AP1000® PLANT UNITED KINGDOM GENERIC DESIGN ASSESSMENT (GDA) CLOSEOUT EFFORTS

B.N. Friedman, R.W. Iddings, P.E. Wick, J.J. Eisenhauer
New Plants and Major Projects, Westinghouse Electric Company LLC
1000 Westinghouse Drive, Cranberry Township, PA, 16066 – United States of America

ABSTRACT

In preparation of the potential construction of three AP1000® plants at the Moorside site in West Cumbria, United Kingdom, Westinghouse has engaged with the United Kingdom Office for Nuclear Regulation (ONR) and Environment Agency (EA) to resolve the remaining 51 Generic Design Assessment (GDA) issues identified as part of the interim approval in 2011. The 51 outstanding GDA issues have covered numerous technical areas including structural integrity, controls and instrumentation, fault studies, radiation protection, reactor chemistry, internal hazards, and cross-cutting issues such as the review and application of the post-Fukushima lessons learned. Efforts to progress the closure of these outstanding open items in collaboration with the ONR, have led to some AP1000 plant design changes for the United Kingdom (UK) design to adapt the standard AP1000 plant design to the UK expectations and requirements. This paper summarises a few of the major design changes made to the AP1000 plant design for application in the UK.

1. Introduction

In 2007, the United Kingdom (UK) updated its energy policy provided in Reference [1]. This policy details the need for the UK to construct new nuclear power stations to support current plants set to retire in the 2020s and successfully meet the energy policy goals of reducing greenhouse gas emissions and ensuring a secure energy supply.

In response to the energy policy review, the Health and Safety Executive (HSE) (which at the time included the Office for Nuclear Regulation (ONR)) and the Environment Agency (EA) developed the Generic Design Assessment (GDA) process. Per Reference [2], "GDA enables the safety, security and environmental implications of new nuclear power station designs to be assessed before applications are made for the permissions required to build that design at a particular site."

Westinghouse was among the first vendors to participate in the GDA process. From 2007 to 2011, Westinghouse, the ONR, and EA completed GDA Steps 1 through 4 for the AP1000 plant. In December 2011, the ONR and EA issued an interim Design Acceptance Confirmation (iDAC) and interim Statement of Design Acceptability (iSODA) per Reference [3] and Reference [4]. The iDAC and iSODA were issued with the confirmation of the satisfaction of the proposed resolution plans submitted by Westinghouse for the remaining 51 GDA issues. The 51 remaining GDA issues require resolution before the ONR and EA will consider the issuance of a Design Acceptance Confirmation (DAC) and Statement of Design Acceptability (SoDA) for the AP1000 plant design.

2. Westinghouse Post-Step 4 Closure Efforts for the AP1000 Plant GDA

In June 2014, NuGeneration Limited, a joint venture between Toshiba Corporation and ENGIE, announced plans for the construction of three AP1000 plants at the Moorside site in West Cumbria, United Kingdom. In preparation of the potential construction of the three AP1000 plants, Westinghouse has engaged with the United Kingdom ONR and EA to resolve the remaining 51 GDA issues identified as part of the interim approval in 2011. The GDA process for the AP1000 plant was reinitiated in January 2015, and is currently on-track for full resolution of the 51 issues and issuance of a DAC and SoDA in March 2017.

The 51 outstanding GDA issues have covered numerous technical areas including structural integrity, controls and instrumentation, fault studies, radiation protection, reactor chemistry, internal hazards, and cross-cutting issues such as post-Fukushima lessons learned. Efforts to progress the closure of these outstanding issues in collaboration with the ONR and EA, have led to some AP1000 plant design changes for the UK design to adapt the standard plant design to UK expectations and requirements.

The safety robustness is demonstrated through the safety, security and environment report (SSER). For the AP1000 plant GDA, the SSER comprises of Reference [5], [6], and [7], and has been updated to incorporate the design enhancements. Some of the design changes incorporated in the SSER identified during the GDA closeout and described within this paper are:

- The AP1000 plant design includes a remote shutdown room (RSR) to safely shutdown the plant following an event which would render the main control room (MCR) unavailable. Due to UK regulations and expectations, the RSR is enhanced to implement UK Safety Class 1 displays and controls. This provides assurance that in the event of a MCR evacuation, an additional location containing UK Safety Class 1 equipment is available to safely shutdown and maintain the plant in a safe shutdown state.

- The configuration of the spent fuel pool (SFP) has been changed to not rely on soluble boron or fuel burn-up for criticality control from UK regulations and expectations. With the change in the configuration of the SFP, subcriticality is ensured via geometric spacing and fixed poisons integrated into the spent fuel racks, while still maintaining soluble boron and fuel burnup in the design. This increases the overall safety margin within the UK AP1000 plant SFP.

- The lessons learned from the Fukushima accident were reviewed and implemented into the AP1000 plant design as part of the industry-wide effort. For the closeout of GDA, an additional review into the assessment performed led to post-Fukushimia related changes to the plant. These enhancements included protecting the UK Safety Class 1 batteries against a beyond design basis (BDB) flood, providing additional means of connecting offsite equipment, and extending the capability of the UK Safety Class 1 batteries to provide better lighting and communication within the plant after a station blackout (SBO) event. This allows the UK AP1000 plant to further ensure a safe plant shutdown in response to a Fukushima-like event.

- As a result of multiple fault studies GDA issues, changes to the control and instrumentation diverse actuation system (DAS) provide an enhancement for the frequent fault diversity protections of the plant. This improves the UK AP000 plant diverse system response to faults such as a boron dilution event during shutdown and a small break loss of coolant accident (SBLOCA).

3. Implementation of UK Safety Class 1 Displays and Controls for the Remote Shutdown Room (RSR)

3.1 Background of GI-AP1000-CI-10

The ONR Step 4 assessment of the AP1000 plant control and instrumentation (C&I) technical area (Reference [8]) consisted of a review of the design of the remote shutdown room (RSR), which is used as the alternative location to the main control room (MCR). The UK regulatory expectations for the classification of the remote shutdown room is UK Safety Class 1 to implement the required safety functions per the ONR Safety Assessment Principles (SAPs) in Reference [9], since the room provides Category A functions. The standard AP1000 plant design provides Class 2 display and controls. As a result, the ONR created GDA issue GI-AP1000-CI-10, which required Westinghouse to evaluate providing UK Safety Class 1 displays in the RSR, or to provide justification on the standard plant design is acceptable per the SAPs and regulatory expectations.

3.2 Westinghouse Assessment of the AP1000 Plant RSR

As a result of the ONR assessment of the AP1000 plant RSR, and the creation of GDA issue GI-AP1000-CI-10, Westinghouse has performed an as low as reasonably practicable (ALARP) assessment of the AP1000 plant RSR for the classification of the displays and controls performing Category A functions. The ALARP assessment determined that the UK AP1000 plant RSR shall have a design change performed to include UK Safety Class 1 displays and controls.

3.2.1 Design Change for the UK AP1000 Plant RSR

To meet the UK regulatory expectations, a new safety panel will replace the existing remote shutdown panel in the RSR. This will add a UK Safety Class 1 remote shutdown panel containing four safety displays and dedicated UK Safety Class 1 system level controls. These displays will be similar to the UK Safety Class 1 primary dedicated safety panel in the MCR. Fig. 1 below shows the safety displays within the MCR that will be added to the UK AP1000 plant RSR:

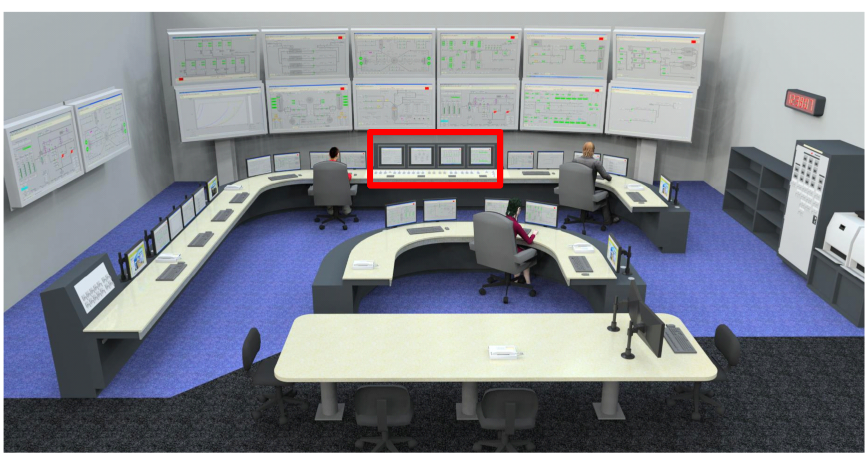

Fig. 1 AP1000 Plant MCR Rendition Showing Class 1 Safety Displays Added to RSR

This added panel within the RSR will provide UK Safety Class 1 displays, soft blocks and resets for the protection and safety monitoring system (PMS), and provide dedicated UK Safety Class 1 switch controls. The addition of the panel will provide the benefit of having an alternative location for controlling the plant in the infrequent event that a MCR evacuation is required. Also, the addition of the panel in the RSR will provide a human factors benefit, since the panels between the MCR and the RSR will now be more similar. Overall, the addition of a Class 1 panel within the RSR provides a more robust safety case for C&I within the UK AP1000 design.

4. Change to the Spent Fuel Pool (SFP) Configuration

4.1 Background of GI-AP1000-RP-01

During the Step 4 assessment of the AP1000 plant radiological protection (RP) features (Reference [10]), the ONR noted that the standard AP1000 plant includes a two region SFP design where Region 1 is designed to maintain criticality control through geometric means alone and Region 2 is designed to maximise SFP capacity by utilising conservative credit for the presence of soluble boron and fuel burnup for criticality control along with the geometric spacing and fixed poisons. The layout of the standard AP1000 plant two region SFP is provided in Fig. 2. The ONR SAPs (Reference [9]) state that criticality safety of spent fuel should be dependent on passive safety measures that do not rely on control systems, active safety systems, or administrative controls. Furthermore, passive criticality safety is considered to be relevant good practice (RGP) for new build nuclear facilities in the UK. As a result, the ONR created GDA Issue GI-AP1000-RP-01, which states that Westinghouse has not adequately demonstrated why it is not reasonably practicable to design the UK AP1000 plant SFP such that criticality control is achieved through geometric control and fixed poisons alone.

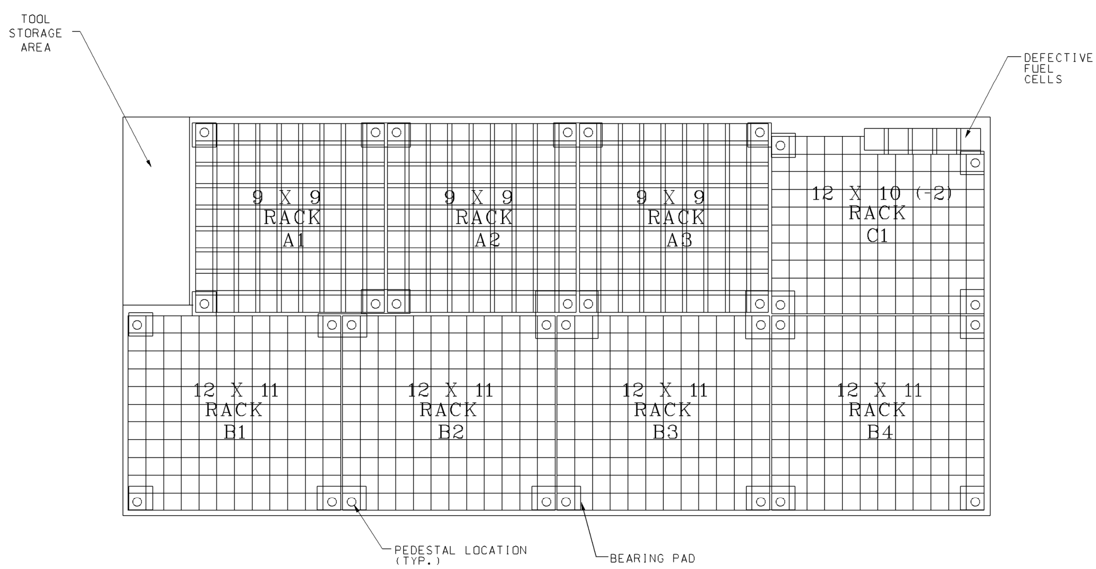

Fig. 2 Standard AP1000 Plant Two Region SFP Layout

4.2 Westinghouse Assessment of the AP1000 Plant SFP

In response to GDA issue GI-AP1000-RP-01, Westinghouse undertook an assessment of the UK AP1000 plant SFP design considering a number of different configurations to determine which configuration reduces risks ALARP and is consistent with RGP for new build nuclear facilities in the UK. The assessment focused on providing a balance of risk reduction for criticality safety as well as adequate SFP capacity to ensure proper fuel performance during dry storage. The ALARP assessment concluded that by utilising only Region 1 style spent fuel racks, which do not require any soluble boron to maintain sub criticality, the SFP design for UK AP1000 plants would be consistent with RGP for new build facilities in the UK and reduces risks ALARP.

4.2.1 Design Change for the UK AP1000 Plant SFP

In order to meet UK regulatory expectations for a new build nuclear facility the UK AP1000 plant SFP will consist of a one region design containing spent fuel racks of the style currently utilised in Region 1 of the standard AP1000 plant SFP. This design provides a SFP which has no requirement for administrative controls on soluble boron and fuel burnup to maintain subcriticality. The design of the racks ensures appropriate geometric spacing to provide criticality safety in the design using passive methods, while still providing adequate cooling time for proper fuel performance during dry storage.

5. Design Change for GDA Issue GI-AP1000-CC-03: Post-Fukushima Related Enhancements

5.1 Background of GI-AP1000-CC-03

On March 11, 2011, a high magnitude earthquake struck the east coast of Japan. The earthquake, together with the resulting series of large tsunami waves affected several nuclear power facilities, either directly by damaging onsite equipment, or indirectly by impairing the supporting infrastructure, such as the electrical power grid. From this event, the Fukushima Dai-ichi Nuclear Power Station faced a particularly challenging situation including a loss of all alternating current (AC) electrical power for four of their six units, and a loss of ultimate heat sink (UHS) makeup. Consequently, severe damage to the fuel and a series of hydrogen explosions occurred.

Considering the accident at the Fukushima Dai-ichi nuclear power station in Japan, several initiatives were launched worldwide to assess the lessons learned. These include but are not limited to the European stress tests, the ONR Interim and Final Report, and the IAEA Expert Mission Report (References [11], [12], and [13]).

At the time of the accident, the ONR Step 4 assessment had already been completed and was in the final closeout period. As a result, the ONR raised GDA Issue GI-AP1000-CC-03, requiring Westinghouse to demonstrate how they will be taking account of the lessons learned from the unprecedented events at Fukushima.

5.2 Westinghouse Assessment of Fukushima Lessons Learnt

Reviewing lessons learned is a hallmark of the nuclear industry and inherent to the Westinghouse safety culture. As part of GDA, Westinghouse evaluated the lessons learned coming from the various international reviews. The assessment of lessons learned and an assessment of the UK AP1000 plant for Post-Fukushima considerations was submitted in response to GDA issue GI-AP1000-CC-03. The assessment concluded that the AP1000 plant is robust and that no additional changes are required to maintain key safety functions. However, design enhancements for the UK AP1000 plant design have been identified as being ALARP for the plant to better withstand the events that occurred at Fukushima.

5.3 Design Changes implemented as part of GI-AP1000-CC-03

For the UK AP1000 plant generic design, Westinghouse identified four design enhancements that provide additional margin against beyond design basis (BDB) extreme external events. These design enhancements resulted from Westinghouse's assessment to evaluate the AP1000 plant response to the Fukushima event, Westinghouse-ONR interactions and a review of the international lessons learned. These enhancements are not required to meet the design safety goals. However, they provide enhanced coping capabilities and support plant operations following such extreme events.

- BDB flood protection for UK Class 1 batteries – This design enhancement protects the UK Safety Class 1 electrical supply system batteries from a BDB flooding event by adding water proof doors, sealing penetrations, adding HVAC snorkels, and adding a latched and gasket seal over ancillary diesel generator exhaust.

- Enhanced power supply for the communication system – This design enhancement extends the power supply for the communication systems during a station black out (SBO). This is accomplished by changing the lighting in the MCR from fluorescent lighting to light emitting diodes (LEDs), which reduces the power demand on the UK Safety Class 1 batteries. The reduction in power demand from the lighting allows the communication system to be powered from the UK Safety Class 1 batteries during a SBO.

- Improved post-72 hour cable connections – This design enhancement improves the connection of the offsite diesel generators by significantly reducing the length of temporary cable as well as the cable diameter required to connect the offsite diesel generators to its loads. This is accomplished by installing two flanged isolatable penetrations in the Auxiliary Building wall and two flanged isolatable penetrations in the floor just inside the wall (4 total) to enhance the means of connecting the offsite diesel generators and post-72 hour loads during a SBO. The overall reduction in cable length and diameter will improve the handling and the installation time of the temporary cables.

- Addition of a passive containment cooling ancillary water storage tank (PCCAWST) connection – This enhancement improves the accessibility to the PCCAWST during a BDB extreme external event to use the PCCAWST as a source of makeup water for the SFP and containment cooling. The proposed design enhancement is comprised of adding a new connection line to the PCCAWST, a new isolation valve and a flanged connection. The new connection allows for the PCCAWST to be connected to the UK Safety Class 1 passive containment cooling system (PCS) line that is used for post-72 containment cooling and SFP makeup.

6. Changes to the Control and Instrumentation Diverse Actuation System (DAS)

6.1 Background of Related GDA Fault Studies Issues

The Step 4 assessment of the AP1000 plant fault studies (FS) technical area (Reference [14]), included the diverse plant response to frequent fault mitigation. The ONR concluded that there is further assessment required for some of the frequent faults with a subsequent failure of the UK Safety Class 1 C&I system. Two of the faults requiring further assessment are the capability for the plant to mitigate frequent reactivity faults, and a small break loss of coolant accident (SBLOCA). These faults contributed the creation of GDA issues GI-AP1000-FS-04 and GI-AP1000-FS-05. The expected resolution of these issues is for Westinghouse to provide an assessment of the means for mitigating these types of faults, and if enhancements for the means of mitigations can be provided.

6.2 Westinghouse Assessment of the Faults Related to GI-AP1000-FS-04 and GI-AP1000-FS-05

From the ONR assessment of reactivity and SBLOCA frequent faults, and the creation of the related GDA issues, Westinghouse has performed an as low as reasonably practicable

(ALARP) assessment of the UK AP1000 plant for the mitigation features. Westinghouse demonstrated that all frequent reactivity faults were adequately addressed for UK regulatory expectations by the standard AP1000 design except for a boron dilution during shutdown fault. The ALARP assessment determined that the UK AP1000 plant diverse actuation system (DAS) design change performed to provide more margin and enhancement to the mitigation of these faults.

6.2.1 Design Change to the UK AP1000 Plant Diverse Actuation System (DAS)

To better mitigate the frequent faults for boron dilution during shutdown and SBLOCA faults, design changes to the UK Safety Class 2 DAS were made to provide extra protection to the mitigation abilities and to add margin enhancement to the plant design. From the ALARP assessment performed on the mitigation of these faults, signals were added to the DAS.

For boron dilution during shutdown, an additional DAS function to actuate the core makeup tanks (CMTs) and isolate any potential dilution sources from the chemical and volume control system (CVS) was added. This DAS function was added when considering that during shutdown events, a common cause failure of the UK Safety Class 1 C&I plant monitoring ans safety system could cause the operator to be relied upon for fault mitigation during shutdown conditions. The addition of the DAS function provides better protection for boron dilution events.

For SBLOCA fault mitigation, bounding fault cases were assessed from an ALARP perspective, and it was determined that an ALARP enhancement can be made to the SBLOCA fault mitigation with a signal addition to DAS to actuate the passive residual heat removal (PRHR) heat exchanger on a low pressuriser level. This additional signal provides increased margins and avoids fuel temperature excursions during a SBLOCA event with a subsequent failure of the UK Safety Class 1 C&I system.

Overall, the additional UK Safety Class 2 DAS signals provide enhancements for the mitigation of frequent faults, to the already robust AP1000 plant response to design basis faults, and ensures the design is ALARP and in line with UK regulatory principles.

7. Conclusion

The closeout process for the GDA of the UK AP1000 plant design with the ONR and EA has led to design enhancements to the safety case to align, and to align with the UK regulatory expectations. The assessments in numerous technical areas, and the changes made to ensure the robustness of the UK AP1000 plant design, and the SSER. The SSER, comprising of References [5], [6], and [7] will be updated to incorporate the design changes determined from the GDA process, in support of the issuance of a DAC and SoDA in March 2017. This will support one of the steps required for the construction of three AP1000 plant units to assist in the overall energy goals and needs for the United Kingdom.

8. References

[1] United Kingdom Department of Trade and Industry Document CM 7124, "*Meeting the Energy Challenge – A White Paper on Energy*," May 2007.

[2] Health and Safety Executive Document "*A Guide to the Regulatory Process*," Revision 0, September 2013.

[3] Office for Nuclear Regulation Document ONR-GDA-iDAC-11-002, Issue 1, "*Generic Design Assessment of Westinghouse AP1000® Nuclear Reactor – Interim Design Acceptance Confirmation For The Westinghouse AP1000 Nuclear Reactor*," December 2011.

[4] Environment Agency Document GEHO1211BTOI-E-E, "*Generic Design Assessment – AP1000® Nuclear Power Plant Design by Westinghouse Electric Company LLC – Decision Document*," December 2011.

[5] Westinghouse Report UKP-GW-GL-793, Revision 0, "*AP1000 Pre-Construction Safety Report*," March 2011.

[6] Westinghouse Report UKP-GW-GL-790, Revision 4, "*UK AP1000 Environment Report*," March 2011.

[7] Westinghouse Report UKP-GW-GLR-019, Revision C, "*AP1000 Security Report*."

[8] Office for Nuclear Regulation Document ONR-GDA-AR-11-006, Revision 0, "*Generic Design Assessment – New Reactor Build – Step 4 Control and Instrumentation Assessment of the Westinghouse AP1000® Reactor*," November 2011.

[9] Office for Nuclear Regulation Document "*Safety Assessment Principles for Nuclear Facilities*," Revision 0, 2014 Edition.

[10] Office for Nuclear Regulation Document ONR-GDA-AR-11-009, Revision 0, "Generic Design Assessment – New Civil Reactor Build – Step 4 Radiological Protection Assessment of the Westinghouse AP1000® Reactor," November 2011.

[11] European Nuclear Safety Regulators Group (ENSREG), "EU 'Stress Tests' Specifications, Annex 1," May 25, 2011.

[12] Office for Nuclear Regulation (ONR), "Japanese Earthquake and Tsunami: Implications for the UK Nuclear Industry, Final Report," September 2011.

[13] International Atomic Energy Agency (IAEA), "International Fact Finding Expert Mission of the Fukushima Dai-ichi NPP Accident Following the Great East Japan Earthquake and Tsunami," May 24 - June 2, 2011.

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