

**Westinghouse UK**  
**AP1000® GENERIC DESIGN ASSESSMENT**  
**Resolution Plan for GI-AP1000-FS-03**  
**Diversity for Frequent Faults**

MAIN ASSESSMENT AREA	RELATED ASSESSMENT AREA(S)	RESOLUTION PLAN REVISION	GDA ISSUE REVISION
Fault Studies	PSA C&I	3	0

<b>GDA ISSUE:</b>	Demonstration of functional diversity for frequent faults.
<b>ACTION: GI-AP1000-FS-03.A1</b>	<p>Implement the revised moderator temperature coefficients assumed in the ATWS analysis reported in UKP-GW-GLR-016 within the <b>AP1000®</b> safety analysis checklist document WCAP-9272-P-A. These should be referenced within the PCSR as the limits and conditions as the relevant core parameters identified by the fault studies for ultimate incorporation within the technical specifications for the <b>AP1000</b> plant (see also GDA issue <b>GI-AP1000-FS-02</b>).</p> <p>Alternatively, Westinghouse may wish to provide a revised analysis with parameters consistent with those presented in Chapter 4 of the DCD.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>
<b>ACTION: GI-AP1000-FS-03.A2</b>	<ul style="list-style-type: none"> <li>• Demonstrate protection for the excessive increase in secondary steam flow fault at full power for both the case with successful reactor trip and the case with failure of the reactor to trip due to either mechanical failure of the rods to insert or failure of the reactor protection system.</li> </ul> <p>Or</p> <ul style="list-style-type: none"> <li>• Propose design changes to provide protection against the excessive increase in secondary steam flow faults.</li> </ul> <p>In the European DCD and the UKP-GW-GLR-016, the analysis of excessive increase in secondary steam flow with failure to trip is limited to consideration of the condition II event, which limits flow increases to less than 10% at full power. Westinghouse has not presented any analysis for a more challenging excessive increase in secondary steam flow fault at full power.</p> <p>Westinghouse will need to demonstrate adequate diverse protection for such faults for both the case with successful reactor trip and for the case with failure of the reactor trip due to either mechanical failure of the rods to insert or failure of the reactor protection system. In</p>

	<p>particular, in the case of PMS failure, Westinghouse will have to demonstrate that there are adequate trip parameters on the diverse actuation system (DAS). Any design modifications identified as necessary will need to complete the six-stage modification process for inclusion in the PCSR.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>
<p><b>ACTION: GI-AP1000-FS-03.A3</b></p>	<ul style="list-style-type: none"> <li>• Demonstrate the provision of diverse protection against rod misplacement faults including one or more dropped rods.</li> </ul> <p>Or</p> <ul style="list-style-type: none"> <li>• Propose design changes to protect against the consequences of such a fault.</li> </ul> <p>The analysis of these faults presented by Westinghouse assumes that although the protection and monitoring system (PMS) is unavailable the flux monitoring system remains available to the plant control system (PLS) and provides protection against these faults. This fails to demonstrate any diversity within the flux protection system. For this reason, Westinghouse are requested to provide explicit transient analysis using design basis analysis techniques for these faults to demonstrate that the diverse actuation system (DAS) is functionally capable of protecting against this fault. A modification to include the provision of a negative rate flux trip signal on the diverse actuation system (DAS) is to be considered as a possible ALARP measure.</p> <p>The design of any proposed modification will need to complete the six-stage modification process for inclusion with the PCSR. Note this action is also closely related to GDA issue GI-<b>AP1000</b>-FS-04.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>
<p><b>ACTION: GI-AP1000-FS-03.A4</b></p>	<p>Implement the proposed modification to provide a high hot leg temperature trip on the Diverse Actuation System to protect against the RCCA bank withdrawal fault at full power with failure of the PMS.</p> <p>Westinghouse has identified that a modification is required to provide a reactor trip signal on high hot leg temperature on the Diverse Actuation System. This is to protect against a RCCA bank withdrawal fault at full power with failure of the Protection and Monitoring System (PMS). The design for the proposed modification will need to complete the sixstage modification process for inclusion within the PCSR.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>

<p><b>ACTION: GI-AP1000-FS-03.A5</b></p>	<p>Demonstrate protection against a complete loss of forced flow fault as a result of perturbations in grid frequency for both the case with successful reactor trip and the case with failure of the reactor trip due either mechanical failure of the rods to insert or failure of the reactor protection system.</p> <p>In the Westinghouse submissions assessed, the analysis of complete loss of flow fault with failure to trip is limited to consideration of initial conditions associated with nominal full power conditions. Westinghouse has not presented any analysis considering the effect of grid perturbations on the initial reactor conditions. It is likely that in such circumstances, the reactor control system will attempt to increase power to compensate for any grid frequency reduction. This will perturb both the initial reactor power and the initial power distribution of the core including the axial offset.</p> <p>Westinghouse will need to demonstrate adequate diverse protection for such faults for both the case with successful reactor trip and for the case with failure of the reactor trip due to either mechanical failure of the rods to insert or failure of the reactor protection system. In particular, in the case of PMS failure, Westinghouse will have to demonstrate that there are adequate trip parameters on the diverse actuation system (DAS). Any design modifications identified as necessary will need to complete the six-stage modification process for inclusion in the PCSR.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>
<p><b>ACTION: GI-AP1000-FS-03.A6</b></p>	<ul style="list-style-type: none"> <li>• Demonstrate the provision of diverse protection against loss of CVS following a normal reactor trip and xenon decay including demonstration of diversity to operator action.</li> </ul> <p>Or</p> <ul style="list-style-type: none"> <li>• Provide a consequence analysis demonstrating the acceptability of the design against ONR's accident frequency targets.</li> </ul> <p>After every reactor trip from full power there is an eventual decay in the level of xenon poisoning within the reactor core. The resultant swing in reactivity needs to be compensated for through increasing the boron concentration in the reactor to ensure an adequate shutdown margin. While the core make-up tanks (CMTs) and the incontainment refuelling water storage tank (IRWST) systems provide two diverse sources of borated water should the operator fail to ensure adequate shutdown margin using the Chemical and Volume control system (CVS), both these systems are also dependent</p>

	<p>upon operator action for actuation. Although timescales are long (many hours), this implies a combined human reliability of <math>1 \times 10^{-7}</math> per demand to meet the design basis target. For this reason, Westinghouse is to provide an ALARP study into the feasibility of automatically actuating the CVS to inject borated water after every reactor trip and for the CMTs to be automatically actuated following failure of the CVS. Alternatively, Westinghouse may wish to provide a consequence analysis of what would happen should the operator fail to ensure adequate shutdown margin.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>
<p><b>ACTION: GI-AP1000-FS-03.A7</b></p>	<p>Analyse the homogenous boron dilution fault occurring in shutdown conditions with failure of the protection and monitoring system to demonstrate that there is diverse protection against the fault.</p> <p>This fault would be very difficult to detect should there be a failure of the flux instrumentation or the protection and monitoring system (PMS). For this reason, Westinghouse is to provide explicit transient analysis using design basis analysis techniques for this fault to demonstrate that the diverse actuation system (DAS) is functionally capable of maintaining adequate margin to departure from nucleate boiling. A modification to include the provision of a boron dilution block signal and a CMT actuation signal on the DAS (actuated by low doubling time and/or high source-range flux level) is to be considered as a possible ALARP measure. The design of any proposed modification will need to complete the six-stage modification process for inclusion within the PCSR.</p> <p>Westinghouse also needs to identify as a limit and condition for the reactor core design technical specifications the limiting moderator reactivity coefficients assumed in the analysis.</p> <p>With agreement from the Regulator this action may be completed by alternative means.</p>
<p><b>RELEVANT REFERENCE DOCUMENTATION RELATED TO GDA ISSUE</b></p>	
<p><b>Technical Queries</b></p>	
<p><b>Regulatory Observations</b></p>	<p>RO-AP1000-47 RO-AP1000-51 RO-AP1000-91</p>
<p><b>Other Documentation</b></p>	

**Scope of work:**

During the Step 4 GDA review, the ONR requested Westinghouse to provide an integrated assessment of the **AP1000** design to demonstrate its capability to address postulated common mode failures for frequent faults.

In UKP-GW-GL-067, Rev 0, Westinghouse has provided an evaluation of the **AP1000** frequent faults demonstrating that diverse protection is provided for frequent faults (i.e. those faults with an expected frequency of occurrence greater than 1E-3/yr). The document includes a list of which faults are frequent. It also includes an evaluation of mitigation of these faults showing what equipment provides the diverse protection. Finally the limiting faults are identified and reference is made to plant analysis that provides evidence that the mitigating features are capable of providing the necessary protection.

Additionally, to address the ONR request that the possibility of a cliff edge in the frequency should be considered, this document also addresses events that have a frequency lower than 1E-3/year but for which there may be a question as to whether the frequency is sufficiently lower than 1E-3/year to ignore the event as a frequent fault.

As a result of the studies summarised in UKP-GW-GL-067, a revised Fault Schedule (documented in UKP-GW-GLR-003, Revision 1) was developed to document an integrated fault schedule for the **AP1000** plant, including how the diversity requirement is met for all frequent faults. This fault schedule is also included in Revision 0 of the **AP1000** PCSR (UKP-GW-GL-793). Additional discussion on diversity for each applicable fault group is provided also in Chapter 9 of the PCSR, as appropriate.

In GI-**AP1000**-FS-03, the ONR has identified some specific areas where additional information and supporting evidence is requested for Westinghouse to ensure that the claims and arguments provided in UKP-GW-GL-067 are fully supported. In some cases Westinghouse believes it will be sufficient to provide extra information following discussions with ONR. In other cases, the actions in this issue require some additional ALARP investigation and assessment to confirm all aspects of the design against the diversity requirement.

**Description of work:**

Westinghouse will provide the following:

FS-03.A1	Westinghouse will implement the ATWS Moderator Temperature Coefficients in the Safety Analysis Checklist. A methodology that provides an acceptably conservative result will be developed and an initial demonstration will be provided.
FS-03.A2	For the successful reactor trip case a parametric sensitivity study will be presented to secondary break size (or equivalent flow rate) for full power operation to demonstrate that the protection prevents fuel from entering DNB for an appropriate range of break sizes (or flow rates).  Westinghouse will perform probability assessment to determine largest

	Frequent Fault steam increase, and will demonstrate diversity for this steam increase fault. Westinghouse will provide additional safety arguments to address the capability of the Plant to mitigate an excessive increase in secondary steam flow fault at full power both with reactor trip and with failure of the reactor to trip. Potential modifications and their ALARP assessment will be evaluated under GDA issue GI- <b>AP1000</b> -FS-04 Flux Protection as therein described.
FS-03.A3	This action is to consider rod misalignment faults including dropped rods is already covered in the Resolution Plan for GI- <b>AP1000</b> -FS-04 Flux Protection.
FS-03.A4	The DAS High Hot Leg logic was clarified and finalised in Design Change APP-GW-GEE-1481, which is included in the Design Reference Point for the <b>AP1000</b> GDA. The DCP has been approved and is now part of the safety case. As part of the resolution plan the DCP will be reviewed with the regulator to confirm that the DAS That reactor trip is correctly implemented in the design.
FS-03.A5	Westinghouse will justify that the effects of grid perturbations on the reactor control system and the RCP power supplies have been taken into account in specifying the initial conditions for the analysis including the effect upon power level, axial offset, radial peaking factors, and transient flow rate. UK specific grid perturbations will be considered within the context of this frequent fault evaluation. The aim will be to demonstrate that the fuel meets relaxed success criteria appropriate for the frequent fault diversity sequence. r. Should this not be the case then potential modifications will be subject to an ALARP assessment. If any plant change is deemed necessary the change will follow the Westinghouse QMS Level II Procedure WEC 3.4.1. "Change control for the <b>AP1000</b> program".
FS-03.A6	Westinghouse will provide to ONR for review VAT_DCP_000001 " <b>AP1000</b> Long Term Boration" which was prepared to address this action to demonstrate the provision of diverse protection against loss of the CVS. Any comments ONR provides will be incorporated along with the information in VAT_DCP_000001 in a new document providing the CVS ALARP arguments.
FS-03.A7	This action is to consider boron dilution faults from shutdown conditions with failure of the flux protection and is now covered in the Resolution Plan for GI- <b>AP1000</b> -FS-04 Flux Protection.

<b>Schedule/ programme milestones:</b>
Please see the following page for the schedule

#	Activity Name	2015												2016												2017	
		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1	<b>UK Generic Design Assessment (GDA) Resolution Plans (51) **LIVE**</b>																										
2	<b>FAULT STUDIES</b>																										
3	FS.02.03.04																										
4	FS.02-A1 Transient Analysis																										
5	Findings Justification Letter and Associated Analysis - Submit to ONR																										
6	Findings Justification Letter and Associated Analysis - ONR Review of Submittal																										
7	FS.02-A2 Core Design Limits																										
8	UK Safety Analysis Checklist Future Limits-Submit to ONR																										
9	UK Safety Analysis Checklist Future Limits-ONR Review of Submittal																										
10	FS.03-A1 Revised Moderator Temperature Coefficients																										
11	UK ATWS/Fault Studies Report - ONR Submit to ONR																										
12	UK ATWS Report - ONR Review of Submittal																										
13	FS.03-A2 and FS-04-A1 Protection for the Excessive Increase in Secondary Steam Flow Fault																										
14	Largest Excessive Load Increase Analysis - Submit to ONR																										
15	Largest Excessive Load Increase Analysis - ONR Review of Submittal																										
16	FS.03-A3 and FS-04-A1 Diverse Protection Against Rod Misplacement																										
17	Rod Drop Evaluation for Diverse Flux Protection - Submit to ONR																										
18	Rod Drop Evaluation for Diverse Flux Protection - ONR Review of Submittal																										
19	FS.03-A4 High Hot Leg Temperature Trip																										
20	DCP APP-GW-GEE-1481 - Submit to ONR																										
21	DCP APP-GW-GEE-1481 - ONR Review of Submittal																										
22	FS.03-A5 Complete Loss of Forced Flow Fault																										
23	UK Specific Grid Perturbations Calc - Submit to ONR																										
24	UK Specific Grid Perturbations Calc - ONR Review of Submittal																										
25	FS.03-A6 Diverse Protection Against Loss of CVS																										
26	VAT_DCP_000001 - Submit to ONR																										
27	VAT_DCP_000001 - ONR Review of Submittal																										
28	FS03 CVS ALARP Document - Submit to ONR																										
29	CVS ALARP Document - ONR Review of Submittal																										
30	FS.03-A7 & FS-04-A1 Boron Dilution Fault																										
31	FS.03 Boron Dilution at Shutdown Analysis - Submit to ONR																										
32	Boron Dilution at Shutdown Analysis - ONR Review of Submittal																										
33	FS.04-A2 Diverse Protection is Provided Against Frequent Faults																										
34	UKP-GW-GL-083 - Submit to ONR																										
35	FS02/03/04 Final PCSR Markups- Submit to ONR																										
36	UKP-GW-GL-083 - ONR Review of Submittal																										
37	FS02/03/04 Final PCSR Markups- ONR Review of Submittal																										
38	FS.02.03.04 Develop PCSR Mark-Ups																										
39	PCSR mark-ups - Submit to ONR																										
40	PCSR mark-ups - ONR Review of Submittal																										

**Methodology:**

No new methodology will be used. Required analyses will be performed with approved US licensing codes and methods, consistent with the latest analysis being supplied as part of GI-**AP1000**-FS-02.

**Justification of adequacy:**

As described above, some of the actions have already been addressed as part of other Resolution Plans. For all remaining actions, the approach outlined above should sufficiently satisfy ONR's concerns by providing the necessary analyses to demonstrate the functional diversity for frequent faults.

**Impact assessment:**

The following documents are anticipated to be affected:

- Chapter 9 of the PCSR
- Chapter 15 of the EDCD, if required.