.
FR-11	Safety Culture	EDF and AREVA commit to continue to promote a high level of safety culture in all their activities.
FR-12	Progress report	Chief Inspector asked industry for a direct response to his Final Report and EDF and AREVA's response to **GI-UKER-CC-03** provides this response.

Annex 1

GDA Assessment Findings Arising from GDA Close-out for Cross Cutting GDA Issue GI-UKEPR-CC-03

Finding No.	Assessment Finding	MILESTONE (by which this item should be addressed)
AF-UKEPR-CC-12	The licensee shall provide the review of emergency plans and building walkdowns that are to be carried out for the civil structures classified as C1 "other structures" as part of the robustness review in light of Fukushima. This review shall justify that the structural performance specified for each structure following an extreme event, provides sufficient beyond design basis margin such that its post event condition does not adversely affect the emergency plans.	Before non-active commissioning
AF-UKEPR-CC-13	A future licensee shall analyse the detailed site specific UK EPR™ design to demonstrate its robustness against beyond design basis seismic events for all plant operating states to a level consistent with the Seismic Margin Assessment provided in GDA.	Mechanical. Electrical and C&I Safety Systems – Before delivery to Site
AF-UKEPR-CC-14	A future licensee shall provide evidence to substantiate the grace times claimed in the EDF and AREVA report PEPS-F DC 133 dated November 2012 for a UK EPR™ following prolonged loss of power and / or cooling events for all operating states.	Mechanical. Electrical and C&I Safety Systems – Before delivery to Site
AF-UKEPR-CC-15	A future licensee shall use relevant arrangements under the licence to review the agreed GDA design change described in CMF 49 to consider the feasibility of enlarging the capacity of the UDG fuel storage to avoid the introduction of a potential common cause failure.	Mechanical. Electrical and C&I Safety Systems – Before delivery to Site
AF-UKEPR-CC-16	A future UK EPR™ Licensee shall review potential plant enhancements identified in the EDF and AREVA report PTS DC 9, November 2012 and develop and implement these as appropriate within a UK EPR™ design.	Mechanical. Electrical and C&I Safety Systems – Before delivery to Site

Annex 1

GDA Assessment Findings Arising from GDA Close-out for Cross Cutting GDA Issue GI-UKEPR-CC-03

Finding No.	Assessment Finding	MILESTONE (by which this item should be addressed)
AF-UKEPR-CC-17	A future UK EPR™ Licensee shall consider the provision of steam turbines as a diverse means of introducing SG feedwater.	Mechanical. Electrical and C&I Safety Systems – Before delivery to Site
AF-UKEPR-CC-18	A future UK EPR™ Licensee shall demonstrate how the long-term control of reactivity will be ensured following the total loss of AC power.	Mechanical. Electrical and C&I Safety Systems – Before delivery to Site

Note: It is the responsibility of the Licensees / Operators to have adequate arrangements to address the Assessment Findings. Future Licensees / Operators can adopt alternative means to those indicated in the findings which give an equivalent level of safety.

For Assessment Findings relevant to the operational phase of the reactor, the Licensees / Operators must adequately address the findings during the operational phase. For other Assessment Findings, it is the regulators' expectation that the findings are adequately addressed no later than the milestones indicated above.

Note: these Assessment Findings are raised by ONR. The Environment Agency has not raised any Assessment Findings related to this GDA Issue.

Annex 2

GDA Issue, GI-UKEPR-CC-03 Revision 3 – Cross-Cutting – UK EPR™

EDF AND AREVA UK EPR GENERIC DESIGN ASSESSMENT

GDA ISSUE

CONSIDER AND ACTION PLANS TO ADDRESS THE LESSONS LEARNT FROM THE FUKUSHIMA EVENT

GI-UKEPR-CC-03 REVISION 3

Technical Area	**CROSS CUTTING**		
Related Technical Areas	**All**		
GDA Issue Reference	**GI-UKEPR-CC-03**	**GDA Issue Action Reference**	**GI-UKEPR-CC-03.A1**
GDA Issue	**EDF and AREVA are required to demonstrate how they will be taking account of the lessons learnt from the unprecedented events at Fukushima, including those lessons and recommendations that are identified in the HM Chief Inspector's interim and final reports.**		
GDA Issue Action	EDF and AREVA to address the lessons learnt from their internal review following the Fukushima event relevant to GDA for the UK EPR. Evidence we expect to see provided to address this action includes: 1) Internal review summary report 2) A plan for the necessary actions arising from the internal review report 3) Modification of the following, as appropriate: a. Design Reference and SSERs b. Submission Master List documentation (Levels 1-3), including amendments to submission level 2 design information such as SDMs in accordance with GDA Issue GI-UKEPR-CC.02 c. Resolution Plans in response to other relevant GDA Issues 4) Confirmation that any design changes resulting from these reviews for inclusion into GDA will be managed in accordance with the UK EPR GDA Project Procedure UKEPR-I-003. With agreement from the Regulators this action may be completed by alternative means.		

Annex 2

GDA Issue, GI-UKEPR-CC-03 Revision 3 – Cross-Cutting – UK EPR™

EDF AND AREVA UK EPR GENERIC DESIGN ASSESSMENT

GDA ISSUE

CONSIDER AND ACTION PLANS TO ADDRESS THE LESSONS LEARNT FROM THE FUKUSHIMA EVENT

GI-UKEPR-CC-03 REVISION 0

Technical Area	**CROSS CUTTING**		
Related Technical Areas	**All**		
GDA Issue Reference	**GI-UKEPR-CC-03**	**GDA Issue Action Reference**	**GI-UKEPR-CC-03.A2**
GDA Issue	**EDF and AREVA are required to demonstrate how they will be taking account of the lessons learnt from the unprecedented events at Fukushima, including those lessons and recommendations that are identified in the HM Chief Inspector's interim and final reports.**		
GDA Issue Action	EDF and AREVA to address the lessons learnt that are relevant to GDA for UK EPR from HM Chief Inspector Nuclear Installations' interim and final reports. Evidence we expect to see provided to address this action includes: 1) A Plan to address the relevant actions arising from HM Chief Inspector's interim and final reports. 2) Modification of the following, as appropriate: a. Design Reference and SSERs b. Submission Master List documentation (Levels 1-3), including amendments to submission level 2 design information such as SDMs in accordance with GDA Issue GI-UKEPR-CC.02 c. Resolution Plans in response to other relevant GDA Issues 3) Confirmation that any design changes resulting from these reviews for inclusion into GDA will be managed in accordance with the UK EPR GDA Project Procedure UKEPR-I-003. With agreement from the Regulator this action may be completed by alternative means.		

Annex 3

Summary of Design Changes Agreed in GDA

Design enhancements for the UK EPR™ following Fukushima reviews are identified by EDF and AREVA in their summary report (Ref. 21) provided in response to our GDA Issue **GI-UKEPR-CC03**.

The report identifies design changes arising from the FA3 and GDA reviews and potential areas for change being considered by future UK EPR™ operator NNBGenco.

Site specific aspects such as platform height and pumping station are outside the scope of GDA therefore enhancements associated with these design aspects are site specific and will be addressed as part of site specific design development activities.

These enhancements are summarised below.

FA3 Review Originated Changes (CMFs 47-51)

Enhancements identified from a review at FA3 have been collated by EDF and AREVA into five design changes (CMFs) which have now been agreed for inclusion in the UK EPR™ design reference and these are:

CMF 47: A sound-powered telephone system will be implemented that can be used in loss of all electrical power supplies situations, to provide a local telecommunication solution for every state of the unit power supplies. The modification will enable bi-directional communication to take place between field operators and the control room. Connection sockets will be installed throughout the plant at appropriate locations which will be indentified in the detailed design phase.

CMF 48: Sealing of penetrations in structures between main diesel generators and UDG diesel generators. Analysis of the Fukushima event has underlined the critical role of the severe accident batteries and the Ultimate Diesel Generators (UDG) in the prevention and mitigation of severe accidents in UK EPR™. This modification will involve sealing of all openings in the walls located between the main diesel generator rooms and the UDG and severe accident battery rooms, between the foundation raft and a height of 1.00 m above the platform level. The seals must be leak tight against a water head between the foundation raft and 1.00 m above the platform level.

CMF 49 comprises four design enhancements described below:

CMF 49 (1): Modification of severe accident batteries capacity (from 12 hours to 24 hours) and implementation of fast connection between the severe accident battery chargers and a mobile diesel generator set. The severe accident batteries will be modified in order to increase the autonomy of the associated equipment. The storage capacity of the two sets of severe accident batteries will be increased from 12 hours to 24 hours. A fast connection between a mobile diesel generator set and the severe accident battery chargers will be provided to enable the batteries to be recharged as necessary.

CMF 49 (2): Activation command added to Severe Accident I&C cabinets. If the electrical power supply is lost in the Severe Accident I&C system, it is not currently possible to reactivate the outputs from the severe accident processing in some accident scenarios. The proposed modification is to add a dedicated pushbutton in the Severe Accident I&C cabinets containing the Severe Accident processing units, in order to ensure that the outputs from the Severe Accident I&C

Annex 3

system severe accident units can always be reactivated. In addition to the pushbutton, a lamp (also located inside the cabinets) will be added to indicate that the outputs are activated.

CMF 49 (3): Implementation of devices and equipment to provide a high electrical power supply from day three after a severe accident. Devices and equipment will be implemented to allow the connection of a high-power mobile diesel generator that could restore power to the PTR [FPCS] and EVU [CHRS] systems in one electrical division in fault situations lasting longer than three days. The high-power mobile diesel generator would supply essential safety functions for controlling a severe accident, including particularly ensuring the habitability of the control room.

CMF 49 (4): Extension of Ultimate Diesel Generator (UDG) running time. The modification is to extend the running time of Ultimate Diesel Generator (UDG) diesels to more than 24 hours, by providing mobile pumping equipment to extract fuel oil from the main diesel generator tanks and supply it to the ultimate diesel generators.

It is assumed that the room containing the UDG fuel oil tank is not flooded, but that the room containing the Emergency Diesel Generator (EDG) fuel oil tank may be flooded. The modification involves providing a leaktight pump to deliver a fuel flow which meets the requirement of the UDG motor. A control panel for the pump will be provided in the UDG "I&C cabinet" room, supplied with power from the UDGs. Connecting pipework will be provided between the day tank feed systems for the Emergency diesel generators and the day tanks for UDG diesel generators.

The connecting pipework will contain a removable section which will be manually connected by the operators in an emergency situation. The pipework will be disconnected in normal operation of the plant to eliminate any risk of Common Cause Failure of EDGs and UDGs due to fuel supply faults. The sharing of fuel between the EDGs and UDGs in emergency conditions is preferred to the enlargement of fuel tanks, as enlargement of the tanks would cause problems of plant congestion and layout which are avoided by the fuel sharing option. In addition, storage of an increased volume of fuel increases the potential consequences of fire, which is a safety disbenefit. As no safety disadvantages are introduced in the fuel sharing option, this option is therefore considered ALARP.

CMF 50 comprises five design enhancements described below:

CMF 50(1): Addition of motor-driven pump for re-supply of Spent Fuel Pool from raw water storage reserve. An ultimate water make-up supply for the Spent Fuel Pool will be installed designed to be operational after an earthquake. External connectors will be protected against external hazards, in particular natural events such as flooding, and will therefore be accessible to allow connection to a mobile make-up device drawing water from onsite raw water storage sources. A fixed connection to the safeguard systems for water make-up of the Spent Fuel Pool will be installed, with the adequate isolation points and the appropriate level of classification.

CMF 50(2): Implementation of passive or automatic qualified facility for opening the outlet from the Fuel Pool Hall to the NAB chimney. In the case of a total loss of all emergency power source supply and/or total loss of heat sink, steaming of the Spent Fuel Pool could result in a pressure increase in the Spent Fuel Pool area which might impact the integrity of the civil engineering structures. To prevent such pressure increases, steam is vented via from the Spent Fuel Pool area to the stack in the Nuclear Auxiliary Building. The outlet duct between the Spent Fuel Pool area and the stack contains an isolation damper that is opened manually from the control room or local to plant. The modification consists of installing a rupture disk in the duct or replacing the current damper by a damper that fails open on total loss of the electrical power supplies. In this way, in the

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event of total loss of power sources, the outlet from the Spent Fuel Pool area will be opened passively, reducing the risk due to over-pressurisation of the Fuel Building.

CMF 50(3): Prevention of generation of an explosive hydrogen atmosphere in the Fuel Pool Hall in the event of long term loss of electrical supplies. During radiolysis of water in the spent fuel pool, hydrogen is released in the fuel pool area. In the event of total loss of electrical supplies, the ventilation system in the fuel pool area would not function. Hydrogen could therefore accumulate in the Spent Fuel Pool area which in the event of ignition may threaten the integrity of the building.

To reduce risks related to hydrogen combustion, the hydrogen concentration in the Spent Fuel Pool area should be reduced and the local formation of regions with higher hydrogen concentrations should be prevented. The modification consists of a study to quantify the hydrogen risk from radiolysis in the absence of ventilation and implementation of mitigation measures if required.

CMF 50(4): Addition of motor-driven pump for re-supply of ASG tanks from raw water storage reserves. The purpose is to increase the running time of the secondary system cooling by setting up a fresh water re-supply of the ASG [EFWS] tanks utilising the raw water storage reserves. The current design already has provisions for a final supply line used to replenish tank ASGi110BA via isolation valve ASGi102VD using a mobile device. The proposed change therefore consists of providing details in the ASG [EFWS] system design manual of how this makeup could be performed by using the raw water storage reserves.

CMF 50(5): Provision of mobile pump for make-up to HR from raw water storage reserves via EVU system. In long term loss of electrical supplies it is not possible to utilise the EVU [CHRS] system to limit pressure build-up in the reactor building. This modification is to enable makeup to be supplied to the reactor building via the EVU [CHRS] system at 48 hours, at which point the pressure in the containment will be below the failure pressure. Make-up water will be provided by a mobile pump located on the platform at +0 m, which would be supplied with water from the raw water storage reserves.

CMF 51 comprises two design enhancements described below:

CMF 51(1): Backup of essential data relating to changing conditions in the Spent Fuel Pool in the event of loss of cooling. The post-Fukushima safety analysis identified the potential loss of essential data required by the operators for ascertaining the physical condition of the Spent Fuel Pool in the event of loss of cooling. The following data were identified as essential:

- Water temperature;
- Water level;
- Dose rate in the fuel pool area.

In extreme events involving total loss of offsite power and of all installed emergency power sources the instrumentation would cease to be powered when the 2-hour batteries are spent. The proposed modification consists of including the pool water temperature, pool water level and pool area dose rate measurements in the dedicated severe accident I&C system and the severe accident control desk. Emergency power for the identified instrumentation will be derived from the severe accident batteries.

CMF 51(2): Study into achieving safe position for fuel assemblies during accident conditions. The post-Fukushima additional safety studies carried out for the FA3 EPR™ indicated the need to secure the ‘move fuel assembly to safe position’ operation during fuel handling, in the scenario:

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Earthquake + Loss of power supplies + Loss of spent fuel pool cooling system. Following loss of the spent Fuel Pool Cooling System (PTR [FPCPS/FPPS]), the rapid increase in water temperature requires that any fuel assembly being handled must be moved to a safe position within a guaranteed timeframe. The modification consists of providing means to ensure that the Refuelling Machine and Spent Fuel Mast Bridge can be operated manually after an earthquake and to identify self-contained, portable devices that could be used to operate the Fuel Handling System to speed up the movement of a fuel assembly to a safe position.

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GDA Design Changes Identified in the Resolution of Other GDA Issues

Classification of key SSCs associated with GDA issue GI-UKEPR-CC01

CMF 37: Upgrade of classification of Ultimate Diesel Generator Safety Features. This design change involves upgrading the safety class of the Ultimate Diesel Generator safety features from Class 3 to Class 2. It will reduce the risk of severe accidents by increasing the reliability that may be claimed from the UDGs in events involving failure of offsite and on-site AC power supplies.

CMF 38: Upgrade of classification of main fuel pool cooling train Safety Features (part of PTR system). This design change involves upgrading the safety class of the main fuel pool cooling train safety features from Class 2 to Class 1. It will benefit nuclear safety by increasing the reliability that may be claimed from the fuel pool cooling system in within and beyond design basis accidents.

Spent fuel pool and reactor pit associated with GDA issue GI-UKEPR-FS03

CMF 70: Modification to install cover plates and standpipes over floor drains in flooded compartments. The modification consists of installing cover plates and standpipes for temporary isolation of pool purification lines in the floors of flooded compartments, avoiding risk of draining compartments due to gross failure of the purification lines.

CMF 71: Upgrade of classification of fuel pool make up safety feature sub system (part of JAC/JPI systems). This modification involves upgrading the fuel pool emergency make up safety feature from Class 2 to Class 1. It will benefit nuclear safety by increasing the reliability that may be claimed from the fuel pool make-up safety function in beyond design basis initiating events leading to pool drainage.

CMF 72: Modification to provide leak tight containment of the Fuel Transfer Tube. The modification consists of making the rooms enclosing the Fuel Transfer Tube watertight to a pressure corresponding to the maximum water level in the pools, significantly reducing risk of pool draining to seismically induced failure of the Fuel Transfer Tube.

CMF 73: Modification to remove personnel access doors to the reactor cavity and Fuel Transfer Comportments. The modification consists of removing the three personnel access doors located at the floor level of the Reactor Cavity and the Fuel Transfer Compartments, removing risks of pool draining due to a hypothetical seismically induced failure of the personnel access doors.

CMF 74: Modification to cask loading procedure. The cask loading procedures will be modified so that the door between the Spent Fuel Pool and the Cask Loading Pit will be closed before the penetration upper cover is opened to allow a fuel assembly to be lowered into the fuel cask. This will prevent drain of the Spent Fuel Pool following seismically induced failure of the bellows connecting the fuel cask to the bottom penetration in the Cask Loading Pit. The modification will allow operators to continue working in the Spent Fuel Pool Hall to recover an uncovered fuel assembly in the Cask Loading Pit in case of failure of the bellows.

Support systems associated with GDA issue GI-UKEPR-FS05

CMF 78: Modifications to address Common Cause Failure (CCFs) of Electrical Systems. The modifications consist of reallocating electrical consumers to different voltage levels so that the

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plant can be brought to a controlled state in beyond design basis events involving CCF of 690V (LJ) or 400V (LV) electrical systems. The modification involves reallocating the back-up ventilation system of the electrical buildings from the 690V (LJ) to 400V supplies, and reallocating various valve actuators from the 400V (LV) to the 220V (LA) supplies. The modifications will benefit nuclear safety by reducing the risk of beyond design basis events involving multiple failures within redundant electrical systems operating at the same voltage level.

Internal flooding associated with GDA issue GI-UKEPR-IH03

CMF 56: This relates to changing seven manual valves to motorised ones that can be operated automatically in the event of sump level detection and operation of the JAC pumps. In addition, a further four motorised valves have been added to take into account single failure. The additional electrical and C&I has also been identified for both the change from manual to motorised and for the new motorised valves. Finally, an isolation signal for the sprinkler system within the Annulus has been introduced to ensure that it is automatically isolated 20 minutes after detection to ensure flood levels do not result in loss of F1 redundancy. The categorisation and classification of the proposed modifications will be undertaken during the site design development phase.

CMF 57: This relates to additional flood level detection and preventative isolation of the Essential Service Water System (ESWS) within the Safeguard Auxiliary Buildings. This modification is similar to that undertaken at OL3 as sensors are to be placed 10cm above the floor at the -9.0m level in each of the SABs to ensure that should failure of the ESWS occur then there is sufficient time for operators to realign the ESWS onto a different division and to isolate the affected ESWS in advance of water reaching the 0.0m level.

CMF 58: This relates again to the Annulus, but this time is associated with the Demineralised Water System (SED) and the proposed change from a manual valve to one that is motorised. Again, the electrical and C&I aspects are considered, as is the need to consider the categorisation and classification during NSL phase. There are also changes to the operational procedures associated with the need to perform a preventative isolation in the event of detection of flooding via the level detection identified within CMF 56.

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NNBGenco – UK EPR™ Areas for consideration for design changes

In the UK the potential EPR™ operator NNBGenco is considering the following areas to improve the robustness of a site specific UK EPR™. Development of these will be progressed during the site design development phase and are covered by AF-UKEPR-CC-16:

- Diverse means for providing emergency feedwater to the steam generators;
- Installed diesel-driven fire pump capability;
- Investigate options for further systems or equipment to control containment overpressure; including containment ventilation;
- Cross connection between individual trains of safety systems (electrical and fluid);
- Adaptation of Severe Accident Management Guidelines to incorporate Fukushima lessons learnt; and
- Further studies on the management of hydrogen accumulation in the fuel building.