Office for Nuclear Regulation

An agency of HSE

Generic Design Assessment – New Civil Reactor Build

Step 4 Electrical Systems Assessment of the Westinghouse AP1000® Reactor

Assessment Report: ONR-GDA-AR-11-007
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PREFACE

The Office for Nuclear Regulation (ONR) was created on 1st April 2011 as an Agency of the Health and Safety Executive (HSE). It was formed from HSE's Nuclear Directorate (ND) and has the same role. Any references in this document to the Nuclear Directorate (ND) or the Nuclear Installations Inspectorate (NII) should be taken as references to ONR.

The assessments supporting this report, undertaken as part of our Generic Design Assessment (GDA) process, and the submissions made by Westinghouse relating to the AP1000® reactor design, were established prior to the events at Fukushima, Japan. Therefore, this report makes no reference to Fukushima in any of its findings or conclusions. However, ONR has raised a GDA Issue which requires Westinghouse to demonstrate how they will be taking account of the lessons learnt from the events at Fukushima, including those lessons and recommendations that are identified in the ONR Chief Inspector's interim and final reports. The details of this GDA Issue can be found on the Joint Regulators' new build website www.hse.gov.uk/newreactors and in ONR's Step 4 Cross-cutting Topics Assessment of the AP1000® reactor.

EXECUTIVE SUMMARY

My report presents the findings of the Electrical Systems assessment of the AP1000 Reactor undertaken as part of Step 4 of the Health and Safety Executive's Generic Design Assessment The assessment has been carried out on the December 2009 Pre-construction Safety Report (Ref. 11) and supporting documentation submitted by Westinghouse during Generic Design Assessment Step 4.

My assessment has followed a step-wise-approach in a claims-argument-evidence hierarchy. In Step 2 the claims made by the Requesting Party (Westinghouse) were examined, in Generic Design Assessment Step 3 the arguments that underpin those claims were examined.

The scope of the Generic Design Assessment Step 4 Assessment was to review the safety aspects of the AP1000 Reactor in greater detail, by examining the evidence, supporting arguments and claims made in the safety documentation, building on the assessments already carried out for Generic Design Assessment Steps 2 and 3, and to make a judgement on the adequacy of the Electrical Systems information contained within the December 2009 Pre-construction Safety Report (Ref. 11) and its supporting documentation.

It is seldom possible, or necessary, to assess a safety case in its entirety, therefore sampling is used to limit the areas scrutinised, and to improve the overall efficiency of the assessment process. Sampling is done in a focused, targeted and structured manner with a view to revealing any topic-specific, or generic, weaknesses in the safety case. To identify the sampling for the Electrical Systems my assessment plan for Generic Design Assessment Step 4 was set-out in advance.

My assessment has focused on:

- Review of power system protection in the generic AP1000 design.
- Review of the resilience of the Electrical Distribution System to the effects of fast transient disturbances.
- Study of three phase and single phase short-circuits on the system.
- Study of the effects of transient disturbances on the Electrical System during motor starting and power system fault conditions.
- Review of the Direct Current and uninterruptible Alternating Current Systems.
- Review of power quality on the distribution system.
- Review of maintenance philosophy and condition monitoring.
- Review of earthing and lightning protection.
- Review of the codes and standards to be used for an AP1000 in the UK.
- Protection against voltage transients.
- Review of the Electrical System design against Nuclear Directorate Safety Assessment Principles

A number of items have been agreed with Westinghouse as being outside the scope of the Generic Design Assessment process and hence have not been included in my assessment.

From my assessment, I have concluded that:

- Westinghouse has to provide claims, arguments and evidence of compliance of the Electrical System architecture defined against the electrical Safety Assessment Principles. Generic Design Assessment Issue **GI-AP1000-EE-01** has been raised to identify the requirement to supply this evidence.

- I commissioned a sample of independent assessments of the Westinghouse design by modelling extremes of transient operating conditions and this work has confirmed the resilience of the design of the Electrical System to system disturbances due to such events as short-circuits and overvoltage transients.
- The architecture of the System provides sufficient capacity to meet load requirements in all operating modes of grid supply, diesel supply and battery supply when all parts of the Electrical System are available and in operation.
- Westinghouse has to demonstrate the capability provided to facilitate maintenance of Electrical Systems whilst maximising supply continuity. Demonstration has to be given that continuity of supply can be maintained in the event of unavailability of equipment due to electrical faults. Generic Design Assessment Issue **GI-AP1000-EE-01** requires this demonstration to be provided in the Pre-construction Safety Report as part of the submission of claims, arguments and evidence.
- The principles proposed in the protection philosophy provide a good basis for protecting the Electrical System to minimise the effects of electrical faults. This enables continuity of system supplies and thus supports the effectiveness of the Electrical System in maintaining plant safety.
- The Class 1 and Class 2 battery powered systems are designed in a well structured manner according to defined and documented processes. Adequate margins are applied and battery rating is based on the worst conditions of operating temperature and ageing.
- Westinghouse has undertaken an impact assessment of meeting the UK Grid Code (Ref. 28) and has demonstrated that all the implications have been assessed. This has included ensuring that there are no implications on the Plant Electrical System when remaining connected to the Grid under fault conditions.
- Westinghouse has presented comprehensive proposals to apply International Electrotechnical Commission Standards to the design of the AP1000 Electrical System as part of implementing the adaptation of the design from an operating frequency of 60Hz to 50Hz.

During the course of my assessment discussions have taken place with Westinghouse on subjects arising from the assessment. This has resulted in a number of changes to the design or to commitments to perform additional design verification studies. The most significant changes agreed have been:

- Incorporation of studies of fast transients and Automatic Voltage Regulator failure in the design process. This incorporates additional studies to address potential threats to system integrity.
- Performing harmonic assessment during detail design. This additional study addresses potential threats to system integrity.
- Incorporation of International Electrotechnical Commission Standard 50Hz equipment in the electrical design of the AP1000 for UK applications.
- Adoption of UK safety classifications in the design of the Plant Electrical Distribution System.
- The reassessment of switchgear fault capabilities following identification of incorrect calculation by Westinghouse of Direct Current components of currents for high voltage switchgear. Due to the incorrect method of calculation the requirements were overstated with potential effects on size and availability of suitable equipment.

The assessment has been carried out on a generic design and on the presentation of fundamental design principles to be followed in carrying out detailed design of the Electrical System. The detailed design information for the Electrical Systems is not available. This has limited the extent of my assessment but sufficient assessment has been undertaken to gain confidence that the design intent is able to meet the Nuclear Directorate Safety Assessment Principles. Nuclear Directorate will then need to underpin their conclusions based on the detailed design when it is available. This design information is identified in Assessment Findings which are to be carried forward as normal regulatory business. An example of a key Assessment Finding is the requirement to model the AP1000 Electrical System in order to perform a load study, further findings then relate to transient studies to be performed using the initial model. Assessment Findings are listed in Annex 1.

Some of the observations identified within my report are of particular significance and will require resolution before the Health and Safety Executive would agree to the commencement of nuclear safety-related construction of an AP1000 Reactor in the UK. These are identified in this report as Generic Design Assessment Issues and are listed in Annex 2. In summary these relate to:

- Westinghouse is required to produce a revised Pre-construction Safety Report Chapter 18 to substantiate the design of the complete Plant Electrical Distribution System. This needs to incorporate a structure of claims, arguments and evidence to demonstrate that the Electrical System fully meets the requirements of its safety role as specified in the other chapters of the Pre-construction Safety Report. This shall incorporate substantiation of the maintenance philosophy supported by a Probabilistic Safety Analysis taking account of all operating conditions.

Overall, based on the sample undertaken in accordance with Nuclear Directorate procedures, I am broadly satisfied with the integrity of the Electrical System laid down within the Pre-construction Safety Report and supporting documentation for the Electrical Systems. This will require substantiation by the presentation of the claims, arguments and evidence within the Pre-construction Safety Report in response to **GI-AP1000-EE-01**. The AP1000 Reactor is therefore suitable for construction in the UK, subject to satisfactory progression and resolution of Generic Design Assessment Issues to be addressed during the forward programme for this reactor and assessment of additional information that becomes available as the Generic Design Assessment Design Reference is supplemented with additional details on a site-by-site basis.

LIST OF ABBREVIATIONS

AC	Alternating Current
ALARP	As Low As Reasonably Practicable
ANSI	American National Standards Institute
AVR	Automatic Voltage Regulator
BMS	(Nuclear Directorate) Business Management System
BSI	British Standards Institution
C&I	Control & Instrumentation
DAS	Diverse Actuation System
DC	Direct Current
DIDELSYS	Defence in Depth of Electrical Systems and Grid Interaction with nuclear power plants
EMI	Electromagnetic Interference
GCB	Generator Circuit Breaker
GDA	Generic Design Assessment
HSE	The Health and Safety Executive
IAEA	The International Atomic Energy Agency
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers
HV	High Voltage
LV	Low Voltage
MCR	Main Control room
MG	Main Generator
MSUT	Main Step Up Transformer
NCB	Non-Classified Building
ND	The (HSE) Nuclear Directorate
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
PCS	Plant Control System
PCSR	Pre-construction Safety Report
PID	Project Initiation Document
PSA	Probabilistic Safety Analysis
RAT	Reserve Auxiliary Transformer
RCP	Reactor Coolant Pump
RI	Regulatory Issue

LIST OF ABBREVIATIONS

RIA	Regulatory Issue Action
RMS	Root Mean Squared
RO	Regulatory Observation
ROA	Regulatory Observation Action
RP	Requesting Party
SAP	Safety Assessment Principle
SSC	System, Structure and Component
TAG	(Nuclear Directorate) Technical Assessment Guide
THD	Total Harmonic Distortion
TQ	Technical Query
TSC	Technical Support Contractor
UAT	Unit Auxiliary Transformer
UPS	Uninterruptible Power Supply
US NRC	Nuclear Regulatory Commission (United States of America)
VFD	Variable Frequency Drive
WEC	Westinghouse Electric Company

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1 INTRODUCTION

1 My report presents the findings of the Step 4 Electrical Systems assessment of the AP1000 Reactor December 2009 Pre-construction Safety Report (PCSR) (Ref. 11) and supporting documentation provided by Westinghouse under the Health and Safety Executive's (HSE) Generic Design Assessment (GDA) process. My assessment was undertaken of the PCSR and the supporting evidentiary information derived from the Master Submission List (MSL) (Ref. 13). My approach was to assess the principal submission, i.e. the PCSR, and then undertake an assessment of the relevant documentation sourced from the Master Submission List on a sampling basis in accordance with the requirements of Nuclear Directorate's (ND) Business Management System (BMS) procedure AST/001 (Ref. 2). I have also used ND's Safety Assessment Principles (SAP) (Ref. 4) as the basis for this assessment. Ultimately, the goal of assessment is to reach an independent and informed judgment on the adequacy of a nuclear safety case.

2 During my assessment a number of Technical Queries (TQ) and Regulatory Observations (RO) were issued and I assessed the responses made by Westinghouse. Where relevant, detailed design information from specific more advanced projects (China and USA) for this reactor type has been assessed to build confidence and assist in forming a view as to whether the design intent proposed within the GDA process can be realised.

3 A number of items have been agreed with Westinghouse as being outside the scope of the GDA process and hence have not been included in this assessment.

2 NUCLEAR DIRECTORATE'S ASSESSMENT STRATEGY FOR ELECTRICAL SYSTEMS

4 My assessment strategy for GDA Step 4 for the Electrical Systems topic area was set out in an Assessment Plan (Ref. 1) that identified the intended scope of the assessment and the standards and criteria that would be applied. This is summarised below.

2.1 Assessment Plan

5 My Assessment Plan (Ref. 1) provided the basis for producing this GDA Step 4 Assessment Report to assess the evidence in support of the claims and arguments in the GDA Step 3 Assessment Report (Ref. 6) and to judge the adequacy of the Electrical Systems contained within the PCSR and supporting documentation.

2.2 Standards and Criteria

6 The assessment was to be carried out in accordance with the relevant electrical subset of SAPs which are identified in Table 7.

2.3 Assessment Scope

7 The scope identified in my Assessment Plan was to review the safety aspects of the Electrical Systems for the proposed reactor designs in a more detailed way by examining the evidence supporting arguments and claims made in the Westinghouse safety documentation. This was to build on my earlier assessment carried out in GDA Step 3 with a view to making a judgment on the adequacy of the Electrical Systems as described within the PCSR (Ref. 11) and supporting documentation.

8 The areas to be covered in GDA Step 4 are detailed in Table 6. My assessment of the evidence to support the claims and arguments in compliance with SAPs was to be carried out in accordance with the subset of SAPs relevant to electrical power supply systems.

2.3.1 Findings from GDA Step 3

9 My GDA Step 3 Assessment Report concluded that Westinghouse had provided adequate claims of compliance for the Electrical Systems architecture defined against the subset of electrical SAPs (Ref. 4). In a number of areas more detailed information would be required in the GDA Step 4 Submission to provide arguments and evidence in support of the claims.

10 During GDA Step 4 I planned to undertake an independent assessment of the Westinghouse design, to verify the integrity of the design. Westinghouse's role was to supply design data to support the process.

2.3.2 Additional Areas for Step 4 Electrical Systems Assessment

11 The additional areas identified in my Assessment Plan for assessment during GDA Step 4 are listed in Table 6.

2.3.3 Use of Technical Support Contractors

12 A Technical Support Contractor (TSC) was used in support of the assessment of the Electrical Systems on the AP1000. The following scope of work was undertaken by the TSC:

- Review of electrical protection.
- Review of earthing arrangements.
- Modelling of Electrical System using power systems analysis system study software.
- Fault Studies using an independent code from that employed by Westinghouse.
- Sample calculation of protection coordination studies.
- Analysis of the effects of transient disturbances to the Electrical System.
- Fast transient assessment of the Electrical System.
- Harmonic assessment of the Electrical System.
- Technical advice to ND.

13 The TSC work was based on studies and reports from Westinghouse documentation. At the completion of each stage of work the results were discussed with ND before being presented to Westinghouse for discussion and comment. Following on from this, reports were produced by the TSC for each study area, which were used to inform my report. A copy of the overall study using the “ERACS” model of the Electrical System has been provided to ND on disk.

2.3.4 Cross-cutting Topics

14 The following Cross-cutting topics have been considered within this report:

- Structures, Systems and Components.
- Design Changes.
- Limits and Conditions.
- Smart Instruments.
- Qualification.
- Metrication.
- Spent Fuel Pond.

2.3.5 Integration with Other Assessment Topics

15 Integration has taken place with other assessment topics as follows:

- Internal Hazards on hydrogen evolution in battery rooms.
- Internal Hazards on cable segregation.
- Internal Hazards on Electromagnetic Interference (EMI).
- Probabilistic Safety Analysis (PSA) on incorporation of the Electrical System in the PSA model.
- Control & Instrumentation (C&I) on Smart Devices.
- Mechanical Engineering on diesel generators.

- Fault Studies on power supplies to safety systems.
- Human Factors on maintenance and manual operations.
- External Hazards from Flooding and Seismic Events.

2.3.6 Out of Scope Items

16 The following items have been agreed with Westinghouse as being outside the scope of GDA. On a number of topics such as fast transients, protection coordination and grid connection arrangements I have taken an initial view for generic assessment as these topics could have significant design impact. The specific out of scope items are:

- Detailed design and specification of main electrical items.
- Detailed fast transient assessment.
- Grid connection arrangements.
- Detailed site-specific study of the Electrical System including load flows, fault studies, transient performance etc.
- Site-specific protection co-ordination study.

3 REQUESTING PARTY'S SAFETY CASE

17 Westinghouse has not provided a clear safety case in the PCSR (Ref. 11) which can be used as the basis of assessment. However, in my opinion, based upon information provided in the European DCD EPS-GW-GL-700 (Ref. 48), other supporting documents and in Westinghouse responses to TQs and ROs, there are no fundamental reasons why a generic safety case cannot be made. This assessment has, therefore, been carried out based on the documents submitted. As a consequence, the safety case will be examined during resolution of the GDA Issue **GI-AP1000-EE-01** which has been raised on Westinghouse to produce a safety case for the Electrical System for the AP1000 (see Section 4.1.1.2).

4 GDA STEP 4 NUCLEAR DIRECTORATE ASSESSMENT FOR ELECTRICAL SYSTEMS

4.1 Electrical System Structure

18 I have assessed the basic structure of the Power Distribution System in the AP1000 Reactor and also the integrity of this structure. I also examined how this system complied with the subset of Electrical SAPs (Ref. 4) most relevant to the electrical power supply systems.

4.1.1 System Structure

19 An overview of the Electrical Supply System is shown in Figure 10. The output from the Main Generator (MG) is connected from the Generator Circuit Breaker (GCB) via the Main Step-up Transformer (MSUT) to the grid substation. The supply to the Plant Auxiliary System is taken from the Main Generator to two Unit Auxiliary Transformers (UAT). These supply high voltage (HV) power at 11kV to the Plant Auxiliary System. When the generator is not operating it can be isolated via the GCB and supplies provided to the Plant Auxiliary System via MSUT and UAT. When operating from the grid with no generation, tap changers on the MSUT and UAT operate in response to grid voltage variations. An alternative grid supply to the 11kV system is provided from the grid substation via Reserve Auxiliary Transformers (RAT). The RATs are provided with tap changers for voltage control.

20 There are two identical independent divisions each fed from an 11kV switchboard. The 11kV switchboards ECS-ES-1 and ECS-ES-2 each have connections for incoming supplies from UATs and RATs. These incoming supplies are electrically interlocked to prevent the supplies being paralleled. A Standby Diesel Generator (SDG) is connected to each of the 11kV switchboards. These will maintain supplies to loads on ECS-ES-1 and ECS-ES-2 in the event of loss of the Main Generator and offsite power supplies. Synchronising facilities are provided to facilitate regular testing of the Standby Diesel Generators on-load in parallel with the main supply.

21 Supplies are provided to the VFDs (Variable Frequency Drives) feeding each of the four Reactor Coolant Pumps (RCP) from the UATs with back up from the RATs.

22 Full segregation is provided between the Electrical Systems on each Division. No cross connections are provided which avoids the potential for a fault on the Electrical System of one Division affecting the other Division.

23 Each of the Divisions of AC power feeds two independent Divisions of UPS power for providing supplies to essential loads. Divisions A and B are fed from one 11KV switchboard and Divisions C and D are fed from the second 11KV switchboard. Divisions A and D and Divisions B and C are identical. The full description and assessment of the battery systems is covered in Section 4.4.

24 Divisions B and C each have a 400V Ancillary Diesel Generator for providing supplies for post 72 hour monitoring, Main Control Room (MCR) lighting, MCR and Control and Instrumentation (C&I) room ventilation and pump power to Plant Control System (PCS) recirculation pumps.

25 HV motors are circuit breaker fed so will remain connected in the event of dips in supply voltage. The arrangements for control of Low Voltage (LV) motors during dips in supply voltage are addressed in the Westinghouse response to TQ-AP1000-976 (Ref. 8). Motor contactors will drop out at 70% voltage, and then will be subject to a staged restart by the computer based PCS. Critical motors supported by the Standby Diesel Generators have DC battery backed control supplies so will remain connected to the supply during dips in main supply voltage.

4.1.1.1 Assessment

26 The basic structure of the Electrical Distribution System is well laid out with two independent Divisions each supported by a Standby Diesel Generator providing supplies to the system loads. Provision is made for alternative supplies from the Main Generator or from separate grid supplies. The layout of the system with independent Divisions reduces the risk of a single event affecting the Electrical Systems on both Divisions.

27 It is important to note that the basic structure for the AP1000 Electrical System differs from many Pressurised Water Reactors (PWR), such as Sizewell B, where safety is dependent on active Class 1 safety systems. Many modern PWRs have four independent Divisions of diesel alternator backed Class 1 Alternating Current (AC) supplies. For AP1000 my assessment has been based on the claims that the alternating current system is required to supply only Class 2 systems. The reason for this is that AP1000's heat transport removal systems are based on passive safety systems. While many of these systems do require some energy to move the valves into the correct alignment the energy requirements for this are very modest and can be met by the main battery supplies which are Class 1 and arranged in four independent and fully segregated divisions as described in Section 4.4.

28 I consider that the motor control arrangements for maintaining essential supplies using diesel backed control supplies are acceptable.

29 The assessment of the system by the Technical Support Contractor (TSC) using an independent power system analysis computer code (known as ERACS) to model the AP1000 Electrical System has included a load flow the results of which are recorded in Report 2010-0643 (Ref. 55). The results of this study show the system to be conservatively rated. The load flow is based on loading information provided in Westinghouse document SMG-ZAS-E0C-001 (Ref. 23). Westinghouse document APP-ZOS-E0C-001 (Ref. 50) provides details of the methodology for sizing of diesel generators. The Westinghouse response to TQ-AP1000-602 (Ref. 8) provides details of the methodology for the sizing of power transformers.

30 RO-AP1000-075 (Ref. 9) was raised on Westinghouse requesting that consideration be given to locating the two Standby Diesel Generators in separate buildings, as the AP1000 design incorporates these in the same building separated by a three hour fire barrier. This RO was raised as a cross-cutting issue, in conjunction with Internal Hazards and External Hazards assessments. The Westinghouse response to the RO details the protective measures in place such as separation of fuel tanks and provision of fire barriers. The main Westinghouse claim as to the adequacy of the design is that essential safety systems can be maintained on loss of both Standby Diesel Generators.

4.1.1.2 Findings

31 Based on the results of the load flow study I consider that the basic structure of the Electrical System is able to meet the load requirements. Demonstration has been made for generic assessment of the methodology used to ensure electrical equipment is adequately rated. I have raised Assessment Finding **AF-AP1000-EE-001** requiring the future licensee to carry out a load flow and assessment on the detail design and specification of the system to ensure that the basic principles are maintained.

32 As explained in Section 3 of this report Westinghouse has not provided a clear safety case to substantiate the design of the Electrical System. As a result of this GDA Issue **GI-AP1000-EE-01** has been raised requiring Westinghouse to provide claims, arguments and evidence to substantiate the safety case for the integrity of the Electrical System on

the AP1000. This will require to be supported by PSA assessment and will be required to substantiate that maintenance operations can be carried out on the reactor whilst maintaining system integrity.

33 The complete GDA Issue and associated action is formally defined in Annex 2 of this report.

34 The presentation of the safety case for the Electrical System will also be assessed in conjunction with the response to GDA Issue **GI-AP1000-FS-01** raised by Fault Studies on the provisions for cooling of the fuel storage ponds (Ref. 73).

35 The presentation of the safety case for the Electrical System will be required to substantiate the statements made in the Westinghouse response to RO-AP1000-75 (Ref. 9) on the capability of the Electrical System to withstand the loss of the two Standby Diesel Generators.

4.1.2 SAPs Compliance

36 I have carried out an assessment in this section of the structure of the Electrical System against the requirements of specific Safety Assessment Principles (SAP) (Ref.4), which have particular relevance to the Electrical System. The full assessment of compliance with all relevant SAPs is provided in Table 8.

4.1.2.1 Assessment

37 EDR.1 covers failure to safety which is addressed by adopting the principles of the electrical protection scheme to provide a coordinated system to ensure that failure at a single point of the Electrical System, will not have an impact throughout the system. My assessment has verified claims that important system loads are duplicated, so loss of supply will not result in loss of functions. My assessment has also established that alternative sources of supply are available from the Main Generator, duplicated grid inputs, Standby Diesel Generators and battery sources independent of the AC power.

38 EDR.2 covers redundancy, diversity and segregation. Redundancy and segregation are achieved by the provision of two segregated Divisions, each with independent diesel generators and by the four independent battery Divisions. Diversity is provided by the Standby Diesel Generators and battery systems providing diverse sources of power. I have some concerns raised in Section 4.4.1.1 of this report that the PCSR (Ref. 11) states that three out of four battery systems are required for safe shutdown of the reactor and whether this requirement is compatible with the SAP EDR.2. The requirement for Westinghouse to substantiate the capability of the battery systems to meet the demands for all design basis faults as defined in the fault schedule is defined in GDA Issue **GI-AP1000-EE-01**.

39 EDR.3 covers common cause failures. This has been addressed in studies undertaken to assess external sources of disturbances such as grid failures, fast transients and lightning disturbances. I have concerns which are raised in GDA Issue **GI-AP1000-EE-01** requiring Westinghouse to provide substantiation in the PCSR (Ref. 11) to show that the Electrical System availability can be achieved to meet the requirements of this SAP.

40 ERL.2 covers measures to achieve reliability. Reliability is achieved by the segregation of the two Divisions and by the diverse sources of power from the Standby Diesel Generators and the four Division battery based systems. I am satisfied with the systems for ensuring that equipment is adequately rated to achieve reliability. I will require substantiation of the maintenance philosophy in the response to GDA Issue **GI-AP1000-EE-01** to complete the substantiation of compliance with the requirements of this SAP.

41 ERL.4 covers margins of conservatism. My assessment has revealed that the AP1000 electrical equipment has been designed using comprehensive and conservative methods to ensure adequate margins. The provision of two independent Divisions of AC power and four independent battery Divisions provides the required level of conservatism in the design to a very wide range of single and multiple faults.

42 ESS.21 covers reliability. My assessment supports Westinghouse's claims that the AP1000 Electrical System has a robust and simple architecture to support system reliability. This is further supported by the use of nuclear qualified equipment. Substantiation is required on the integrity of the Smart Devices which are planned to be used extensively throughout the Electrical System. GDA Issue **GI-AP1000-CI-05** (Ref. 61) raised by C&I requires Westinghouse to document the verification and validation process and to demonstrate its application. Provision of a PSA Assessment by Westinghouse is required to support the safety claims as identified in GDA Issue **GI-AP1000-EE-01**.

43 EKP.3 covers defence in depth. The provisions for defence in depth can be summarised as follows:

- Two sources of grid supply in addition to the Main Generator with duplication of main transformers.
- The provision of two independent divisions of AC power each backed up by a Standby Diesel Generator.
- The provision of four Divisions of battery power with segregated Class 1 and Class 2 systems.
- The provision of fire barriers separating the Standby Diesel Generators.
- The provision of bypass supplies to the AC Inverters.
- The provision of two Ancillary Diesel Generators to provide 400V supplies for passive containment cooling pumps and post 72 hour monitoring in the event of a sustained loss of the grid and both of the Standby Diesel Generators.

4.1.2.2 Findings

44 My assessment of the structure of the Electrical System in accordance with the SAPs having particular relevance to Electrical Systems has shown that the system has the structure to be compliant in most respects.

45 The areas where compliance has not been demonstrated require the provision of the safety case on the PCSR in the form of claims arguments and evidence supported by PSA Assessment and by substantiation of the maintenance philosophy. These requirements are covered in GDA Issue **GI-AP1000-EE-01**.

46 I will also require to examine the structure of Electrical System as part of the review of the power supply arrangements for spent fuel cooling in resolution of GDA Issue **GI-AP1000-FS-01** raised by Fault Studies (Ref. 73).

4.2 Power System Protection

47 My assessment of the electrical protection on the Plant Auxiliary Distribution Network is based on Westinghouse document APP-GW-E1-004 (Ref.18). This provides guidelines and specifies criteria for the design of the plant electrical protection scheme. TSC Report 2010-0649 (Ref. 51) which independently assesses the principles of power system

protection in the generic AP1000 design has been used as input information to this report.

4.2.1 Assessment

48 Westinghouse document APP-GW-E1-004 (Ref. 18) comprehensively describes a circuit protection philosophy applied to the three phase and earth fault protection of the Electrical Power System of the AP1000 which is well developed. The phase overcurrent protection approach described uses conventional time graded protection, which in places backs up fast acting differential protection. In addition a range of other conventional and proven protection measures and devices are described for equipment protection. Overall, I consider the protection philosophy is appropriate to provide a robust system.

49 The philosophy document describes the basis by which the setting for time graded phase overcurrent protection would be selected. I consider this basis to be correct.

50 The Westinghouse response to TQ-AP1000-302 (Ref. 8) describes the methodology for establishing and controlling relay protection settings. I consider that the methodology proposed is sound and will ensure robust controls are in place to maintain correct settings throughout the life of the plant.

51 The High Voltage (HV) earth fault protection uses a conventional time/current graded approach but relies upon residual earth fault protection on feeders with only a 20ms delay.

52 The HV system is low impedance earthed when supplied from the supply transformers, but high impedance earthed when supplied from the Standby Diesel Generators. This is to allow continuing generator operation until the earth fault is located and cleared. This approach offers increased supply availability in critical power supply systems as explained in the response to TQ-AP1000-548 (Ref. 8) and TQ-AP1000-833 (Ref. 8).

53 There are a number of references to the use of microprocessor-based protection relays. I would expect these to be subject to appropriate verification and validation of software integrity. This subject is more fully covered in Section 4.16.

4.2.2 Findings

54 My assessment is that the protection principles proposed by Westinghouse provide a good basis for protecting the Electrical System. This minimises the effects of electrical faults on system supplies and thus supports the effectiveness of the Electrical System in supporting plant safety.

55 The Electrical System on a reactor is dependent on various site-specific aspects such as grid connections and site-specific auxiliary loads. I require a site-specific protection scheme to be designed by the future licensee to ensure effective coordination and discrimination of protective devices. This should demonstrate the stability of the system with the 20ms time delay on earth fault protection.

56 I consider the provision of high impedance HV system earthing during Standby Diesel Generator operation to be correct as this provides increased supply availability. During detailed design of the protection scheme facilities should be provided for detection, alarm and location of earth faults on the system.

57 This scheme should be the subject of a detailed study to determine correct protection settings. These activities carried out in accordance with the principles defined in the protection principles document should ensure effective plant protection. Assessment

Finding **AF-AP1000-EE-002** has been raised requiring the future licensee to undertake a protection study based on actual site configurations during detail design of the plant.

4.3 Cable Routing

58 I have assessed the basic principles to be adopted for the routing of electrical cables in conjunction with the GDA Step 4 Internal Hazards Assessment (Ref. 74). The electrical assessment has focused on the design of cable routes to meet specific electrical requirements regarding segregation, separation and rating whilst the Internal Hazards assessment has considered the effects of specific hazards such as fire, flooding and internally generated missiles.

4.3.1 Assessment

59 The design of the main cable routes for the Class 1 systems provides the basic framework consistent with the philosophy of segregation between Divisions.

60 The Westinghouse response to TQ-AP1000-1183 (Ref. 8) describes the segregation of cable routes for Class 2 systems within the AP1000 design.

61 The Electrical Codes and Standards document UKP-GW-GL-059 (Ref. 30) compares the cable sizing on the standard AP1000 design based on National Fire Protection Association (NFPA) 70 (Ref. 33) with sizing requirements based on British Standard BS 7671 (Ref. 34). Cable sizing calculations have been undertaken for sample applications and the conclusion reached by Westinghouse is that cables sized in accordance with BS 7671 (Ref. 34) are generally smaller than those defined using National Fire Protection Association (NFPA) (Ref. 33) standards.

62 Westinghouse proposes to use non-armoured power cables in the AP1000 plant as this is the basis of the standard design. This proposal needs to be considered in conjunction with details of the mechanical protection provided for cables.

4.3.2 Findings

63 I consider that the design principles documented by Westinghouse for the segregation of cable routes between Divisions for Class 1 systems are acceptable.

64 I consider that the principles proposed in the response to TQ-AP1000-1183 (Ref. 8) for the segregation of cables for Class 2 systems are acceptable.

65 I note the Westinghouse proposal to standardise on non-armoured power cables. I accept this proposal, but subject to adequate mechanical protection being provided so that there is no additional vulnerability of the cables to mechanical damage. The requirement for mechanical protection of non-armoured cable should be defined by the future licensee during detail cable routing design. Where cables are field routed they should be installed by the licensee in accordance with defined and agreed principles. This requirement is covered by Assessment Finding **AF-AP1000-EE-003**.

66 I have raised **AF-AP1000-EE-003** for the future licensee to define the criteria adopted for the detailed design of cable routes. This will require verification of cable sizes based on protection provisions, separation, mechanical protection, ambient de-rating factors in worst conditions and voltage drop due to cable length.

67 Assessment Finding **AF-AP1000-EE-003** also requires the definition of cable segregation criteria for protection against Electromagnetic Interference (EMI).

4.4 DC and Uninterruptible AC Systems

68 My assessment is based on the following documents and the configuration of the systems shown in Figure 10:

- Westinghouse document CPP-IDS-E0C-001 (Ref. 19).
- Westinghouse document CPP-IDS-E0C-002 (Ref. 20).
- Westinghouse document APP-EDS-E8-001 (Ref. 21).
- Westinghouse response to TQ-AP1000-400 (Ref. 8).
- Westinghouse response to TQ-AP1000-600 (Ref. 8).
- Westinghouse response to TQ-AP1000-601 (Ref. 8).
- Westinghouse response to TQ-AP1000-823 (Ref. 8).
- Westinghouse response to TQ-AP1000-829 (Ref. 8).
- Westinghouse response to TQ-AP1000-1017 (Ref. 8).
- Westinghouse response to TQ-AP1000-1103 (Ref.8).

69 The battery and inverter systems have been assessed by the TSC in Report 2010-0699 (Ref. 52).

70 The Class 1 batteries consist of the following six systems all rated at a nominal voltage of 250V DC:

- Division A: One – 250V DC 24 hour battery.
- Division B: One – 250V DC 24 hour and one – 250V DC 72 hour battery.
- Division C: One – 250V DC 24 hour and one – 250V DC 72 hour battery.
- Division D: One – 250V DC 24 hour battery.

71 The Class 1 inverters consist of the following:

- Division A: One – 230V AC single phase inverter fed from the 24 hour battery.
- Division B: One – 230V AC single phase inverter fed from the 24 hour battery and one – 230V AC single phase inverter fed from the 72 hour battery.
- Division C: One – 230V AC single phase inverter fed from the 24 hour battery and one – 230V AC single phase inverter fed from the 72 hour battery.
- Division D: One – 230V AC single phase inverter fed from the 24 hour battery.

72 The Class 2 batteries consist of four 125V DC 2 hour systems each organised in two sub-systems and one 250V DC 2 hour system used for power to large DC motors.

73 Each of the 250V DC systems consists of two sets of 125V DC batteries

4.4.1 Battery Systems

74 This assessment considers the design of the battery systems and chargers.

4.4.1.1 Assessment

75 I have assessed the procedure described in Westinghouse document CPP-IDS-E0C-001 (Ref. 19) used to determine the ratings of batteries. For Class 1 systems the peak duties have been determined by Westinghouse to occur during the following loading scenarios:

- Large-break loss of coolant accident.
- Loss of AC power.

76 The maximum momentary current in the first and last minutes of each duty cycle has been determined and the peak value from the two scenarios has been selected as the load cycle for the entire period.

77 For Class 2 systems, the load has been calculated based on an assessment of connected equipment.

78 The following factors have been applied to the calculated loads to determine actual ratings:

- An ambient correction factor of 11% to account for the assumed minimum temperature of 15.5 °C.
- A battery ageing factor of 125% to ensure an acceptable voltage at the postulated end of life.
- A sizing design margin of 110% to account for potential future load growth.
- All batteries are specified with the same capacity based on the battery with the worst-case duty cycle.

79 Westinghouse document CPP-IDS-E0C-001 (Ref. 19) identifies an expected 20 year life for battery cells. The sizing of batteries has been carried out in accordance with IEEE 485 (Ref. 31) which identifies a 20% decline in battery capacity as being typical of the capacity of a battery at the end of service life. Thus the ageing factor of 25% applied to the battery capacity is in accordance with IEEE 485 (Ref. 31).

80 Regular monitoring is carried out of batteries by checking electrolyte level, containers, connectors and cell voltage. The primary assessment of the in service battery integrity is by these regular checks.

81 A battery monitoring system is also provided to assist with maintaining the batteries but no safety claims are made on this system. Westinghouse has provided substantiation of the integrity of the battery monitoring system in the response to TQ-AP1000-601 (Ref. 8).

82 The generic design for protection facilities for earth fault detection and alarm and for undervoltage protection is described in the Westinghouse response to TQ-AP1000-600 (Ref. 8).

83 The PCSR (Ref. 11) states that three out of four Class 1 battery systems are required for safe reactor shutdown. This claim places significant availability constraints on the battery systems and requires further clarification or substantiation from Westinghouse.

84 I have verified the short-circuit ratings of the DC distribution network and agree with the fault levels calculated by Westinghouse to give a 30kA rating.

85 A spare battery is provided consisting of two sets of 125V DC batteries. This can be used to support both the Class 1 and Class 2 systems as one of the battery sets can be switched in to support the 125V systems. The spare set will be used when a battery system is off-load under maintenance or on boost charge. The switching between battery sets is a manual operation and is mechanically interlocked to prevent any interconnections between Divisions.

86 The Westinghouse response to RO-AP1000-75 (Ref. 9) refers to an independent power supply to the secondary Diverse Actuation System (DAS) Panel. No details have been supplied for this equipment so I have not been able to carry out an assessment.

4.4.1.2 Findings

87 I consider that the methodology for battery sizing based on the functional scenarios whilst taking account of peak loading is acceptable. Adequate margins are applied and battery rating is based on the worst condition of operating temperature and ageing. The DC systems are designed in a well structured manner according to defined and documented processes. The design limits of the supplies produced by these sources are in line with good practice.

88 I consider that the methodology proposed for the calculation of ratings is acceptable for GDA. Assessment Finding **AF-AP1000-EE-004** defines the requirement for the future licensee to determine the battery ratings for each plant based on actual load conditions.

89 I consider that the protection facilities described for earth and undervoltage faults are acceptable.

90 I consider that the calculated short-circuit rating of the DC system is adequate for the duty.

91 No details have been provided regarding the sources for supply of tripping and closing supplies to circuit breakers. Assessment Finding **AF-AP1000-EE-005** covers the substantiation of the integrity of these supplies by the future licensee.

92 I require the future licensee to provide details of the power supply to the secondary DAS Panel for assessment. This requirement is covered in the C&I GDA Issue **GI-AP1000-CI-02** (Ref. 61).

93 I require Westinghouse to substantiate the capability of the battery systems to meet the demands for all design basis faults as defined in the fault schedule in response to GDA Issue **GI-AP1000-EE-01**. This substantiation shall provide a more detailed explanation of the claim that three out of four battery systems are required for safe reactor shutdown.

94 I consider that the safety case in the PCSR (Ref. 12) should substantiate the design of the Class 1 battery systems to safely shutdown the reactor. The requirement to produce the PCSR to substantiate the safety case is covered by GDA Issue **GI-AP1000-EE-01**.

4.4.2 Inverters

95 This assessment considers the design of the Class 1 inverter fed AC system.

4.4.2.1 Assessment

96 Based on an estimation of maximum allowable circuit length, I conclude that the maximum calculated circuit lengths are significantly longer than the lengths likely to exist in the plant. The application of overcurrent protection to prevent a single circuit fault from disabling a Division before it is cleared is achievable.

97 The inverter sizing methodology adopted by Westinghouse in document CPP-IDS-E0C-002 (Ref. 20) incorporates significant margins to accommodate the worst case loading conditions.

98 Westinghouse System Specification document APP-EDS-E8-001 (Ref. 21) covers the inverter. This document describes the resilience of the inverters to operate during normal plant operation, plant transients and accidents, and abnormal system conditions such as

failures of batteries, chargers and inverters. My review of this document shows the specification to define a design that is thermally robust, fault tolerant and self-protecting.

99 The capability of the AC UPS systems to withstand undervoltages is demonstrated in the Westinghouse responses to TQ-AP1000-823 (Ref. 8) and TQ-AP1000-1017 (Ref. 8). These describe the system settings to ensure resilience of the AC systems to the identified worst case voltage disturbance of 100% load rejection identified in Section 4.10.

4.4.2.2 Findings

100 My assessment of the integrity of the Class 1 inverter fed AC system is that for GDA purposes the design principles are sound. The inverters are sized with adequate margins to accommodate the worst case loading conditions. The design specification for the inverters considers the capability of withstanding abnormal plant conditions and electrical failures. The specification stipulates the ability to withstand the effects of electrical faults and the worst case voltage disturbances.

101 Assessment Finding **AF-AP1000-EE-006** defines the requirements for the future licensee to calculate actual loadings and to determine adequate grading of protective devices during detailed design.

4.5 Short-circuit Studies

102 My assessment of the short-circuit calculation studies is based on the following documents:

- Westinghouse document CPP-ZAS-E0C-003 (Ref. 22).
- Westinghouse document SMG-ZAS-E0C-001 (Ref. 23).
- Westinghouse document UKP-GW-GL-064 (Ref. 24).
- Westinghouse response to TQ-AP1000-550 (Ref. 8).
- Westinghouse response to TQ-AP1000-609 (Ref. 8).

103 The above Westinghouse documents describe the results of short-circuit studies determining the three phase and single phase fault currents on the high voltage and low voltage systems. The results have been compared with independent calculations carried out by the TSC using the SKM Power System Model of the AP1000 Electrical Network which are covered by TSC Report 2010-0698 (Ref. 53).

4.5.1 Assessment

104 The calculations of three phase fault currents by Westinghouse are presented in Report SMG-ZAS-E0C-001 (Ref. 23) which was undertaken for the Sanmen plant in China. This station operates at 50Hz so is relevant to UK applications. The report defines acceptance criteria for each switchboard based on commercially available equipment. The worst case was identified as operation with the grid supply in parallel with a Standby Diesel Generator which is the operating condition during regular load testing of diesels. As there are grid connections through either the UAT or RATs calculations were carried out for each connection arrangement. The results show minor differences between the fault levels associated with the two incoming supply arrangements but I do not consider these to be significant.

Table 1: Fault Currents on AP1000 System Fed from UAT Transformer

Bus	***TSC Result***				***Westinghouse Result***				***Acceptance Criteria***			
	Ip 3P (kA)	***Ib Sym 3P (kA)***	***Ib Asym 3P (kA)***	***Idc 3P (kA)***	***Ip 3P (kA)***	***Ib Sym 3P (kA)***	***Ib Asym 3P (kA)***	***Idc 3P (kA)***	***Ip 3P (kA)***	***Ib Sym 3P (kA)***	***Ib Asym 3P (kA)***	***Idc 3P (kA)***
ECS-ES-1	118.60	39.89	45.36	21.59	116.94	40.27	47.80	25.75	125	50	53.43	40
ECS-ES-3	115.61	40.74	46.75	22.94	108.13	38.44	42.45	18.00	125	50	53.43	40
ECS-ES-5	119.81	40.35	45.20	20.37	117.69	40.77	46.69	22.74	125	50	53.43	40
ECS-EK-11	159.80	55.29	56.57	11.98	163.67	58.59	59.83	12.1	187	85	-	-
ECS-EK-12	137.11	49.27	50.55	11.31	147.92	55.15	56.21	10.86	187	85	-	-
ECS-EK-13	134.55	48.73	50.03	11.33	145.99	54.62	55.72	11.04	187	85	-	-
ECS-EK-14	120.90	46.71	48.04	11.21	135.02	52.66	54.00	11.94	187	85	-	-
ECS-EK-31	158.10	52.27	53.40	10.91	164.60	57.56	58.23	8.82	187	85	-	-
ECS-EC-111	120.02	49.23	49.23	0.74	117.04	49.01	49.03	1.09	154	70	-	-
ECS-EC-112	103.13	45.56	45.56	0.24	98.89	45.19	45.19	0.28	154	70	-	-
ECS-EC-121	68.70	33.81	33.81	0.05	66.36	34.60	34.59	0.02	154	70	-	-
ECS-EC-122	55.05	27.12	27.12	0.08	54.12	27.02	27.02	0.09	154	70	-	-
ECS-EC-123	60.62	30.28	30.28	0.03	58.50	30.57	30.57	0.02	154	70	-	-
ECS-EC-131	37.69	20.51	20.51	0.00	35.94	20.01	20.01	0.01	154	70	-	-
ECS-EC-132	75.63	35.27	35.27	0.13	74.35	36.42	36.43	0.09	154	70	-	-
ECS-EC-133	73.96	35.10	35.10	0.11	72.34	36.07	36.07	0.05	154	70	-	-
ECS-EC-141	57.72	28.77	28.77	0.03	57.37	29.10	29.10	0.06	154	70	-	-
ECS-EC-311	73.67	32.17	32.17	0.22	72.79	32.53	32.53	0.30	154	70	-	-
ECS-EC-312	74.21	33.91	33.91	0.34	74.30	33.92	33.93	0.43	154	70	-	-

105 The comparison of the study results for the case fed from UAT with a Standby Diesel Generator operating in parallel is shown in Table 1. This shows the calculated fault currents for three phase faults from the TSC study and from the Westinghouse study compared with the criteria defined by Westinghouse. The TSC study used computer codes different to those used by Westinghouse.

106 The results of the calculations show good agreement between the TSC and Westinghouse results which gives confidence that the methodology used in the calculation is correct.

107 Westinghouse document SMG-ZAS-E0C-001 (Ref. 23) identifies that the calculated DC component of three phase AC fault current on the HV buses exceeds the nominal rating of the switchgear. It then states that circuit breakers must be specified with a DC component of 80% of a short-circuit breaking current of 50kA. In discussion with Westinghouse it was agreed that the calculation used to reach the figure of 80% is incorrect as it is related to the RMS current rather than the peak current as defined in IEC 62271-100 (Ref. 25). The correct DC component as defined in IEC 62271-100 (Ref. 25) is 56%.

108 I have reviewed the fault calculations for the Generator Circuit Breaker and bus duct in document CPP-ZAS-E0C-003 (Ref. 22) and information provided in Westinghouse response to TQ-AP1000-828 (Ref. 8). The report calculates the short-circuit ratings for Generator Circuit Breaker ZAS-ES-01, main Isolated Phase Bus ZAS-EB-B01, Isolated Phase Tap Bus ZAS-EB-B02, 03 and 04 and Isolated Phase Tap Bus connected to PT/Excitation System 3.1.2 in accordance with IEEE C37.013 (Ref. 26) and IEEE C37.23 (Ref. 27).

109 I have reviewed the results of single phase fault studies reported in Westinghouse document UKP-GW-GL-064 (Ref. 24). This considered the same supply configurations used for three phase faults supplied from either the UAT or RAT in parallel with a Standby Diesel Generator. The calculated single phase fault currents are below the calculated three phase fault currents and thus within equipment ratings.

4.5.2 Findings

110 There is good correlation between the fault current calculations by the TSC and Westinghouse which demonstrates a sound methodology for calculation. I have raised Assessment Finding **AF-AP1000-EE-007** for the future licensee to undertake detailed studies based on actual site ratings to determine fault levels to be used for equipment specified for an AP1000 in the UK.

111 The calculations for fault currents should include calculations of the DC components on the HV system. Assessment Finding **AF-AP1000-EE-007** identifies the requirement for the future licensee to determine DC components of fault currents and to specify the precise DC component levels to ensure that suitable switchgear is procured.

112 I consider the calculations for the Generator Circuit Breaker and associated bus duct are acceptable. They are necessarily based on US Institute of Electrical and Electronics Engineers (IEEE) Standards as no equivalent International Electrotechnical Commission (IEC) standard exists.

113 I consider that the results of the single phase fault studies are acceptable for GDA purposes.

4.6 Study of Generator AVR Failure

114 The intention of this study is to investigate the possible implications of an Automatic Voltage Regulator (AVR) failure on the Electrical System. The risk that such a failure presents is the possibility of a single event producing potentially damaging overvoltage that could affect both Divisions. The precise effects can only be determined when details are available on the Main Generator AVR and the method of control used. Simulation was made of the effects of a failure using typically conservative assumptions.

115 The possible effects of a failure of the AVR were modelled by my TSC using the ERACS power system model of the AP1000 Electrical Network. The results of this study are presented in Report 2010-0697 (Ref. 54).

116 The study results are summarised and the Westinghouse proposals for protecting against the possibility of overvoltage due to a failure on the Main Generator AVR are assessed.

4.6.1 Assessment

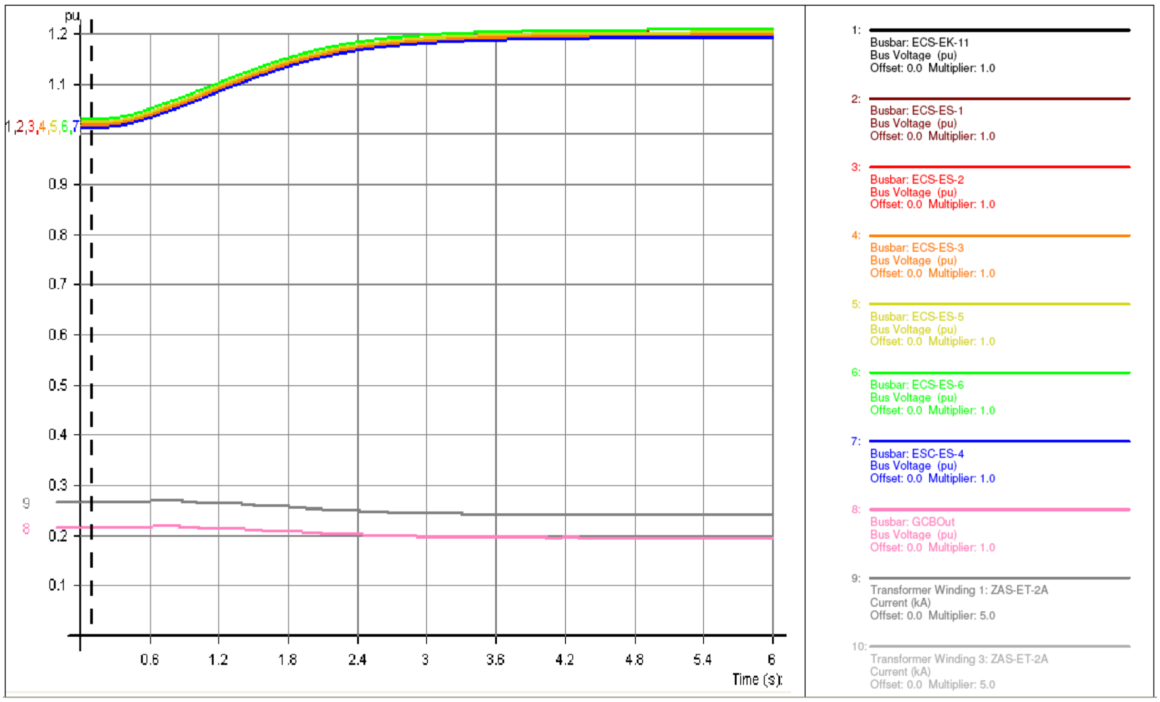
117 In the study, two scenarios were considered; one with the generator on light load to simulate house load operation with no grid connection and one with the generator connected to the grid on full load. The station auxiliary power is supplied through the

UATs. For the assessment it was assumed that no protective devices operate so the Generator Circuit Breaker does not trip due to fault conditions. Scenario 1 covers AVR failure when operating on house load with no grid connection. For Scenario 2 the power plant was assumed to be operating with the generator supplying power to the grid at full load. The results for Scenario 2 with the generator on full load are shown in Figure 1.

118 At a study time of t = 0.1s the Main Alternator AVR reference point set was altered from 1 to 1.3pu[1] to simulate a possible failure of the AVR in regulation performance. The simulation was of the effect of the failure rather than attempting to recreate precisely an actual AVR mode of failure.

119 Similar voltage increases were obtained for both scenarios with a 1.3pu AVR reference change resulting in voltages of 1.15pu to 1.2pu on the system busbars. The sustained overvoltage condition was reached in 1 second with the alternator on low load and 5 seconds with the alternator on full load.

Figure 1: Busbar Voltage and UAT Current following AVR increase (Full Load)



120 In the response to TQ-AP1000-822 (Ref. 8) Westinghouse have advised protective measures to protect against an AVR failure consisting of the following measures:

- Dual channel design.
- Over-excitation protection.
- Potential Transformer circuit fuse failure protection.
- AVR fault detection.
- Volts/Hz protection.
- Dual protection system.

[1] To simplify calculations electrical engineers use a system to normalise values known as the per unit system (pu). A pu is defined as the actual quantity (volts, amps, watts etc.) divided by the selected base level. For example if 600 volts was the base level a 0.8 pu would represent 480 volts.

4.6.2 Findings

121 The potential for an AVR failure to result in significant overvoltages on the Plant Electrical System has been demonstrated by the studies which have been undertaken.

122 I consider that protective measures proposed by Westinghouse to protect against the risk of an AVR fault are comprehensive and effective.

123 Assessment Finding **AF-AP1000-EE-008** requires the future licensee to carry out transient studies for each power plant to address the consequences of AVR failure for the actual equipment to be installed on an AP1000 in the UK. These studies should address the following:

- The upper limits of voltage that could be developed by the Main Alternator in the event of AVR failure relative to the voltage tolerance of the critical system loads.
- The compatibility between the settings being considered on the Main Alternator and the expected overvoltage resilience of the system and in particular critical plant such as battery chargers.
- The development of an overvoltage protection philosophy for the critical plant that takes account of voltages developed during AVR failure so as to quantify the risk of overvoltage failure and verify that it will not result in overvoltage stress at any point on the system.

4.7 Motor Starting Studies

124 The purpose of the motor start study was to simulate the voltage at the terminals of the starting and running motors and at nuclear island buses when the largest motor on each bus is started. For the study of supply from the Standby Diesel Generators, equipment details are not available as these are part of detail design so the study was carried out using library data based on preliminary equipment rating information. The aim of the simulation was to verify that start-up can take place. Three different supply arrangements were modelled as these represent the most onerous conditions for starting of motors:

- Supply from UAT with no Main Generator or Standby Diesel Generator – studied by Westinghouse.
- Supply from RAT with no Main Generator or Standby Diesel Generator – studied by Westinghouse.
- Supply from the Standby Diesel Generator – studied by TSC.

125 The Westinghouse studies are reported in Westinghouse document SMG-ZAS-E0C-001 (Ref. 23). The TSC studies were modelled using the ERACS power system model of the AP1000 Electrical System and are reported in 2010-0643 (Ref. 55).

126 The studies were performed by examining the starting of the largest motor on the switchboard with all other running motors operating.

4.7.1 Assessment

127 Curves were produced for each configuration showing busbar voltage, starting current and shaft speed for the motor during starting and running and shaft speeds for existing running motors, where relevant.

128 When the motor starts, the starting current causes a voltage drop at the busbars. When the bus voltage decreases, the AVR of the generator recovers the voltage to nominal. When the motor speed reaches close to 1pu the current drops down to 1pu in a very short period. Consequently, the voltage drop due to the internal impedance of the generator decreases sharply and terminal voltage increases. As the AVR of the generator is not able to respond as quickly as the rate of change of the load current, the busbar voltage overshoots when the motor current falls. The voltage then recovers to 1pu with the response of the AVR. This is typical of motor start-up and of voltage response performance during a successful motor start.

129 The acceptance criteria determined for a successful start is a minimum transient voltage of 0.8pu during motor starting.

4.7.2 Findings

130 In each case studied I consider that for GDA purposes the motor starts are acceptable with motor starting times and busbar voltages within acceptable limits.

131 I consider that this demonstrates that the largest motors can be started under the most onerous conditions without any adverse impact on the operation of existing running loads or on system voltage. Assessment Finding **AF-AP1000-EE-009** requires the future licensee to undertake motor starting studies for each site during detail design based on actual equipment ratings selected for the AP1000 in the UK.

4.8 Fast Bus Transfer

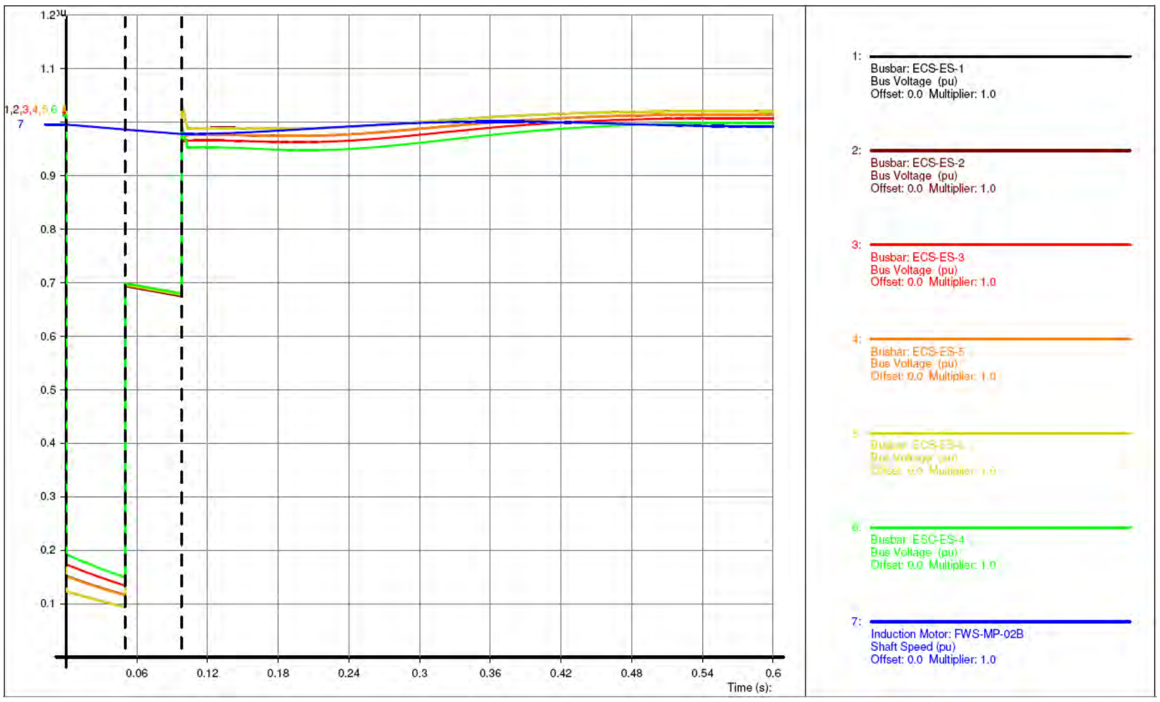
132 A fast bus transfer scheme is used by Westinghouse to transfer loads from the UAT supply to the RAT supply. This system is provided for investment protection only as no safety claims are placed on it. The purpose of this assessment is to determine whether operation of the fast bus transfer can adversely affect the integrity of the Electrical Distribution Network and its capability to ensure nuclear safety.

133 The assessment is based on the following:

- ERACS power system model of the Electrical System developed by the TSC Report 2010-0654 (Ref. 56)
- Westinghouse document APP-GW-E1-004 (Ref. 18).
- Westinghouse response to TQ-AP1000-827 (Ref. 8).
- Westinghouse response to TQ-AP1000-1105 (Ref. 8).

134 The fast bus transfer operates to switch loads from the UAT to RAT when a fault occurs with a transfer time allowing continuity of service. Initiation is from electrical faults on the Main Step Up Transformers, isophase bus duct, UAT or UAT secondary leads. Detection of a fault will initiate simultaneous signals to open the circuit breaker from UAT and close the supply from the RAT. If the transfer is not completed within the dead bus time limit then fast bus transfer is blocked and a delayed residual bus transfer is initiated.

Figure 2: Fast Bus Transfer with a Dead Time of 48ms



4.8.1 Assessment

135 Studies were carried out assessing the voltage on each bus in three different configurations as follows:

- Fast bus transfer with an assumed dead bus time of 48ms shown in Figure 2.
- Residual bus transfer with an assumed dead bus time of 3.076s shown in Figure 3.
- Fast bus transfer with delay in opening of the UAT circuit breaker M1 which results in an overlap time with both circuit breakers closed of 52ms shown in Figure 4.

136 The studies show that fast bus transfer results in voltages of the order of 90% initially with the voltage recovering within 1s which is acceptable.

137 Residual voltage transfer will result in motor loads tripping so a controlled restart will be required.

138 An overlap due to delayed opening of M1 circuit breaker could result in overcurrent stresses on both UAT and RAT. The Westinghouse response to TQ-AP1000-1105 (Ref. 8) states that electrical protection is provided during automatic transfer as the initiating event will be a short-circuit and overcurrent protection will operate to trip circuit breaker M2 and thus de-energise the bus.

139 A failure to trip M1 during manual transfer would result in the supplies from UAT and RAT being paralleled. Protection would be required to prevent this situation occurring.

Figure 3: Residual Bus Transfer with a dead time of 3.076s

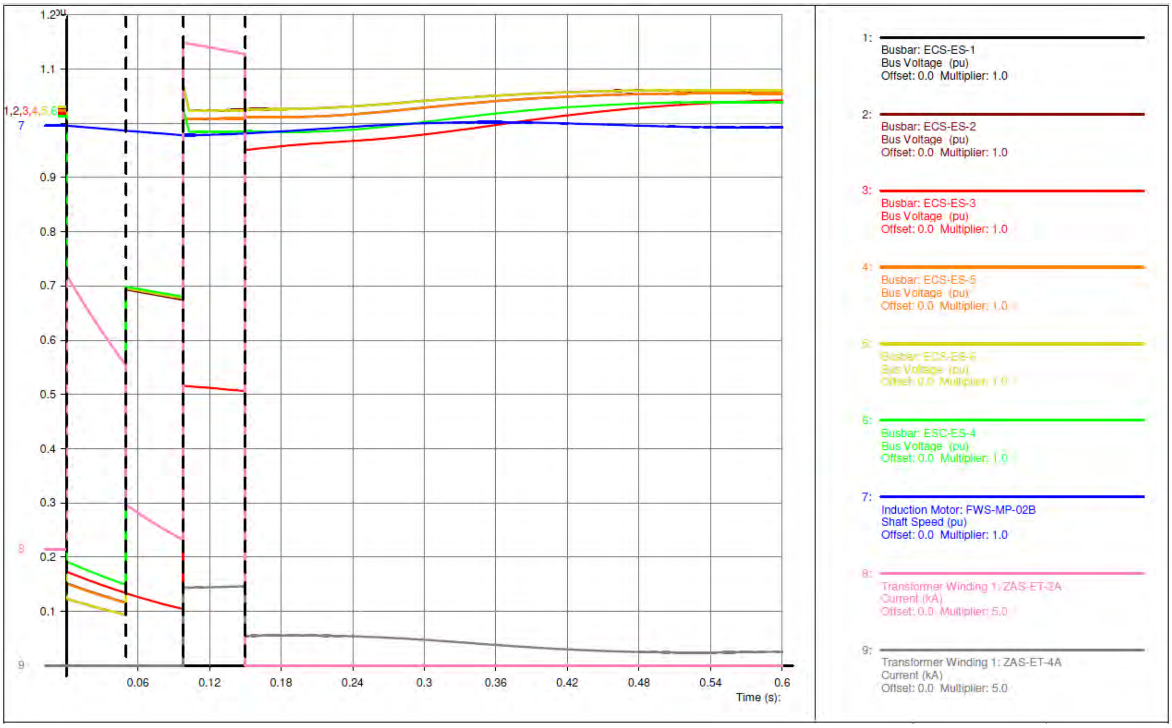
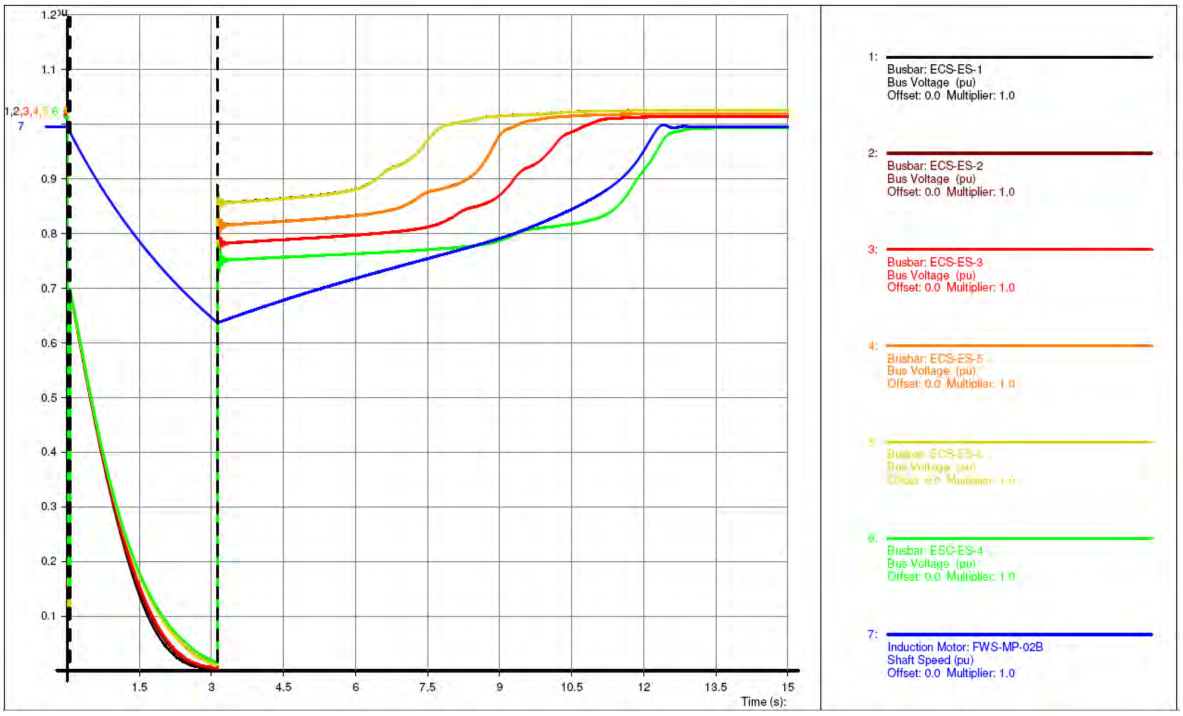


Figure 4: Fast Bus Transfer with Overlap Time of 52ms



4.8.2 Findings

140 I consider that the fast bus transfer operation does not have any adverse effects on the integrity of the Electrical Distribution System and its function to ensure nuclear safety provided that protection settings and lock-out times to initiate residual bus transfer are correct. These aspects are critical to the successful implementation of the scheme so will require detailed study by the future licensee.

141 I consider that protection will be required to prevent paralleling of M1 and M2 after a manual transfer.

142 Assessment Finding **AF-AP1000-EE-010** requires the following actions by the future licensee:

- Conducting studies to determine lock-out times.
- Conducting studies to determine protection settings for relays to prevent circuit breakers M1 and M2 being simultaneously closed during fault conditions.
- Provision of appropriate protection to prevent circuit breakers M1 and M2 remaining simultaneously closed following a manual transfer.

4.9 Grid Code Compliance

143 It is a requirement for a Connection Agreement to be in place for the AP1000 to be connected to the UK Grid. A requirement before this is put in place is for the grid technical requirements to be met. These technical requirements are defined in the UK Grid Code (Ref. 28).

144 The Connection Agreement for each reactor will be site-specific and this will be based on agreement of technical parameters for each site based on the specific grid connection arrangements. Assessment of the site-specific arrangements is outside the scope of GDA.

145 There are various requirements within the UK Grid Code (Ref. 28) for generating plant to remain connected at times of grid disturbances which are important for the grid operator in maintaining continuity of supply. However, this requires the Main Generator and the distribution network for the reactor to remain operational up to defined disturbance limits. It is the purpose of this assessment to ensure that the electrical support system for the reactor is not adversely affected by the requirement to operate the Electrical Distribution System at the limits defined in the UK Grid Code (Ref. 28).

146 This assessment is based on Westinghouse letter to ND reference UN REG WEC 000505 (Ref. 29) and the Westinghouse response to TQ-AP1000-1189 (Ref. 8). These consider the pertinent points in the UK Grid Code (Ref. 28) for which compliance is required in the design of the Electrical Distribution System for the AP1000.

4.9.1 Assessment

147 The UK Grid Code (Ref. 28) requires generating plant to remain connected over the frequency range of 47.5Hz to 52Hz. There is also a requirement to be able to operate for a period of 20 seconds each time the frequency goes in to the range of 47Hz to 47.5Hz. These requirements have an impact on the following equipment:

- Reactor Coolant Pumps (RCP).
- Battery chargers, inverters and C&I power supplies.
- AC motors.

148 Westinghouse has identified that equipment specifications will cover the requirements for the input frequency variations on the RCP drives, battery chargers, inverters and C&I power supplies.

149 Motors can be impacted by the frequency requirement as the driven load and absorbed power changes in response to frequency changes. Westinghouse have identified in the Codes and Standards Review (Ref. 30) that all motors will have to be individually assessed due to the requirement for 50Hz motors for the AP1000 in the UK. This assessment of motor suitability will include, as part of the analysis, an assessment by process engineers of the effects on motor operation over the frequency range of 47Hz to 52Hz.

150 The UK Grid Code (Ref. 28) Section C6.1.4 stipulates a voltage variation of ±10% for a limited time. Westinghouse state compliance in their communication UN REG WEC 000505 (Ref. 29). When the Main Generator is operating the main influence on the terminal voltage is the generator which is controlled by the AVR. When the Main Generator is not in operation the AP1000 auxiliaries are exposed to grid voltage variations. On-load tap changers are fitted to the MSUT, UAT and RAT which can, therefore, regulate the voltage on the auxiliary system. Westinghouse state that simulations have been carried out on the impact of grid voltage changes of ±10% and that satisfactory operation is maintained with no plant overloaded and no motors stalling.

151 Fault ride-through requirements are stipulated in Section C6.3.15 of the UK Grid Code (Ref. 28). This requires generating plant to remain connected and transiently stable for a fault on the grid resulting in a voltage of 15% with a clearing time of 140ms, 80% for 2.5 seconds, 85% for 3 minutes and 90% continuously. Westinghouse state that simulations have been conducted to demonstrate that the AP1000 design can meet the specified fault ride-through requirements.

152 Westinghouse has assessed other UK Grid Code (Ref. 28) requirements. These impose operational requirements on the Main Generator on subjects such as reactive power, power quality and generator voltage and frequency variations. Westinghouse confirmed in communication UN REG WEC 000505 (Ref. 29) that it is able to comply with these requirements and there is no impact on the Auxiliary Electrical System.

4.9.2 Findings

153 I consider that the work carried out by Westinghouse in providing a generic assessment of the implications of the UK Grid Code (Ref. 28) confirms that the important points have been considered to ensure compliance.

154 Westinghouse has stated that simulations have been carried out to confirm compliance and that these simulations demonstrate that there is no impact on the integrity of the Auxiliary Electrical System from UK Grid Code (Ref. 28) compliance. The results of these simulations have not been submitted to ND for assessment.

155 Assessment Finding **AF-AP1000-EE-011** requires the future licensee to carry out studies to prove UK Grid Code compliance can be achieved with no impact on the integrity of the Plant Electrical System.

4.10 Transient System Disturbances

156 A series of studies have been performed by Westinghouse and the TSC to investigate the responses of the Electrical System on the power plant to disturbances both internal and external which could challenge the stability of the Electrical System with the potential for loss of electrical supplies.

157 My assessment is based on the following:

- ERACS power system model of the Electrical System developed by the TSC covered by Report 2010-0643 (Ref. 55).
- Westinghouse document SMG-ZAS-E0C-001(Ref. 23).
- Westinghouse document UKP-GW-GL-064 (Ref. 24).
- Westinghouse document APP-GW-E1-004 (Ref. 18).
- Westinghouse response to TQ-AP1000-823 (Ref. 8).
- Westinghouse response to TQ-AP1000-824 (Ref. 8).

158 A number of scenarios have been studied to assess the resilience of the Electrical System to maintain stability and thus continuity of supply. The particular studies which have been performed consist of the following:

- Post-fault recovery following a three phase fault at the Standby Diesel Generator terminals.
- Post-fault recovery following a three phase fault at the grid connection point to UAT resulting in an islanding condition.
- Post-fault recovery following a three phase fault at the Main Generator or grid connection point terminals.

4.10.1 Post-fault Recovery Study – Diesel Generator

159 The purpose of the post-fault recovery study was to identify the recovery capability of the system following a three phase fault when operating with electrical supplies fed from the Standby Diesel Generators with no Main Generator or grid connection.

4.10.1.1 Assessment

160 When the fault occurs at the terminals of the Standby Diesel Generator, the bus voltage falls to zero. The motors will initially contribute current into the fault due to their internal voltage. The motor speed reduces during the fault period because the developed torque falls to zero.

161 After the clearance of the fault, the motor terminal voltage recovers and the motors will collectively draw more current than in the pre-fault condition because they are running more slowly. The magnitude and duration of this reacceleration current depends upon the duration of the fault and the voltage conditions in the post-fault period. If voltage does not recover sufficiently quickly some motors may stall and, in practice, could trip on overcurrent. The results of the post-fault recovery study were examined to identify if any of these symptoms of instability or stall were indicated.

162 The approach taken was to impose a 150ms duration fault and examine the results for evidence of instability. The fault duration was increased in steps of 100ms and after each step change in fault duration the results were examined for evidence of instability. The purpose of this approach to the study was to examine if there was an upper limit of fault duration above which instability could occur. A maximum duration of 2s was adopted because a fault duration of longer than this interval is not credible with a correctly graded circuit protection system.

163 The largest post-fault overvoltage calculated is 29% for the 150ms fault duration. This calculation is based on library models for the AVR which are not optimised for the actual installation.

4.10.1.2 Findings

164 The studies performed showed that the voltage can be recovered when operating from the Standby Diesel Generator with no evidence of instability.

165 The post-fault overvoltage calculated of 29% allows little margin on the overvoltage limits of equipment connected to the system. This can in practice be reduced by correct selection and setting of the Standby Diesel Generator AVR. Assessment Finding **AF-AP1000-EE-012** requires the future licensee to conduct studies based on actual diesel generator parameters and AVR settings to demonstrate that post-fault recovery on a diesel fed system will not impose excessive overvoltages on the system.

166 Assessment Finding **AF-AP1000-EE-012** requires the future licensee to carry out post-fault recovery studies for scenarios operating from the Standby Diesel Generators based on actual equipment ratings.

4.10.2 Islanding at 100% Power

167 The intention of this study was to simulate the effects on the Plant Electrical Distribution System of a loss of grid connection when the Main Generator is operating at full power. The requirement is to confirm that islanding from the grid does not result in unacceptable voltages on the Plant Electrical System which could result in failures of safety-critical equipment. As the Main Generator has not yet been selected, the simulation was carried out by my TSC using library data of typical generator characteristics. The study considered the following four scenarios which represent the most onerous conditions for islanding of the Main Generator and the Plant Electrical Distribution System from the grid:

- Scenario 1: three phase fault with duration of 0.2s applied at the point of connection to the grid followed by grid disconnection and the station auxiliary load supported by the Main Generator.
- Scenario 2: three phase fault with duration of 0.5s applied at the point of connection to the grid followed by grid disconnection and the station auxiliary load supported by the Main Generator.
- Scenario 3: three phase fault with duration of 0.2s applied at the point of connection to the grid followed by grid disconnection and the station auxiliary load supported by the Main Generator. Also all conventional island motors were tripped so that the overvoltage is then likely to be most extreme.
- Scenario 4: 100% load rejection without a prior grid fault condition.

4.10.2.1 Assessment

168 The results for Scenario 1 are shown in Figure 5. At the inception of the fault the Main Generator contributes fault current via the MSUT and a proportion of the system voltage is maintained. On fault clearance the voltage recovers at the same time as the generator AVR is increasing the excitation to maintain system voltage which results in an overvoltage on the first cycle of the recovery voltage. The transient voltage at switchboard ECS-ES-6 reaches a maximum value of 1.164pu.

169 Scenario 2 with a 0.5s fault produces similar results to Scenario 1 with a marginal increase in the maximum transient voltage at switchboard ECS-ES-6 to 1.178pu.

170 Scenario 3 considers the 0.2s fault as for Scenario 1 but with the conventional island motor load tripped during the fault. This is done to consider the impact of the post-fault

current demand on the system voltage and results in a maximum transient voltage at switchboard ECS-ES-6 of 1.18pu.

Figure 5: Scenario 1: Islanding Following a 0.2s three phase Fault at Grid Connection

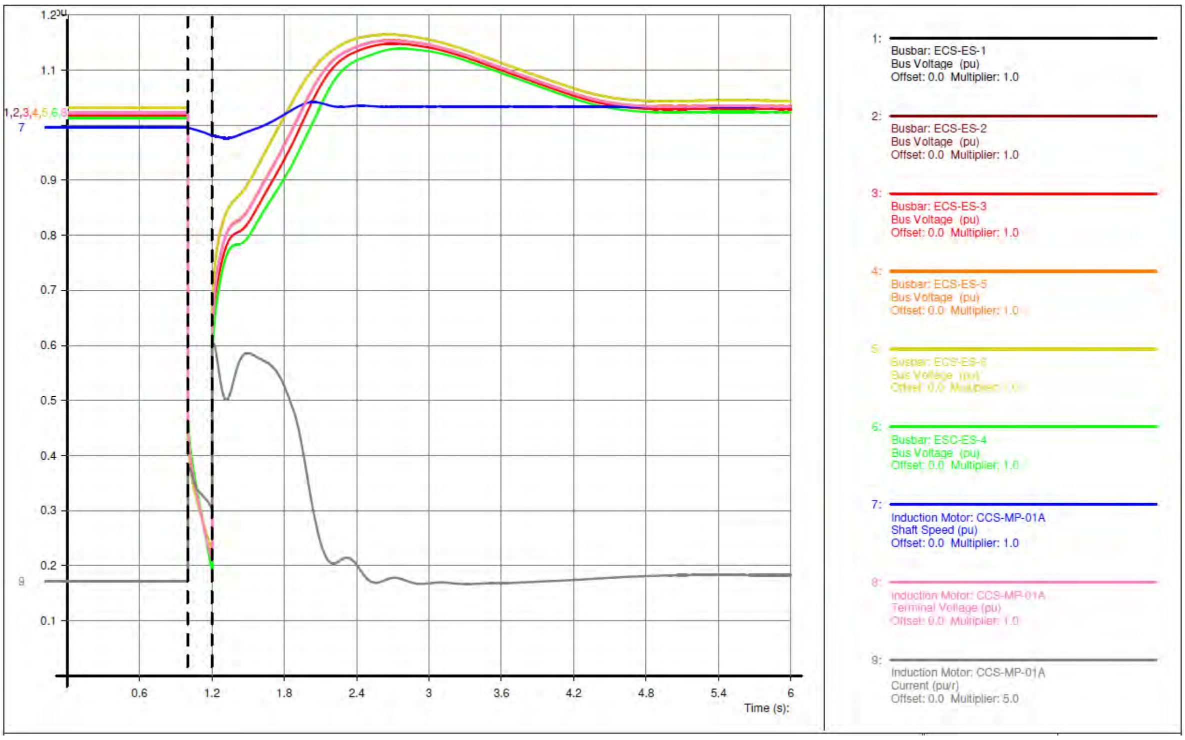
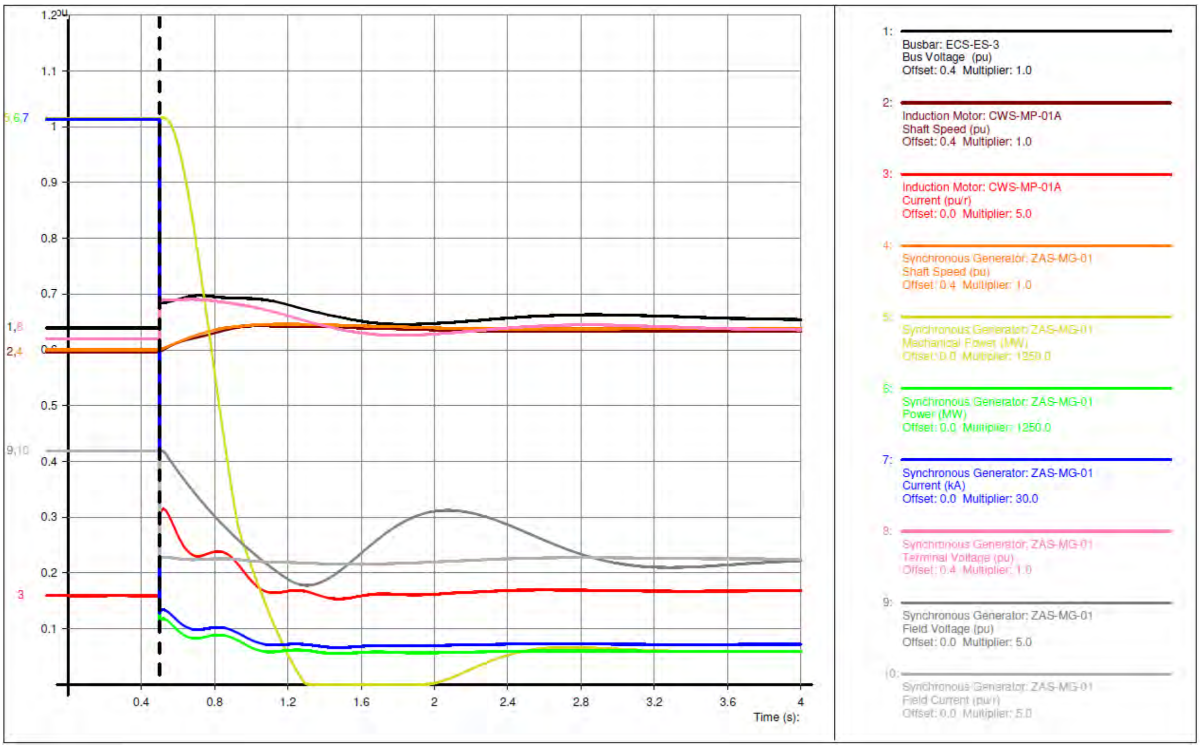


Figure 6: Scenario 4: 100% Load Rejection Without a Prior Grid Fault Condition



171 Scenario 4 considers a loss of grid connection resulting in islanding of the Main Generator with no prior grid fault condition. The results of this study are shown in Figure 6. This considers initial conditions of generator power output of 1266 MW which reduces to 74 MW on grid disconnection. The case considered resulted in a maximum transient voltage 1.09pu. Studies showed that this value is influenced by the reactive output of the generator prior to load rejection.

172 Studies have been carried out by Westinghouse investigating the effects of 100% load rejection of the Main Generator to an islanding condition. The results of these studies are recorded in Westinghouse document UKP-GW-GL-064 (Ref. 24). The results of the Westinghouse studies show a close correlation with the results from Scenario 4 of the studies conducted by the TSC.

4.10.2.2 Findings

173 The main findings from the studies performed are as follows:

- Islanding of the Main Generator from full power will result in an overvoltage on the islanded system.
- The overvoltage will occur in all situations irrespective of whether a fault occurs immediately prior to the islanding.
- The overvoltage is greater when a fault occurs immediately prior to the islanding of the system.
- The reactive power output from the generator immediately prior to the islanding affects the value of the system overvoltage on recovery.
- Westinghouse states that there is a contractual overvoltage limit of 118% following load rejection. The studies show that this value is not exceeded.
- I consider that the study results show that the islanding of the Plant Electrical System can be accepted by the system with overvoltages restricted to acceptable levels.

174 I consider that the future licensee should conduct studies to consider the effects of islanding of the Electrical System based on actual site arrangements using detail design data specific to the AP1000 in the UK. This should take account of scenarios with and without prior faults and should consider the range of power factors prior to the islanding of the plant. This requirement is the subject of Assessment Finding **AF-AP1000-EE-013**.

175 The future licensee should utilise the results of these studies in determining the transient voltage limits for electrical equipment. The requirement to consider voltage limits is defined in Assessment Finding **AF-AP1000-EE-016**.

4.10.3 Post-fault Recovery Study – Grid Faults

176 The purpose of the post-fault recovery study is to investigate the recovery capability of the Electrical System following a three phase fault at the grid or main 11 KV switchboard terminals. Failure of the Electrical System to recover could result in loss of supply to system loads supporting nuclear safety. In these studies it is assumed that the grid remains connected to the plant.

177 Studies were performed by Westinghouse and reported in document UKP-GW-GL-064 (Ref. 24). Further studies were then performed by the TSC recorded in report 2010-0656 (Ref. 57) using longer fault clearing times. The longer fault clearance times result in the most severe conditions as there is a higher motor reacceleration load for longer faults which have greater potential for system stability. The upper limit on fault clearance time

is determined by maximum protection operating times for the incoming grid feeders before the grid connection is tripped.

178 The following studies were performed by the TSC:

- Scenario 1: three phase fault at grid substation for 200ms with plant fed from UAT. The results of this study are shown in Figure 7.
- Scenario 2: three phase fault at grid substation for 200ms with plant fed from RAT. The results of this study are shown in Figure 8.
- Scenario 3: three phase fault at switchboard ECS-ES-3 for 100ms with plant fed from UAT. The results of this study are shown in Figure 9.
- Scenario 4: three phase fault at switchboard ECS-ES-1 for 100ms with plant fed from UAT.
- Scenario 5: three phase fault at switchboard ECS-ES-3 for 100ms with plant fed from RAT.
- Scenario 6: three phase fault at switchboard ECS-ES-1 for 100ms with plant fed from RAT.

179 Further studies were conducted by Westinghouse considering the effects of 300 ms 3 phase and 2 phase faults. The results of these studies are covered by the response to TQ-AP1000-824 (Ref. 8).

4.10.3.1 Assessment

180 The results of Scenario 1 are shown in Figure 7. At the inception of the fault the generator contributes fault current via MSUT and a proportion of system voltage is maintained falling to approximately 20% by the end of the fault period. After the fault is cleared the voltage recovers whilst the AVR is increasing the excitation to maintain the terminal voltage which results in a transient overvoltage. The transient overvoltage at switchboard ECS-ES-6 reaches a maximum of 1.07pu 1.8s after fault clearance. The post-fault current in UAT is greater than the pre-fault current due to the demand from reaccelerating system motors which has the effect of limiting the peak transient overvoltage on the station busbars.

181 For Scenario 2, the results are shown in Figure 8. The supply is derived from a separate grid source which is not influenced by the Main Generator and thus the system response is different. The internal voltage drops to 5% as the mechanical energy from the rotation of the internal motors is the only form of voltage support. On fault clearance there is no overvoltage tendency as the generator is not providing voltage support via the AVR and the switchboard voltages recover at a rate determined by the reacceleration of station motors.

182 For Scenario 3, the results are shown in Figure 9. These results are typical for each of Scenarios 3 to 6. A fault on an internal switchboard leads to a deeper internal voltage depression. The voltage then returns to nominal more quickly following fault clearance due to the grid transformers preventing the source voltage being affected by the fault.

183 There is a good level of agreement between the studies performed by Westinghouse and by my TSC. No post-fault instability was found in any of the configurations or fault durations studied. I consider that this generic assessment shows a good resilience of the system to faults with good stability margins.

Figure 7: Scenario 1 - Post-Fault Recovery on Grid Fed from UAT with 200ms Fault

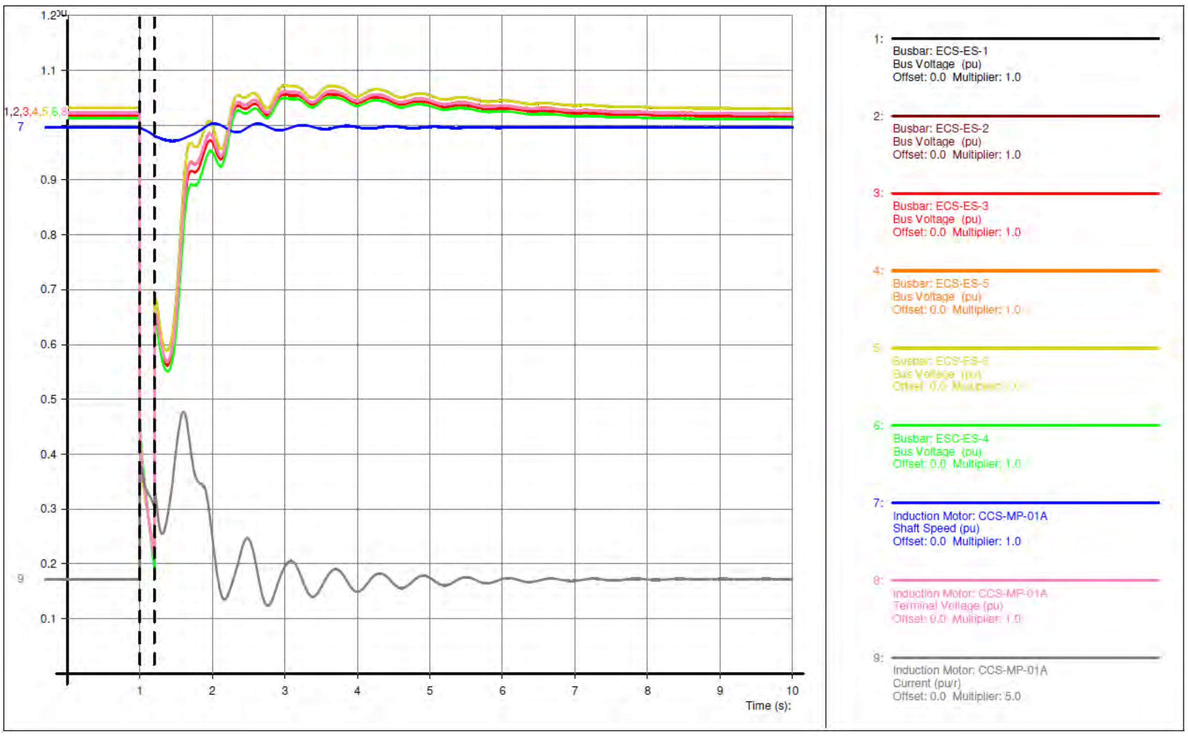


Figure 8: Scenario 2 - Post-Fault Recovery on Grid Fed from RAT with 200ms Fault

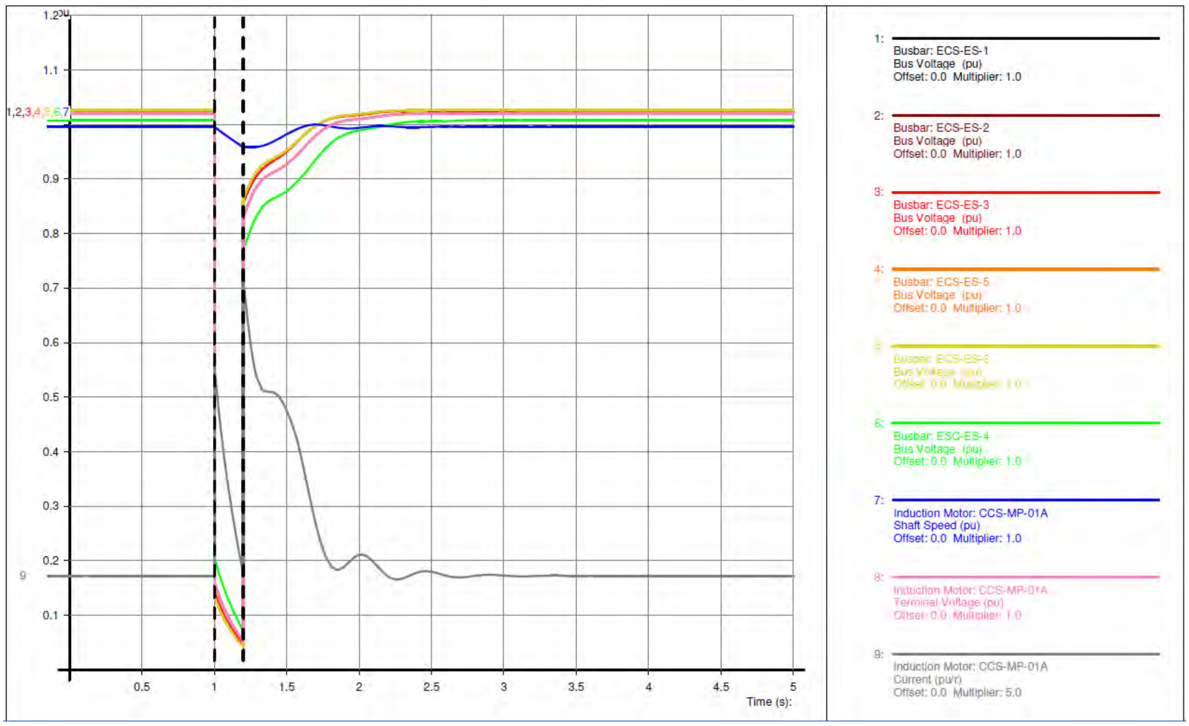
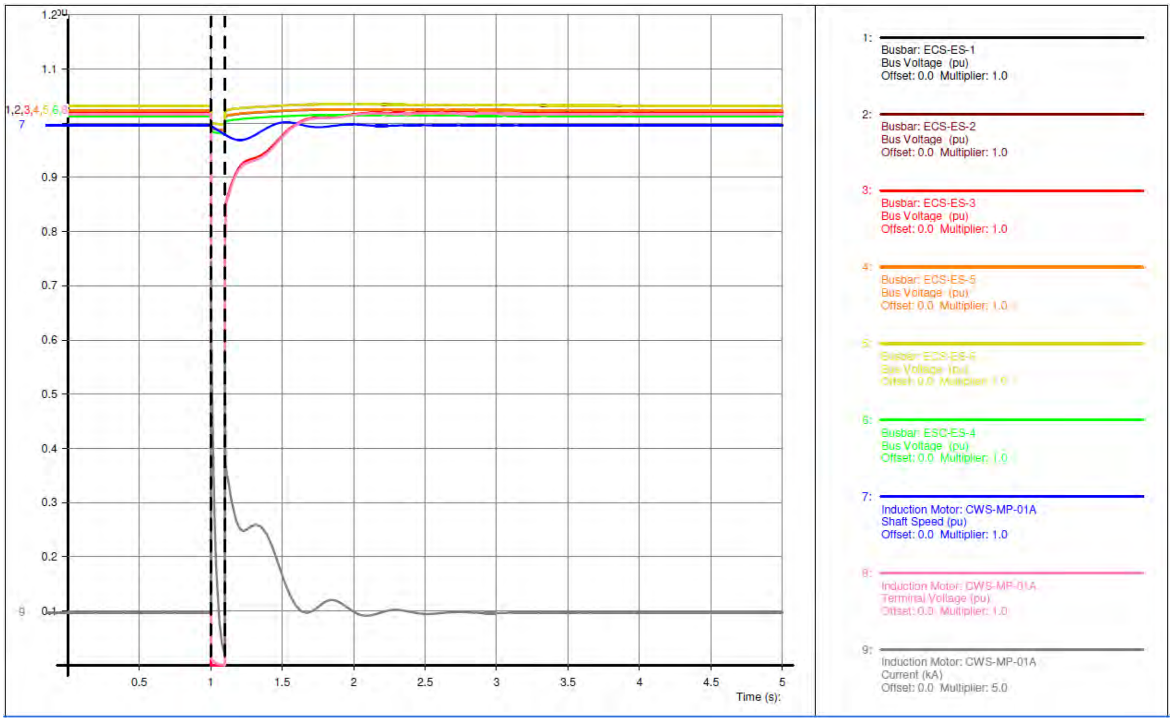


Figure 9: Scenario 3 - Post-fault Recovery on ECS-ES-3 With 100ms Fault Fed from UAT



4.10.3.2 Findings

184 The future licensee shall conduct post-fault recovery studies for the system following grid faults based on actual site conditions. This is identified in Assessment Finding **AF-AP1000-EE-014**.

185 The future licensee shall utilise the results of these studies in determining voltage limits for electrical equipment. The requirement to consider and define voltage limits is covered by Assessment Finding **AF-AP1000-EE-016**.

4.11 Power Quality

186 The potential sources of harmonic distortion are the battery chargers and the RCP Variable Frequency Drives. Consideration is given to the effects of voltage distortion resulting from these sources.

4.11.1 Assessment

187 The Reactor Coolant Pumps are controlled by large variable frequency drives which have the potential to cause significant harmonic distortion on the Electrical Distribution System. Design details for the drive unit proposed, show that the drives are designed to minimise the generation of harmonics and the manufacturer states that no filtration is required to protect against harmonic distortion generated by these drives.

188 A study was carried out by the TSC using the ERACS power system model of the AP1000 Electrical System to assess the potential harmonic distortion on the AC system reported in TSC Report 2010-0799 (Ref. 58). It has been assumed that other than the Reactor Coolant Pumps the only non-linear loads on the system are battery chargers. As the detail design of the battery chargers has not been completed, the assessment has

been carried out on the assumption of battery chargers consisting of phase controlled rectifiers of the 6 pulse type as this represents the most pessimistic condition.

189 The maximum number of battery chargers on the system on an individual Low Voltage (LV) switchboard is on switchboards ECS-EC-111 and ECS-EC-211, so the assessment has been carried out based on switchboard ECS-EC-111 as being representative of the worst case. This switchboard has one Class 1 24 hour battery charger and two Class 2 battery chargers connected.

190 Scenario 1 considers switchboard ECS-EC-111 supplied from the Standby Diesel Generator. This scenario is considered because it represents the lowest rated supply source which could result in the highest voltage distortion. The harmonic profile was examined with connected loads of the Class 2 battery chargers each rated at 117 KVA and the Class 1 battery charger rated at 78 KVA.

Table 2: Scenario 1 - Harmonic Profile at Busbar ECS-EC-111

Harmonic Number	Voltage (% of fundamental) at LJA when charger feed	Compatibility Levels for Class 1 Equipment	Compatibility Levels for Class 2 Equipment	Compatibility Levels for Class 3 Equipment
THD	5.21	5	8	10
5	1.54	3	6	8
7	1.56	3	5	7
11	1.59	3	3.5	5
13	1.62	3	3	4.5
17	1.68	2	2	4
19	1.73	1.8	1.8	3.5
23	1.80	1.4	1.4	2.8
25	1.90	1.3	1.3	2.6
29	2.12	1.1	1.1	2.1

191 The results for Scenario 1 are shown in Table 2. This shows that the 23rd and 25th harmonic exceed the levels for Class 2 equipment and the 29th harmonic exceeds the limit for Class 3 equipment as defined in IEC 61000-2-4: 2002 (Ref. 46). This would need to be verified by the future licensee to ensure that the voltage waveform is compatible with the battery chargers and all other equipment supplied from the same point of coupling.

192 Scenario 2 assesses the condition where the C&I systems, which are normally sourced from the inverters, are fed from the alternative supply via the inverter bypass from a regulated voltage supply. This could occur if the inverter control circuits detected an internal fault causing automatic transfer to the bypass. The harmonic content of the C&I system load current would then be expected to cause voltage distortion with the supply taken through the regulated voltage supply. This compares with the normal supply from the inverter where the output is regulated to minimise load distortion.

193 In this scenario it is assumed that collectively the C&I equipment has a harmonic current frequency spectrum relative to fundamental current similar to that of a rectifier. The analysis has been conducted to establish the amplitude levels of the harmonic

component relative to the total fundamental load current that gives rise to a distortion equivalent to the Class 1 limits defined in IEC Standard 61000-2-4: 2002 (Ref. 46).

194 The results in Table 3 show that the current harmonic levels could give rise to voltage harmonic levels equivalent to the voltage limits of Class 1 equipment as defined in IEC 61000-2-4: 2002 (Ref. 46). This condition should be examined by the future licensee to verify that the voltage waveform distortion is compatible with the C&I equipment requirements when supplied from the bypass. In general the study shows that it is important that power quality conditions on the supplies to the critical battery chargers and inverters while on bypass are examined by study during the site-specific design. This will verify compatibility with all equipment supplied from all switchboards supplying critical equipment.

Table 3: Scenario 2: Harmonic Spectrum of the C&I Load Current Giving Rise to a 5% Voltage THD at the Regular Transformer Output

Harmonic Number	Current Harmonic Content Relative to Fundamental	Voltage (% of fundamental) at ECS-EC-111	Compatibility Levels for Class 1 Equipment
THD		5.0	5
5	13.64%	1.4	3
7	9.74%	1.5	3
11	6.20%	1.6	3
13	5.25%	1.6	3
17	4.01%	1.7	2
19	3.59%	1.7	1.8
23	2.97%	1.8	1.4
25	2.73%	1.8	1.3
29	1.53%	1.9	1.1

4.11.2 Findings

195 I consider that a harmonic study should be conducted by the future licensee to verify that voltage distortion resulting from the Reactor Coolant Pump Variable Frequency Drives does not have a safety impact on other safety systems. This requirement is the subject of Assessment Finding **AF-AP1000-EE-015**.

196 I consider that the worst case voltage distortion due to the battery chargers should be examined by the future licensee to verify that the voltage waveform distortion is compatible with the battery chargers and all other equipment supplied from the same point of coupling. Assessment Finding **AF-AP1000-EE-016** covers the requirement for the future licensee to incorporate this in purchase specifications.

197 I consider that the future licensee should conduct studies to verify that voltage distortion is within the compatibility levels of the C&I equipment that are sourced from the inverters in all inverter operating modes. Assessment Finding **AF-AP1000-EE-015** covers the requirement for the harmonic analysis to be undertaken.

4.12 Codes and Standards Analysis

198 The Electrical System of the US Standard AP1000 plant was originally designed for US applications and was based on 60Hz operating frequency and US Electrical Codes and Standards. It has been recognised that an AP1000 in the UK would require 50Hz operation and to be compliant with BS and IEC Standards.

199 An analysis of the full implications of this change was carried out by Westinghouse with input from the Utility members of the European Passive Plant Group (EPP). This analysis is provided in Westinghouse document UKP-GW-GL-059 (Ref. 30) which has been used as the basis of my assessment.

4.12.1 Switchgear Standards and Operating Voltages

200 This considers the conclusions from the Westinghouse analysis related to operating voltages, fault levels and applicable standards.

4.12.1.1 Assessment

201 The ratings and standards detailed in Table 4 below were adopted as standards by Westinghouse to be used as the basis of GDA.

Table 4: Switchgear Ratings

	HV Switchgear	**LV Switchgear**
Operating Voltage	11kV	400V
Frequency	50Hz	50Hz
three phase RMS Fault Current	50kA	50kA
Switchgear Standard	BS EN 62271-200 (Ref. 64)	BS EN 60439-1 (Ref. 65)
Circuit breaker Standard	BS EN 62271-100 (Ref. 25)	BS EN 60947-2 (Ref. 66)
Internal Arc Classification	AFLR 50kA for 0.5s	Not defined

202 The fault rating defined for LV switchgear is not sufficient to meet the fault currents identified by the fault calculations the results of which are recorded in Table 1.

203 Comparisons are performed in Westinghouse document UKP-GW-GL-059 (Ref. 30) between the requirements of IEC and IEEE Standards to confirm that the requirements for such as switching capability and dielectric performance are broadly equivalent. It is concluded by Westinghouse that the use of IEC Standards would not be detrimental to the AP1000 design in the UK.

204 The space requirements for switchgear complying with IEC Standards have been assessed by Westinghouse and they have concluded that it is possible to fit IEC compliant equipment within the envelope of the AP1000 design.

205 An exception is identified by Westinghouse where it is proposed to utilise IEEE C37.013 (Ref. 67) standard switchgear for the Generator Circuit Breaker as there is no suitable IEC Standard to cover such devices.

206 Another exception identified by Westinghouse where it is proposed to utilise ANSI standard switchgear in accordance with IEEE C37.20 (Ref. 68) for the Class 1 Reactor

Coolant Pump isolation circuit breakers. These operate at 60Hz fed from the variable frequency drives and are required to trip the RCPs. The specification of the switchgear for this application would be identical to that for the 60Hz design for AP1000.

4.12.1.2 Findings

207 I find the proposals for codes and standards for switchgear to be generally acceptable for generic assessment. An assessment has been carried out by Westinghouse to ensure that switchgear complying with IEC Standards will fit in the available space within the AP1000 design.

208 The future licensee shall correctly define fault ratings for LV switchgear to match the calculated levels from the fault study. The requirement to do this is covered in Assessment Finding **AF-AP1000-EE-017**.

209 I accept the Westinghouse proposals to use ANSI standard switchgear for the Generator Circuit Breaker and Reactor Coolant Pump circuit breakers.

210 The future licensee shall prepare detailed specifications for electrical equipment to IEC Standards to meet the plant requirements. This requirement is covered in Assessment Finding **AF-AP1000-EE-018**.

4.12.2 DC and Inverter Systems

211 This section considers the equivalence between IEEE and IEC Standards for DC and AC Uninterruptible Power Supply (UPS) systems and considers the acceptability of the Westinghouse proposals.

4.12.2.1 Assessment

212 Westinghouse state that charger and inverter equipment complying with IEEE 308 (Ref. 69) and IEEE 323 (Ref. 70) will comply with the equivalent IEC Standards BS EN 61225 (Ref. 71) and BS IEC 60780 (Ref. 72) with only minor modifications. Westinghouse does not quantify these modifications. Westinghouse state that IEEE Standards provide more detailed requirements than the equivalent IEC Standards.

213 Westinghouse state that software qualification standards were not always listed by manufacturers. This would have to be included by the future licensee in equipment purchase specifications. The assessment of software qualification is covered in Section 4.16.

214 Westinghouse state that European EMI compliance is not covered by US manufacturers. Compliance with the EU directive 2004/108/EC (Ref. 32) is a mandatory requirement which would have to be included in purchase specifications by the future licensee. The assessment of EMI is covered in Section 4.19.

215 The IEEE Standards proposed by Westinghouse for UPS systems are related to US safety classifications.

4.12.2.2 Findings

216 I accept the Westinghouse proposal to utilise IEEE Standards for specifying UPS systems on the basis that they are more comprehensive. However, I would expect that the future licensee should specify that full compliance with appropriate IEC Standards is maintained. This requirement is defined in Assessment Finding **AF-AP1000-EE-019**.

217 I require the future licensee to produce specifications to define protection against EMI and arrangements shall be made for compliance with the requirements of EU directive 2004/108/EC (Ref. 32). This requirement is defined in Assessment Finding **AF-AP1000-EE-020**.

218 I require the future licensee to specify full compliance with software qualification requirements for Smart Devices as defined in section 4.16. This requirement is defined in Assessment Finding **AF-AP1000-EE-021** and is also related to GDA Issue No **GI-AP1000-CI-05** in ND's Step 4 C&I Assessment Report (Ref. 61).

219 I require the future licensee to specify full compliance with UK safety classifications. This requirement is defined in Assessment Finding **AF-AP1000-EE-022**.

4.12.3 Motors

220 Westinghouse state that the AP1000 standard plant design is based on the use of US National Electrical Manufacturers Association (NEMA) Standard 460V 60Hz motors. The design utilises modular units with skid mounted assemblies containing motors. I have assessed the Westinghouse proposals for utilising IEC motors in an AP1000 design in the UK.

4.12.3.1 Assessment

221 Westinghouse has identified the standard LV motor as 400V 50Hz to IEC Standards. The requirement has been identified to individually assess motor requirements taking into account the following factors:

- Motor frame sizes are not expected to increase significantly when using IEC motors in lieu of NEMA motors for a given speed and rating.
- The shaft centreline will usually be higher for IEC motors.
- The lower synchronous speed of 50Hz motors will require accounting for in the driven load by re-gearing or equipment modification.
- Motor voltage and frequency tolerances will accommodate the worst case envelope of grid and generator conditions.

222 Westinghouse identify the Reactor Coolant Pumps as an item where US Codes and Standards will apply as these are a custom built item for the AP1000 fed from the Variable Frequency Drives (VFD) with a 60Hz supply.

223 Westinghouse state that certain specialist motors forming integral parts of devices such as valve actuators would be to the 60Hz US design.

224 No specific mention is made of HV motors. I would expect the same principles as used for LV motors to be followed for the design utilising IEC Standard 50Hz motors.

4.12.3.2 Findings

225 I consider the proposals for the LV motors to be acceptable. I expect that due account be taken of the requirements for metrication of equipment when the assessment is carried out for individual drives. The requirement for the future licensee to assess each motor and determine adequate ratings for IEC Standard 50Hz 400V motors is detailed in Assessment Finding **AF-AP1000-EE-023**.

226 I consider the proposals for the RCPs to be acceptable. The full requirements of Reactor Coolant Pumps and associated equipment are assessed in Section 4.20.

227 I require specialist motors which form integral parts of devices to be fully assessed for their suitability for installation on the 400V 50Hz system. This requirement is defined in Assessment Finding **AF-AP1000-EE-024**.

228 I require that HV motors be subject to the same assessment as LV motors to ensure that appropriately rated IEC Standard motors are utilised. This requirement is covered by Assessment Finding **AF-AP1000-EE-023**.

4.12.4 Cabling

229 This considers the various standards applicable to cable selection and sizing. The assessment of the routing and sizing of cables is covered in Section 4.3.

4.12.4.1 Assessment

230 Westinghouse document UKP-GW-GL-059 (Ref. 30) gives consideration to the relative merits of compliance with the US Standard NFPA 70 (Ref. 33) and the British Standard BS7671 (Ref. 34). The main issue which arises is the consequences of utilising armoured cable in line with common UK practice.

231 The conclusion reached by Westinghouse is that for the purposes of GDA the cable should be non-armoured and sized and installed in accordance with BS 7671 (Ref. 34).

4.12.4.2 Findings

232 I accept the Westinghouse proposals to base their design for the AP1000 on the use of non-armoured cable. The issue which will be addressed in the detailed assessment of cabling is the provision of mechanical protection for the non-armoured cables. Cabling and cable routing are covered in more detail in Section 4.3.

4.12.5 Earthing and Lightning Protection

233 The AP1000 has been designed with a detailed earthing and grounding philosophy. This section considers the Westinghouse proposals for earthing the AP1000 for UK applications.

4.12.5.1 Assessment

234 The assessment in document UKP-GW-GL-059 (Ref. 30) considers the various standards applied to earthing and lightning protection and identifies that different standards apply in different countries. It concludes that the earthing system of an AP1000 should comply with the following standards:

- BS 7430: 1998 (Ref. 35).
- BS 6739: 2009 (Ref. 36).
- BS 7354: 1990 (Ref. 37).
- BS 7671: 2008 (Ref. 34).
- British Electricity Association EA-TS 41-24 (Ref. 38).
- BS EN 62305-1: 2006 (Ref. 39).

4.12.5.2 Findings

235 I consider that the proposals for addressing the codes and standards applicable to earthing and lightning protection are acceptable. The full assessment of earthing and lightning protection is included in Section 4.14.

4.12.6 Cable Penetrations

236 The standard AP1000 plant is designed with cable penetrations through containment structures in line with US Standards. This section considers the options for the AP1000 for UK applications.

4.12.6.1 Assessment

237 The standard AP1000 plant is designed with cable penetrations to IEEE 317:2006 (Ref. 40). Westinghouse has conducted a comparison with the equivalent IEC 60772: 1983 (Ref. 41). Westinghouse states that the clause by clause comparison has not identified any conflicting requirements between the two standards.

238 The Westinghouse proposal is to procure the penetrations in accordance with the IEEE standard as there is no difference in the requirements of the different standards.

4.12.6.2 Findings

239 I consider that the Westinghouse proposal to use the existing US Standards for the electrical penetrations is acceptable. I expect Westinghouse to provide confirmation that penetrations to US Standards meet all IEC Standard requirements. Assessment Finding **AF-AP1000-EE-032** has been raised to define this requirement.

4.12.7 Diesel Generators

240 This section considers the application of Electrical Codes and Standards to the design of the electrical sections of the diesel generators.

4.12.7.1 Assessment

241 Westinghouse state that diesel driven plant is mechanical equipment. In its response to TQ-AP1000-974 (Ref. 8), Westinghouse state that the normal practice is for specifications for this type of equipment to be incorporated into mechanical specifications detailing all electrical requirements. Westinghouse states that this specification will define all electrical equipment to be in accordance with all relevant IEC and European Union Electrical Codes and Standards.

242 I note that the Westinghouse statement only applies to the Standby Diesel Generators. I expect the same approach to be applied to the Ancillary Diesel Generators.

4.12.7.2 Findings

243 Assessment Finding **AF-AP1000-EE-025** requires the future licensee to produce electrical specifications for incorporation in the purchase specifications for the Standby and Ancillary Diesel Generators. These specifications shall define the requirements for equipment to IEC Standards.

4.13 Fast Transient Disturbances

244 TQ-AP1000-545 (Ref. 8) required Westinghouse to justify its claims by providing arguments and evidence to show that fast transient disturbances on the Electrical Power Systems will not cause loss of essential services due to damage or disruption to these services. The particular areas to be considered were:

- Capacitive switching.
- Current chopping.
- Re-strike.
- Voltage escalation.
- Pre-strike.
- Virtual current chopping.

4.13.1 Assessment

245 Westinghouse's response to TQ-AP1000-545 (Ref. 8) states that issues due to capacitive switching would not arise as there are no capacitor banks on the AP1000 design either for power factor correction or for motor starting. The response then states that there are no long open circuited lines which would pose capacitor switching concerns. TQ-AP1000-604 (Ref. 8) requested substantiation of the claims made. In response, Westinghouse identified the cable with the largest capacitance and provided details and selection criteria for surge arrestors which will be supplied mounted in switchgear.

246 Westinghouse's response to TQ-AP1000-545 (Ref. 8) states that current chopping is prevented by the design of vacuum circuit breaker contact materials and by the provision of surge arrestors in switchgear. TQ-AP1000-605 (Ref. 8) requested substantiation of the statements made. In response, Westinghouse provided details of actual chopping current limits which are achievable with vacuum interrupters. Further substantiation is provided by Westinghouse that a current chop would not result in voltage escalation due to multiple re-ignitions being prevented by the use of surge arrestors and by design of transformers. An example is provided from an AP1000 plant design of a transformer where it is shown that the design does not allow sufficient stored energy for a re-ignition to occur.

247 Westinghouse's response to TQ-AP1000-545 (Ref. 8) explains that re-strike occurs when the rate of rise of recovery voltage exceeds the rate of build up of dielectric strength between circuit breaker contacts. The protection provided against this is surge arrestors in the circuit breaker cubicles. Further clarification was requested on the selection of surge arrestors in TQ-AP1000-606 (Ref. 8). This provided details of studies conducted on the AP1000 design which showed that small high voltage motors were susceptible to re-strikes. Some of the means for protecting against this are described such as R-C snubbers, surge capacitors or surge arrestors.

248 The issue of voltage escalation is addressed in the responses by Westinghouse to the issues of current chopping which are covered in responses to TQ-AP1000-545 (Ref. 8) and TQ-AP1000-605 (Ref. 8).

249 Westinghouse's responses to TQ-AP1000-545 (Ref. 8) and TQ-AP1000-607 (Ref. 8) consider the factors which may cause overvoltages or high inrush currents due to pre-striking. The responses calculate the maximum system capacitance and demonstrate that this is sufficiently low as to prevent any adverse system effects from pre-striking.

250 Westinghouse considers the possibility of virtual current chopping occurring in the responses to TQ-AP1000-545 (Ref. 8) and TQ-AP1000-608 (Ref. 8). Virtual current

chopping, which can lead to damaging overvoltages, occurs when re-ignition causes high frequency currents in one phase to be induced in the other two phases. This can result in a high frequency current zero if the magnitude is equal to the power frequency load current which can result in chopping a very high power current. This is prevented in the AP1000 design by the measures to protect against re-ignition which is the initiator of virtual current chopping.

4.13.2 Findings

251 I consider that the measures described by Westinghouse to protect against the effects of fast transient disturbances show a good understanding of the potential threats to the Electrical Distribution System and the measures required to provide protection against these phenomena. For a generic assessment this provides adequate justification of the steps taken by Westinghouse to ensure that adequate protection is in place.

252 Fast transients are highly dependent on matters of detail and therefore this topic needs to be addressed during the site-specific assessment. The future licensee will need to analyse the threats from fast transients based on the actual site configuration and then identify the measures to protect against such transients. This requirement is identified in **AF-AP1000-EE-026**.

4.14 Earthing

253 The assessment of the earthing provisions is based on Westinghouse System Specification Document CPP-EGS-E8-001 (Ref. 43). Table 5 identifies the earthing methods employed for each part of the Electrical Distribution Network.

Table 5: Summary of AP1000 Power System Earthing Methods

System	Voltage	Method of Earthing
Main turbo-alternator	24kV AC three phase	High Impedance earthing via a neutral grounding transformer. Referred resistance equivalent to between 1385 and 2770 ohms (limiting to 5-10 amps). 1 minute rated.
UAT and RAT secondary providing supplies to the conventional and nuclear island	11kV AC three phase	3.3 ohms Low resistance earthed rated to provide 1000 amps for 10s.
On-site Standby Diesel Generators	11kV AC three phase	High resistance earth by grounding transformer. Selected to limit fault current to 2 to 6 amps. Continuously rated.
Load Centre transformer	400V AC three phase	Directly earthed at transformer secondary winding star point.
Lighting and distribution transformer	380-380Y/220 V AC three phase	Directly earthed at transformer secondary winding star point.
Class 1 UPS systems	220V AC systems	Solidly earthed.
Class 1 and Class 2 DC	125V DC and 220V DC	Unearthed.

Table 5: Summary of AP1000 Power System Earthing Methods

System	Voltage	Method of Earthing
systems		
Class 1 UPS systems	220V AC	Solidly earthed.

4.14.1 Assessment

254 The turbo-alternator has a high impedance star point earth which is line with normal power plant practice.

255 The 11kV transformer fed system is impedance earthed and the 11kV Standby Diesel Generator is high impedance earthed.

256 The LV system neutrals will be solidly earthed. This form of earthing results in a high fault level current, but fault energy can be kept to a practical minimum by using time graded earth fault circuit protection. There is no significant risk of widespread transient system overvoltage and a low risk of localised transient overvoltage caused by a phase to earth fault.

257 Westinghouse System Specification Document CPP-EGS-E8-001 (Ref. 43) refers to earthing the system neutral in line with the recommendations of IEEE 142 (Ref. 44). This standard details a range of earthing techniques which are compatible with equivalent European Standards and could be implemented on the AP1000 without modification in the UK.

258 The approach described in CPP-EGS-E8-001 (Ref. 43) is for DC systems to be unearthed but that the insulation integrity is continuously monitored. The risks of using an unearthed DC system are that the location of an earth fault can be difficult to detect and while the earth fault is present on one pole the voltage to earth of the other pole with be at full rated pole-to-pole value.

259 However, the alternative approach of using a high resistance centre tapped earth does not improve fault location or limit voltage stress on the insulation. Therefore, both methods are comparable in this regard, with the unearthed scheme having the benefit that no heating should occur at the point of fault due to the negligible fault current resulting from the high resistance earth.

260 CPP-EGS-E8-001 (Ref. 43) specifies a system where Electrical System neutrals, equipment, instrumentation and lightning protection systems are connected to the plant earthing grid. There is a plant earthing grid which encompasses the total plant area with individual building circled with ring conductors connected to the main plant grid.

261 The metal enclosure of all electrical equipment, air terminals of lightning protection systems, building steel and reinforcing bars and other metallic objects which could become energised are connected to the earthing system. Principles are described for the spacing of interconnections between the building steelwork and the building earthing system.

4.14.2 Findings

262 I consider that the earthing design proposed is in line with conventional power plant practice and the system does not present a risk to system operation.

263 I consider the earth fault detection proposed for the DC battery systems will adequately meet the requirement for detection and location of earth faults on the system.

264 I consider that the principles described for the main building earth of the building and connections to this system to be sound.

4.15 Protection Against Voltage Transients

265 I have carried out an assessment of the protective measures which have been taken to protect against the effects of voltage impulses on the Electrical Distribution System. I have assessed potential threats to the distribution network which could affect more than one Division as a result of a single initiating event in addition to conditions which could challenge the integrity of supplies in a single Division. In carrying out an assessment of the protection against overvoltage transients I have taken into account the recommendations of the DIDELSYS Task Group Report (Ref. 45) on Defence *in Depth of Electrical Systems and Grid Interaction* which was produced following the incident at Forsmark in July 2006.

266 The assessment has been based on the following documents:

- Westinghouse System Specification Document CPP-EGS-E8-001 (Ref. 43).
- Westinghouse response to TQ-AP1000-465 (Ref. 8).
- Westinghouse response to TQ-AP1000-712 (Ref. 8).
- Westinghouse response to TQ-AP1000-1180 (Ref. 8).

267 The particular aspects which have been assessed are as follows:

- Protection against the effects of lightning strikes.
- Protection against a fast transient disturbance propagating from one Division to another.
- Resilience of the co-ordinated voltage protection system to withstand the loss of a single line of defence.
- Consideration of the effects on electrical equipment of overvoltage transients due to failures in the Electrical System resulting from conditions such as short-circuit faults, AVR failure, resonant effects etc.

4.15.1 Protection Against Lightning Strikes

268 This section considers the generic measures adopted to protect against the effects of lightning strikes.

4.15.1.1 Assessment

269 Westinghouse System Specification Document CPP-EGS-E8-001 (Ref. 43) describes an approach to structural lightning protection which in conjunction with the building structure I consider provides a robust defence against lightning strikes. The structure of reinforcing bars in the building structure is used to provide a path for lightning to earth. The arrangements for the connection of this to the main building earth throughout the building are described.

270 CPP-EGS-E8-001 (Ref. 43) refers to IEEE Codes and Standards. I consider that the constructional features of the design as described would enable compliance with IEC 62305 (Ref. 39) Parts 1, 2 and 3.

271 The documentation does not provide evidence of compliance with IEC 62305-4 (Ref. 62) regarding magnetic field levels and the compatibility levels with Electrical Systems within buildings during direct lightning strike.

272 Protection is provided to limit the effects of lightning surges by the fitting of surge arrestors. The generic process of surge arrestor selection is described in the Westinghouse response to TQ-AP1000-465 (Ref. 8).

273 TSC report 2010-0787 (Ref. 59) assesses the Westinghouse proposals for lightning protection and has been used to inform this report.

4.15.1.2 Findings

274 I consider that the structure of the lightning protection proposed demonstrates that the generic design provides adequate protection against lightning strikes. During detailed design and construction ND will assess the facilities for maintenance of the lightning protection through all phases of operation.

275 I am satisfied for the purposes of generic assessment with the calculation methodology described in the Westinghouse response to TQ-AP1000-465 (Ref. 8).

276 I require the future licensee to demonstrate the protection provisions against the magnetic field levels generated by lightning strikes as defined in IEC 62305-4 (Ref. 62). This requirement is defined in Assessment Finding **AF-AP1000-EE-027**.

4.15.2 Protection Against Fast Transient Disturbances

277 Fast transient disturbances are covered in Section 4.11; this assessment covers the protection against the transmission of fast transient disturbances between Divisions.

4.15.2.1 Assessment

278 The Electrical System does not incorporate any interconnections between Divisions so there are no conductive paths for fast transients to propagate between Divisions through interconnections. The UATs and RATs which feed the reactor Electrical System each have dual secondary windings which are electrically separated thus preventing fast transient disturbances from conducting between Divisions.

279 Radiated transmission is prevented by the separation of cable routes and the absence of physical interconnections of cables between Divisions. Other measures which provide protection are the design of the earthing and bonding network described in System Specification Document CPP-EGS-E8-001 (Ref. 43) and assessed in Section 4.14 and the protection against EMI assessed in Section 4.19.

4.15.2.2 Findings

280 I consider that the Westinghouse generic design provides adequate protection to prevent fast transient disturbances propagating between Divisions.

4.15.3 Loss of a Line of Defence

281 This considers the potential for a failure of a single component in the voltage coordination system to impact throughout the Electrical Distribution System. The assessment is based on the Westinghouse response to TQ-AP1000-1180 (Ref. 8).

4.15.3.1 Assessment

282 The lines of defence provided to protect against transient overvoltages are identified by Westinghouse in their response to TQ-AP1000-1180 (Ref. 8) as follows:

- Surge arrestors on HV bushings of MSUT and RAT.
- Surge arrestors on LV bushings of MSUT and RAT.
- Surge arrestors on isolated phase bus and upstream side of the Generator Circuit Breaker.
- Surge arrestors on HV switchgear incomers.
- Surge arrestors on HV switchgear feeders.

283 Two possible modes for the loss of the first line of defence are postulated by Westinghouse and consideration given to the consequences of loss of each of these modes.

284 The first mode considered for loss of the first line of defence is a catastrophic failure of a surge arrestor upon discharging a travelling surge from the transmission grid. In the worst case, Westinghouse state that this could result in the destruction of MSUT and RAT. It is then stated that this event will initiate a trip and then an orderly reactor shutdown. No information is provided on how the reactor trip will be initiated or substantiation that equipment downstream of the MSUT and RAT will not be subject to damage by overvoltage.

285 The second mode considered for loss of the first line of defence is failure of the surge arrestors to operate. Westinghouse states that this failure mode would initiate the orderly shutdown of the reactor. No information is provided on how the reactor trip would be initiated. It is demonstrated in the response to TQ-AP1000-465 (Ref. 8) that this failure mode would not subject the downstream equipment to fast transient voltages beyond their withstand capability. This demonstration considers the two possible feeder routes from the grid supply through both the MSUT and UAT or through the RAT.

4.15.3.2 Findings

286 I consider that the response provided by Westinghouse provides a partial demonstration of the capability of the Electrical System to withstand the loss of a single line of defence against transient overvoltages. There is, however, no explanation of how a safe reactor trip would be initiated or substantiation that electrical equipment required for the safe reactor shutdown would not be damaged by the failure of a surge arrestor.

287 I have raised Assessment Finding **AF-AP1000-EE-028** which requires the future licensee to conduct studies to quantify the effects of a loss of a line of defence and to demonstrate that the loss of a line of defence will not affect the safe operation and shutdown of the reactor.

4.15.4 Voltage Transients Due to System Disturbances

288 The Westinghouse response to TQ-AP1000-971 (Ref. 8) covers the consideration of the effects of stresses due to voltage transients on motors. The following scenarios were considered:

- Grid voltage disturbances.
- Fast and residual bus transfer.
- Diesel generator operation.

4.15.4.1 Assessment

289 Studies of the effects of grid voltage disturbances are covered in Westinghouse document UKP-GW-GL-064 (Ref. 24) and the response to TQ-AP1000-824 (Ref. 8) with clearance times of up to 300ms. These results show in each scenario considered that the transient current upon voltage restoration is less than the locked rotor current of the motor. Westinghouse states the acceptable conclusion that this would result in a torque less than the starting torque of the motor.

290 The most severe situation postulated by Westinghouse is when a busbar is transferred from one source of power to another. A requirement is identified by Westinghouse to calculate transient torques for all large motors based on actual motor loadings. This study will determine the resultant volts per Hz at the instant of circuit breaker closing.

291 Westinghouse state that the loading of the Standby Diesel Generators will be controlled to ensure that loads are restarted without imposing excessive mechanical forces. This will be achieved by starting motors in ten pre-determined loading sequences.

4.15.4.2 Findings

292 I consider that Westinghouse have demonstrated for generic purposes that the effects of voltage disturbances on the system following grid faults have been adequately assessed. A commitment is given by Westinghouse to undertake further studies based on actual motor loadings.

293 I have raised Assessment Finding **AF-AP1000-EE-030** requiring the future licensee to conduct studies to assess the effects of overvoltages following disturbances on the Electrical System including the effects of grid faults. I will also require the studies by the future licensee to take account of the recommendations of the DIDELSYS Task Group Report (Ref. 45) on *Defence in Depth of Electrical Systems and Grid Interaction*.

4.15.5 Specification of Voltage Limits

294 This considers the potential for voltage disturbances to occur in the AP1000's internal Electrical Distribution Network and the methodology for ensuring that equipment specifications make due allowance for these disturbances. This ensures that protection is provided against the most onerous potential voltages on the system.

4.15.5.1 Assessment

295 Studies have been undertaken by Westinghouse to assess the effects on the Electrical Systems of conditions causing voltage disturbances. The results of these studies are presented in the relevant section of this report. These studies have generally concluded that the conditions will not result in the Electrical Systems becoming unstable. I will require the future licensee to use data from studies to accurately specify electrical and C&I equipment. The particular areas which potentially result in the maximum voltage disturbances and thus require consideration in determining the specification of voltage operating ranges include:

- Generator AVR faults.
- Automatic transfer operations.
- Post-fault recovery.
- Power plant islanding.

- System voltage dips.
- Part winding resonance on transformers.
- Ferro-resonance.
- Battery system operating ranges.
- Grid supply tolerances and ranges of transformer tappings.

4.15.5.2 Findings

296 I consider that the voltage limits on the system will have to be determined by the future licensee from site-specific study data taking account of a full range of operating conditions. I require that these limits should be incorporated by the future licensee in purchase specifications for equipment. This requirement is the subject of Assessment Finding **AF-AP1000-EE-029**.

4.16 Smart Devices

297 I have carried out an assessment of the use of Smart Devices in Electrical Systems to ensure that adequate steps are taken to ensure that there are processes in place to verify the integrity of software used in these devices. This is a cross-cutting topic with assessment of the methodology for ensuring the integrity of the software being carried out as part of the GDA Step 4 C&I Assessment Report (Ref. 61).

298 Westinghouse has provided a list of Smart Devices as part of their response to RO-AP1000-70 (Ref. 9). This RO was raised by my C&I colleagues during the assessment of the methodology for verifying software in Smart Devices. Westinghouse document UKP-GW-GLR-017 (Ref. 42) provides the plan for handling the assessment of Smart Devices.

4.16.1 Assessment

299 Smart Devices are extensively used within electrical equipment for functions such as protective relaying, battery charging and voltage regulation. Many of these devices will be key to the correct functioning of Class 1 and Class 2 safety systems and therefore the hardware and software of the Smart Devices will have to conform to the appropriate standards for hardware and software as listed in the GDA Step 4 C&I Assessment Report (Ref. 61). A key element of these standards is a rigorous approach to the verification and validation of both the hardware and software design. Many suppliers of sub-system Smart Devices such as protective relays are not aware of nuclear safety standards and therefore a future licensee will need to work closely with Westinghouse to ensure that suppliers are identified early in the process so that suitable verification and validation processes can be employed.

300 The list of Smart Devices submitted in response to RO-AP1000-70 (Ref. 9) identifies a significant number of them in Class 1 electrical equipment. Westinghouse also intends to use Smart Devices in electrical protection relays on the Class 2 AC Electrical Distribution System.

4.16.2 Findings

301 Due to the extensive use of Smart Devices proposed by Westinghouse in the AP1000 I consider it to be essential that confirmation of the actual devices proposed and subsequent verification and validation is addressed at an early stage by the future licensee.

302 Assessment Finding **AF-AP1000-EE-021** has been raised for the future licensee to identify and validate the software of all Smart Devices which will be used in specific site applications. GDA Issue **GI-AP1000-CI-05** raised by the C&I assessors (Ref. 61) requires Westinghouse to document the verification and validation process and to demonstrate its application.

4.17 Purchase Specifications

303 Westinghouse has submitted a number of system specification documents covering electrical equipment for GDA assessment. These are based on US Standards and do not take any account of the Codes and Standards Assessment document UKP-GW-GL-059 (Ref. 30).

4.17.1 Assessment

304 The design of the electrical equipment for the AP1000 will be defined by the equipment purchase specifications used to specify the requirements. Details of the structures of these specifications based on IEC Standards have not been provided for generic assessment so it has not been possible to assess this aspect of the detailed design to ensure that technical requirements are comprehensively defined to manufacturers.

4.17.2 Findings

305 I have raised Assessment Finding **AF-AP1000-EE-031** which requires that the future licensee prepares a comprehensive set of technical specifications to define requirements for all electrical equipment. These shall take account of performance requirements and environmental operating limits such as operating temperatures, voltage limits and short-circuit ratings.

4.18 Electrical Maintenance Philosophy

306 I have assessed the high-level maintenance philosophy for the AP1000 reactor based on Westinghouse document UKP-GW-GL-065 (Ref. 47). This provides a high-level statement of the maintenance philosophy to operate and maintain the electrical equipment in a safe manner.

4.18.1 Assessment

307 The document provides a good introduction to the maintenance to be carried out on the electrical equipment with definitions of corrective and preventive maintenance and then further dividing preventive maintenance into periodic, predictive and condition based maintenance activities.

308 Reference is made to the need to meet the requirements of the AP1000 Technical Specifications in the European DCD document EPS-GW-GL-700 (Ref. 48). These may require the plant to be shutdown if maintenance activities are not carried out within specified time periods.

309 There are no requirements laid down in the document supported by PSA assessment for availability of electrical equipment to be defined during different operating modes. An identical comment also applies to proof test intervals.

310 The document defines the operating modes in which maintenance work can be carried out for Class 1 and Class 2 equipment. There are no requirements specified for Class 3 equipment.

311 There is no reference in the document to supporting the safety claims defined in the PCSR (Ref. 11).

312 The specified operational requirements for equipment all relate to the requirements for supplies to the reactor. There are no references to requirements to ensure availability of supplies to the spent fuel cooling ponds or radwaste facilities.

313 There are references to the European DCD document EPS-GW-GL-700 (Ref. 48) regarding investment protection availability controls. There are no availability requirements specified in relation to safety claims for the plant in the PCSR (Ref. 11).

314 There is no information provided on maximum allowable maintenance intervals for major items of electrical equipment which would be required to maintain the system to achieve maximum availability to ensure plant safety.

4.18.2 Findings

315 I consider that the sections of the document defining the approaches to corrective and preventive maintenance to be well structured.

316 I do not consider that the document meets the requirement for supporting the safety case in demonstrating that the Electrical Power System can be maintained to meet the availability and proof test requirements. This will need to be supported by PSA assessment of the different operating modes when equipment is out of service for maintenance purposes. The document needs to be related to the claims, arguments and evidence in support of the safety case which is the subject of GDA Issue **GI-AP1000-EE-01**. I expect that this demonstration will be provided in the maintenance philosophy document as part of the resolution of the GDA Issue.

317 I consider that an updated PSA assessment of the Electrical System is required to support the presentation of the safety case for the Electrical System as defined in GDA Issue **GI-AP1000-EE-01**.

318 GDA Issue **GI-AP1000-FS-01** (Ref. 73) has been raised on the cross-cutting subject of spent fuel cooling. I expect that the resolution of this issue will require demonstration that the maintenance of the Electrical Distribution System can be achieved whilst meeting the safety case for the pond cooling.

4.19 Electromagnetic Interference

319 The assessment of the provisions made by Westinghouse for the protection against the effects of Electromagnetic Interference (EMI) has been based on Westinghouse document UKP-GW-GL-062 (Ref. 49) and on the Westinghouse response to TQ-AP1000-907 (Ref. 8). The assessment has also considered the requirements of EU Directive 2004/108/EC (Ref. 32).

320 This is a cross-cutting topic area which has been assessed in conjunction with the GDA Step 4 Internal Hazards assessment (Ref. 74).

4.19.1 Assessment

321 Westinghouse document UKP-GW-GL-062 (Ref. 49) is a high-level document which defines the steps which will be taken to comply with EU Directive 2004/108/EC (Ref. 32).

The document defines in general terms the requirements associated with the designation of the station as a ‘fixed installation’. The requirements within the directive for the appointment of a responsible person are covered together with compliance with the generic IEC 61000 series of Standards.

322 A commitment is given by Westinghouse to develop a comprehensive list of EMC Standards and test criteria. The Westinghouse response to TQ-AP1000-907 (Ref. 8) states that a general electrical requirements specification will be produced for incorporation into procurement packages which will define EMI requirements.

323 There are features of the design which I have assessed which provide protection against the effects of EMI as follows:

- Provision of an effective lightning protection system to screen equipment rooms from the effects of lightning.
- Design of an earthing system to limit fault currents.
- Use of surge suppressors to prevent transients.

4.19.2 Findings

324 I am satisfied that Westinghouse document UKP-GW-GL-062 (Ref. 49) provides a high-level commitment to comply with EU Directive 2004/108/EC (Ref. 32).

325 I am satisfied that the design of the lightning protection and earthing systems will provide the foundations for adequate protection against EMI.

326 I am satisfied that the methodology exists in the Westinghouse design processes to ensure that specifications for equipment detail the requirements to protect against the effects of EMI.

327 I have raised Assessment Finding **AF-AP1000-EE-020** which requires the future licensee to carry out the following steps to protect against EMI:

- Define all standards applicable to the installation.
- Define test standards and immunity levels applicable to equipment.
- Incorporate immunity levels and test requirements in to purchase specifications.
- Define criteria for cable installation such as separation and shielding requirements.

4.20 Reactor Coolant Pumps

328 There are four Reactor Coolant Pumps on the AP1000 plant. These pumps are controlled by Variable Frequency Drives (VFD). There are Class 1 circuit breakers in series with these drives which are required to trip following reactor shutdown to allow reactor cooling by natural convection to take place. This section assesses the electrical equipment associated with the Reactor Coolant Pumps.

4.20.1 Assessment

329 The Reactor Coolant Pumps are each fed from a VFD. In order for the standard AP1000 design to be used for these pumps the motors will operate at 60Hz fed from the VFDs. The method of operation for 50Hz plants differs from that on 60Hz plants where the VFDs are used during pump start-up before transferring to a bypass supply for continuous pump operation. On the 50Hz plant the input supply to the VFD is 50Hz with a 60Hz

output so the provision of a bypass is not possible. I do not consider that this has any impact on the integrity of the supplies to the Reactor Coolant Pumps.

330 The design requires the Reactor Coolant Pumps to trip on reactor shutdown to facilitate rapid natural circulation. In order to achieve this function two Class 1 circuit breakers are located in series with each Reactor Coolant Pump on the pump side of the VFD. The circuit breakers are duplicated as the isolation function is essential to safety.

331 As described in the codes and standards assessment in Section 4.9 these circuit breakers will comply with ANSI Standards as they will operate on the 60Hz system.

332 The features of the circuit breakers to ensure the integrity of the tripping function are described in the Westinghouse response to TQ-AP1000-402 (Ref. 8). In addition to the QA and seismic provisions for the Class 1 classification the circuit breakers have tripping supplies from independent battery Divisions and have separate redundant tripping signals to each circuit breaker.

333 The supplies from the VFDs are operated with the motor star point unearthed. The justification for this arrangement is provided in the Westinghouse response to TQ-AP1000-309 (Ref. 8). Under this condition an alarm is initiated to alert operator action whilst the drive control operates to remove the imbalance and maintain balanced output to the motor.

334 Westinghouse’s response to TQ-AP1000-467 (Ref. 8) compares the alternative motor designs for wet winding pumps on the European design and the canned motor design on the standard AP1000. This confirms that the design of the VFD for the RCPs is not affected by the motor design.

4.20.2 Findings

335 I consider that the design of the VFDs and the tripping facilities from the Class 1 circuit breakers is acceptable.

4.21 Safety Classification of Electrical Equipment

336 The safety classification of electrical equipment is part of a cross-cutting topic on safety classification of Structures, Systems and Components. The AP1000 design was based on US safety classifications and Westinghouse document UKP-GW-GL-144 (Ref. 60) defines safety classifications for UK applications.

4.21.1 Assessment

337 The US safety classification treated only Class 1 battery and associated UPS systems and RCP tripping breakers as safety-related equipment. Westinghouse document UKP-GW-GL-144 (Ref. 60) classifies as Class 2 the Standby and Ancillary Diesel Generators together with the associated distribution networks and all battery systems except the Class 1 systems. Other parts of the AC distribution system are Class 3.

4.21.2 Findings

338 I require the safety classifications of electrical equipment to be taken account of in preparing equipment purchase specifications. This requirement is defined in Assessment Finding **AF-AP1000-EE-022**.

4.22 Safety Assessment Principles (SAP)

339 I have carried out an assessment of the design of the Electrical System to assess its compliance with the subset of electrical SAPs (Ref. 4) identified in Table 7. My assessment considers each of the SAPs (Ref. 4) and assesses the generic capability of the design of the AP1000 Electrical System to comply. The assessment is shown in Table 8.

4.22.1 Assessment

340 My generic assessment of the compliance of the Electrical Distribution System with the requirements of the electrical subset of SAPs (Ref. 4) is that the structure of the system design generally complies with the requirements of these SAPs (Ref. 4). There are a number of SAPs (Ref. 4) where insufficient information has been provided in the PCSR (Ref. 11) to conclude the assessment. The requirements for further information and substantiation are identified against the specific SAPs (Ref. 4).

4.22.2 Findings

341 I have raised GDA Issue **GI-AP1000-EE-01** requiring the submission of the electrical section of the PCSR with claims, arguments and evidence to present the safety case. I expect the PCSR to address the items in the SAPs (Ref. 4) assessment where insufficient information has been provided to enable completion of my assessment.

342 With the exception of the specific areas identified the generic assessment demonstrates the capability of the electrical design submission to comply with the requirements of the SAPs (Ref. 4). A significant proportion of SAPs require substantiation of design details to provide full evidence of compliance. These details will require the future licensee to incorporate designs in accordance with Assessment Findings or justifying a suitable equivalent.

5 CONCLUSIONS

343 This report presents the findings of the Step 4 Electrical Systems assessment of the Westinghouse AP1000 design.

344 To conclude, I am broadly satisfied with the integrity of the Electrical System laid down within the PCSR (Ref. 11) and supporting documentation for the Electrical Systems. This will require substantiation by the presentation of the claims, arguments and evidence within the PCSR supported by PSA assessment in response to **GI-AP1000-EE-01**. I consider that from an Electrical Systems viewpoint, the Westinghouse AP1000 design is suitable for construction in the UK. However, this conclusion is subject to satisfactory progression and resolution of GDA Issues to be addressed during the forward programme for this reactor and assessment of additional information that becomes available as the GDA Design Reference is supplemented with additional details on a site-by-site basis.

5.1 Key Findings from the Step 4 Assessment

345 My key findings and conclusions are as follows:

- Westinghouse has to provide claims, arguments and evidence of compliance of the Electrical System architecture defined against the electrical SAPs. GDA Issue **GI-AP1000-EE-01** has been raised to identify the requirement to supply this evidence.
- My independent assessment of the Westinghouse design by modelling extremes of transient operating conditions has demonstrated the resilience of the design of the Electrical System to system disturbances due to such events as short-circuits and overvoltage transients.
- The architecture of the Electrical System provides sufficient capacity to meet load requirements in all operating modes of grid supply, diesel supply and battery supply when all parts of the Electrical System are available and in operation.
- Westinghouse has to demonstrate the capability provided to facilitate maintenance of Electrical Systems whilst maximising supply continuity in the event of unavailability of equipment due to electrical faults. GDA Issue **GI-AP1000-EE-01** requires this demonstration to be provided in the PCSR as part of the submission of claims, arguments and evidence.
- The principles proposed in the protection philosophy document provide a good basis for protecting the Electrical System to minimise the effects of electrical faults. This enables continuity of system supplies and thus supports the effectiveness of the Electrical System in maintaining plant safety.
- The Class 1 and Class 2 battery powered systems are designed in a well structured manner according to defined documented processes. Adequate margins are applied and battery rating is based on the worst conditions of operating temperature and ageing.
- Westinghouse has undertaken an impact assessment of meeting the UK Grid Code (Ref. 28) and has demonstrated that all the implications have been assessed. This has included ensuring that there are no implications on the Plant Electrical System when remaining connected to the Grid under fault conditions.
- Westinghouse has presented comprehensive proposals to apply IEC Standards to the AP1000 Electrical System as part of implementing the adaptation of the design from a frequency of 60Hz to 50Hz.

5.1.1 Assessment Findings

346 I conclude that the following Assessment Findings listed in Annex 1 should be implemented during the forward programme of this reactor as normal regulatory business.

5.1.2 GDA Issues

347 I conclude that the GDA Issue listed in Annex 2 must be satisfactorily addressed before Consent will be granted for the commencement of nuclear island safety-related construction.

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Table 6

Areas Identified in Assessment Plan for Further Assessment During Step 4

Identifier	Assessment Area	Description	Topic Lead	Required Timescale
1	Electrical	High-level assessment of the maintenance proposals for the reactor concentrating on requirements for availability of items of main electrical equipment, maintenance intervals and access for maintaining the electrical equipment in a safe manner	Electric Systems	Step 4
2	Electrical	Assessment of key aspects of the safety-related battery systems supplying AC and DC loads addressing the design operation and monitoring of the systems and including assessment of the systems using system study programs	Electric Systems	Step 4
3	Electrical	Sample assessment of the AC distribution system considering load flows and electrical fault calculations to confirm the adequacy of the system design	Electric Systems	Step 4
4	Electrical	Undertaking an assessment of a sample of the calculations carried out by Westinghouse to ensure that the electrical protection relays can provide adequate protection and discrimination throughout the system for a wide range of fault calculations	Electric Systems	Step 4
5	Electrical	Review of key aspects of Westinghouse's transient stability studies on the Electrical Systems using Technical Support Contractor Cobham to evaluate a small sample of the system to confirm the tolerance of the system to electrical faults	Electric Systems	Step 4
6	Electrical	In conjunction with the C&I assessment team to assess the control of software for programmable equipment including protection relays	Electric Systems	Step 4
7	Electrical	Assessment of the diesel backed AC system based on the classification determined for this system	Electric Systems	Step 4
8	Electrical	Assessment of the codes and standards determined to be applicable for the UK design	Electric Systems	Step 4
9	Electrical	Review of the arguments to support the safety claims made for compliance with the electrical subset of SAPs	Electric Systems	Step 4

Table 6

Areas Identified in Assessment Plan for Further Assessment During Step 4

Identifier	Assessment Area	Description	Topic Lead	Required Timescale
10	Electrical	Assessment of EMC compliance and design of earthing and lightning protection	Electric Systems	Step 4

Table 7

Relevant Safety Assessment Principles for Electrical Systems Considered During Step 4

SAP No.	SAP Title	Description
EQU.1	Qualification Procedures	Qualification procedures should be in place to confirm that structures, systems and components that are important to safety will perform their required safety function(s) throughout their operational lives
EDR.1	Failure to safety	Due account should be taken of the need for structures, systems and components important to safety to be designed to be inherently safe or to fail in a safe manner and potential failure modes should be identified, using a formal analysis where appropriate
EDR.2	Redundancy, diversity and segregation	Redundancy, diversity and segregation should be incorporated as appropriate within the designs of structures, systems and components important to safety
EDR.3	Common cause failure	Common cause failure (CCF) should be explicitly addressed where a structure, system or component important to safety employs redundant or diverse components, measurements or actions to provide high reliability
EDR.4	Single failure criterion	During any normally permissible state of plant availability no single random failure, assumed to occur anywhere within the systems provided to secure a safety function, should prevent the performance of that safety function.
ERL.2	Measures to achieve reliability	The measures whereby the claimed reliability of systems and components will be achieved in practice should be stated
ERL.4	Margins of conservatism	Where multiple safety-related systems and/or other means are claimed to reduce the frequency of a fault sequence, the reduction in frequency should have a margin of conservatism with allowance for uncertainties.
EMT.1	Identification of requirements	Safety requirements for in-service testing, inspection and other maintenance procedures and frequencies should be identified in the safety case.
EMT.3	Type-testing	Structures, systems and components important to safety should be type tested before they are installed to conditions equal to, at least, the most severe expected in all modes of normal operational service.

Table 7

Relevant Safety Assessment Principles for Electrical Systems Considered During Step 4

SAP No.	SAP Title	Description
EMT.6	Reliability claims	Provision should be made for testing, maintaining, monitoring and inspecting structures, systems and components important to safety in service or at intervals throughout plant life commensurate with the reliability required of each item.
EMT.7	Functional testing	In-service functional testing of systems, structures and components important to safety should prove the complete system and the safety-related function of each component
ELO.1	Access	The design and layout should facilitate access for necessary activities and minimise adverse interactions during such activities.
EHA.10	Electromagnetic interference	The design of facility should include protective measures against the effects of electromagnetic interference
ESS.1	Requirement for Safety Systems	All nuclear facilities should be provided with Safety Systems that reduce the frequency or limit the consequences of fault sequences, and that achieve and maintain a defined safe state
ESS.2	Determination of Safety System requirements	The extent of Safety System provisions, their functions, levels of protection necessary to achieve defence in depth and required reliabilities should be determined
ESS.3	Monitoring of plant safety	Adequate provisions should be made to enable the monitoring of the plant state in relation to safety and to enable the taking of any necessary safety actions.
ESS.7	Diversity in the detection of fault sequences	The protection system should employ diversity in the detection of fault sequences, preferably by the use of different variables, and in the initiation of the Safety System action to terminate the sequences
ESS.8	Automatic initiation	A Safety System should be automatically initiated and normally no human intervention should be necessary following the start of a requirement for protective action.
ESS.9	Time for Human Intervention	Where human intervention is necessary following the start of a requirement for protective action, then the time before such intervention is required should be demonstrated to be sufficient.
ESS.10	Definition of capability	The capability of a Safety System, and of each of its constituent sub-systems and components, should be defined.

Table 7

Relevant Safety Assessment Principles for Electrical Systems Considered During Step 4

SAP No.	SAP Title	Description
ESS.11	Demonstration of adequacy	The adequacy of the system design as the means of achieving the specified function and reliability should be demonstrated for each system.
ESS.12	Prevention of service infringement	Adequate provisions should be made to prevent the infringement of any service requirement of a Safety System, its sub-systems and components.
ESS.15	Alteration of configuration, operational logic or associated data	No means should be provided, or be readily available, by which the configuration of a Safety System, its operational logic or the associated data (trip levels etc) may be altered, other than by specifically engineered and adequately secured maintenance/testing provisions used under strict administrative control
ESS.16	No dependency on external sources of energy	Where practicable, following a Safety System action, maintaining a safe facility state should not depend on an external source of energy
ESS.19	Dedication to a single task	A Safety System should be dedicated to the single task of performing its safety function.
ESS.20	Avoidance of connections to other systems	Connections between any part of a Safety System (other than the Safety System support features) and a system external to the plant should be avoided
ESS.21	Reliability	The design of a Safety System should avoid complexity, apply a fail-safe approach and incorporate the means of revealing internal faults from the time of their occurrence
ESS.23	Allowance for unavailability of equipment	In determining the Safety System provisions, allowance should be made for the unavailability of equipment
ESS.24	Minimum operational equipment requirements	The minimum amount of operational Safety System equipment for which any specified facility operation will be permitted should be defined and shown to meet the single failure criterion.
EES.1	Provision	Essential services should be provided to ensure the maintenance of a safe plant state in normal operation and fault conditions
EES.2	Sources external to the site	Where a service is obtained from a source external to the nuclear site, that service should also be obtainable from a back-up source on the site.

Table 7

Relevant Safety Assessment Principles for Electrical Systems Considered During Step 4

SAP No.	SAP Title	Description
EES.3	Capacity, duration, availability and reliability	Each back-up source should have the capacity, duration, availability and reliability to meet the maximum requirements of its dependent systems.
EES.4	Sharing with other plants	Where essential services are shared with other plants on a multi-facility site, the effect of the sharing should be taken into account in assessing the adequacy of the supply.
EES.5	Cross-connections to other services	The capacity of the essential services to meet the demands of the supported safety functional requirement(s) should not be undermined by making cross-connections to services provided for non-safety functions.
EES.6	Alternative sources	Alternative sources of essential services should be designed so that their reliability would not be prejudiced by adverse conditions in the services to which they provide a back-up.
EES.7	Protection devices	Protection devices provided for essential service components or systems should be limited to those that are necessary and that are consistent with facility requirements
EES.8	Sources external to the site	Where a source external to the nuclear site is employed as the only source of the essential services needed to provide adequate protection, the specification and in particular the availability and reliability should be the same as for an on-site source.
EES.9	Loss of service	Essential services should be designed so that the simultaneous loss of both normal and back-up services will not lead to unacceptable consequences.
EKP.3	Defence in Depth	A nuclear facility should be so designed and operated that defence in depth against potentially significant faults or failures is achieved by the provision of several levels of protection.
EKP.5	Safety measures	Safety measures should be identified to deliver the required safety function(s).

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
EQU.1	Equipment Qualification	The requirements of this SAP are met for the electrical equipment. The UK AP1000 Electrical Systems codes and standards document UKP-GW-GL-059 (Ref. 30) identifies applicable equipment standards and type test requirements to demonstrate compliance. Incorporation of these requirements in equipment purchase specifications will ensure compliance with the SAP.
EDR.1	Failure to Safety	The AP1000's Electrical Systems provide energy to other Safety Systems such as the reactor protection system (PMS) and Diverse safety Actuation System (DAS). Both, among other things, perform the role of the Category A function of safely shutting down the reactor. For the PMS loss of electrical power supply is a safe state as it results in an automatic shutdown of the reactor. However for the DAS power is needed for reactor shutdown and therefore for that system's function loss of electrical power does not result in a failure to safety. The requirements for power supply to the DAS to be resolved are covered in the Cross-cutting GDA Issue GI-AP1000-CI-02 raised by C&I. Where failure to safety cannot be guaranteed then systems such as the Electrical Systems use redundancy, diversity and defence in depth against a wide range of single and multiple faults to ensure the safety function can be achieved. I am satisfied that the defences against widespread loss of capability are sufficient in areas where electrical power is required to actuate safety functions other than those identified for the DAS.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
EDR.2	Redundancy, Diversity and Segregation	The electrical structure of the conventional island's high voltage scheme separates the nuclear island's distribution system into two divisions. This results in the creation of two sections each equipped with a main 11 kV switchboard supplied by a unit transformer secondary winding. The allocation of loads to the busbars takes into account the redundancy requirements of the Safety Systems and the power requirements of the static converters and batteries. The architecture of the supply to the instrumentation and control cabinets and for the switchgear actuation provides adequate redundancy and diversity. The Class 2 AC system consists of two Divisions each provided with a Standby Diesel Generator for back up supplies. The separation into divisions ensures that in the event of an internal hazard within a division, only the division in question is affected. Four divisions of battery based DC systems are provided with separate systems provided for Class 1 and Class 2 loads. Charging is provided from the low voltage AC system. Each division is supplied by an independent Standby Diesel Generator which is started automatically on loss of voltage on the busbars. Diverse sources of supply are provided by the Standby Diesel Generators and battery systems supporting the main power supply. Power cable routes are fully segregated between divisions. The requirements of the SAP are generally met apart from concerns I have with section 4.4.1.1 of the PCSR (Ref. 11) which states that 3 out of 4 battery systems are required for safe shutdown. I require Westinghouse to substantiate the capability of the battery systems to meet the demands for all design basis faults as defined in the fault schedule in response to GDA Issue GI-AP1000-EE-01. This substantiation shall provide a more detailed explanation of the claim that three out of four battery systems are required for safe reactor shutdown.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
EDR.3	Common Cause Failure	Particular attention is given by Westinghouse to minimizing the possibilities of common cause failures. Physical and spatial separation is applied as far as possible. Support functions (energy, control, cooling, etc.) are independent to the largest possible degree. Special emphasis is placed on the redundancy and diversity of electrical power supplies although this will have to fully assessed when equipment is fully specified. Common cause failure has been addressed in studies undertaken by Westinghouse to assess external sources of disturbances such as grid failures, fast transients and lightning disturbances and through externally and internally generated hazards such as seismic events, fires and flooding. I have concerns which are raised in GDA Issue GI-AP1000-EE-01 at the need for Westinghouse to provide a safety substantiation in the PCSR to show that system availability can be achieved to meet the requirements of common cause failure.
EDR.4	Single Failure Criterion	The provision of the four divisions of batteries for Class 1 and Class 2 battery systems meets the requirement of the SAP. The Class 2 AC system consists of two independent divisions each backed up by a Diesel Generator. The Class 2 AC system does not meet the single failure criterion in that this can only be met by having a minimum of three divisions. However, the full rigor of the single failure criterion is only applied to Category A functions and as the Class 2 AC system is only a back up to the principle line of defence provided by systems dependent on the four divisional Class 1 battery backed system this is acceptable. The final confirmation of compliance with the requirements of this SAP will be made when the PCSR is completed for the Electrical System with the completed safety case.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
ERL.2	Measures to achieve reliability	In design this SAP is met by the proposed implementation of a combination of redundant and diverse sub-systems and equipment. The basic architecture is two divisions of redundant equipment for electrical power supplies to the nuclear island. Each division is completely segregated with a Standby Diesel Generator providing a diverse supply to that from the grid. On the nuclear island there are four divisions of battery system with two divisions fed from each of the incoming supplies to the nuclear island. Separate battery systems are provided for Class 1 and 2 battery systems. Diversity is provided by the passive nature of the plant which does not require the AC sources of power to achieve safe shutdown and by the provision of two Ancillary Diesel Generators to provide post 72 hour monitoring and to feed the passive containment recirculation pumps. These diesels are of different rating and have diverse control arrangements and will be supplied from different manufacturer from the Standby Diesel Generators. Westinghouse has provided segregation between divisions with no physical interconnections between equipment on different divisions. The maintenance philosophy describes the principles for in-service maintenance but I will require development of this document to substantiate full compliance with the SAP by providing evidence supported by PSA assessment that maintenance can be carried out whilst ensuring availability of equipment to operate safely.
ERL.4	Margins of Conservatism	I consider that the requirements of the SAP are met by the design of the Electrical Distribution System providing margins of conservatism. Two separate divisions of AC power are provided each having a Standby Diesel Generator to support the grid supply. Four divisions of battery power are provided which are supported for essential functions by two Ancillary Diesel Generators. An analysis of the transients also show that there are margins to plant damage provided the detailed design follows the principles adopted for the generic design. The transients defining the overall equipment safety margins are also conservative using the most onerous conditions which will be used in equipment specifications. The methodology used for equipment rating calculations is comprehensive and conservative.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
EMT.1	Identification of Requirements	The maintenance philosophy describes a structured philosophy with definitions of corrective and preventive maintenance with preventive maintenance further divided into periodic and condition based activities. There are no requirements laid down in the document supported by PSA assessment for availability of electrical equipment to be defined during different operating modes. I expect this to be provided in response to GDA Issue GI-AP1000-EE-01 which requires the PCSR to provide the presentation of the safety case.
EMT.3	Type-testing	I consider that this SAP is met by the requirements defined in the Codes and Standards document for type testing of IEC standard equipment.
EMT.6	Reliability Claims	The requirements of this SAP have not been substantiated by Westinghouse as the maintenance philosophy does not demonstrate a system for testing, monitoring and inspecting electrical equipment to ensure the reliability of the equipment.
EMT.7	Functional Testing	I do not consider that the requirements of this SAP have been fully substantiated by Westinghouse. They have stated a philosophy requiring the in-service functional testing of systems, structures and components important to safety to prove the complete system and the safety-related function of each component. They have not demonstrated the capability of the Electrical System to permit these functions to be carried out.
ELO.1	Access	The layout provides for working on equipment on one division in safety without impacting on equipment in other divisions. Access to equipment for maintenance facilitates safe working. Westinghouse has not demonstrated that access for maintenance can be provided for all operating modes. This demonstration will be required to substantiate that the requirements of the SAP have been met.
EHA.10	Electromagnetic Interference	The requirements of the SAP are met by the philosophy described in Westinghouse document UKP-GW-GL-062 (Ref. 49) which provides a high-level methodology to restrict levels of EMI. Design provisions to restrict levels of EMI have been demonstrated by building design, design of cable routing and by fitting of suppression devices.
ESS.1	Requirement for Safety Systems	I consider that Westinghouse has met this principle by the integrity of the four divisions of DC power supply systems and by the design of the Class 1 circuit breakers used to trip the RCPs on reactor shutdown to facilitate rapid natural circulation.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
ESS.2	Determination of Safety System Requirements	I consider that full demonstration of compliance with the requirements of this SAP requires the use of PSA as an essential part of AP1000 safety and design considerations. In order to demonstrate compliance the PSA should be used with the full input of electrical design teams to substantiate the design within the original project objectives (See Annex 2).
ESS.3	Monitoring of Plant Safety	I consider that this SAP is met by the facilities to monitor the status of the Electrical Distribution System. Monitoring is provided of the status of switchgear, battery systems, transformers and generators and relevant data transmitted to the central control room independently from each division.
ESS.7	Diversity in the Selection of Fault Sequences	The requirements of this SAP are met in the design of the Electrical Protection System where the grading of the system is used to provide back up to protective devices whist ensuring maximum supply integrity. As support to Safety Systems this principle is also met in that the AC system supplies energy to the active Class 2 Safety Systems whereas the battery backed Class 1 DC systems supply energy to the Class 1 C&I equipment for actuation of many of the passive systems.
ESS.8	Automatic Initiation	I consider that the requirements of the SAP are met by the design of the Electrical System. Standby Diesel Generators are started automatically on loss of grid supply. Automatic changeover is provided to the reserve grid supply. Electrical protection operates automatically to clear faults. No human intervention is required to initiate these activities.
ESS.9	Time for Human Intervention	I consider that the requirements of this SAP are met by the requirements defined in the European DCD EPS-GW-GL-700 (Ref. 48) which states that Safety Systems do not normally require human intervention following the start of a requirement for protective action for as long as 3 days. Actions in less than 3 days will be in accordance with procedures but will not be credited for less than 30 minutes.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
ESS.10	Definition of Capability	I consider that the requirements of the SAP have been met. Westinghouse has provided details of the calculation methodology to determine electrical equipment fault ratings. Westinghouse has provided calculations for determining ratings of main transformers and Standby Diesel Generators. Calculations have been submitted to demonstrate that the standby generator can start the largest system motor. The method for determining battery capacity has been demonstrated to take account of worst case loading conditions, operating temperatures and to apply aging factors and margins for future load growth.
ESS.11	Demonstration of Adequacy	I consider that the requirements of the SAP are met by the studies which have been carried out by Westinghouse recorded in document UKP-GW-GL-064 (Ref.24). This considers worst case operating conditions and the resulting maximum system voltage transients. Equipment thermal ratings have been demonstrated in documents covering generators, transformers and batteries. Calculations have been provided for voltage coordination showing rating requirements for surge arrestors.
ESS.12	Prevention of Service Infringement	Four trains of battery power are provided which are used to provide redundancy to maintain supplies to Safety Systems. These systems are supported by the Class 2 AC power system. To fully demonstrate compliance with this SAP I require Westinghouse to demonstrate that AC power systems can be maintained during required maintenance operations (See Annex 2).
ESS.15	Alteration of Configuration, Operational Logic or Associated Data	The requirements of this SAP are met by the application of the procedure for verification and validation of Smart Devices UKP-GW-GLR-017 (Ref. 42) and by the procedure for controlling protection settings in switchgear described in the response to TQ-AP1000-302 (Ref. 8).
ESS.16	No Dependence on External Sources of Energy	I consider that Westinghouse have met this principle by the incorporation of Standby Diesel Generators, Ancillary Diesel Generators and battery based uninterruptible power supplies to back-up the two external sources of electricity supply. Westinghouse claim that the Ancillary Diesel Generators can maintain supplies for monitoring and make up water post 72 hours.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
ESS.19	Dedication to a Single Task	I consider that the design meets the requirements of this SAP for the electrical power supply systems since there are no safety or safety-related systems present that have more than one function.
ESS.20	Avoidance of Connections to Other Systems	No external sources have been identified so I consider the requirements of this SAP are met.
ESS.21	Reliability	This SAP has been met through the provision of a robust Electrical System architecture that can withstand a very wide range of challenging single, and from the perspective of the PSA, multiple faults while still being able to perform its safety function. At the equipment level the use of nuclear qualified equipment and attention to important matters such as system health monitoring and comprehensive maintenance also helps to assure high reliability. I have concerns at the extensive use of Smart Devices on the Electrical System and there is significant work to be carried out on the verification and validation of these devices (See **AF-AP1000-EE-21** Annex 1).
ESS.23	Allowance for Unavailability of Equipment	Westinghouse must demonstrate that the requirements of this SAP are met during maintenance operations. For normal operations the requirements are met by the use of four divisions of battery power which are supported by the two divisions of AC power with back up from the Standby Diesel Generators.
ESS.24	Minimum Operational Equipment Requirements	In order to demonstrate compliance with this SAP I require Westinghouse to clarify with claims arguments and evidence in the PCSR (Ref. 11) the minimum availability of battery systems to safely shut down the reactor from all operating conditions (See Annex 2).
EES.1	Provision	I cannot fully assess compliance with the requirements of this SAP until Westinghouse provide clarification with claims arguments and evidence in the PCSR (Ref. 11) of the minimum availability of battery systems to safely shut down the reactor from all operating conditions.
EES.2	Sources External to the Site	The plant can be shut down and maintained in a safe state without any external sources of power. From an electrical assessment this SAP is met. Adequate sources of diesel fuel would require to be demonstrated for full compliance.
EES.3	Capacity, Duration, Availability and Reliability	Westinghouse has demonstrated the methodology for calculation of equipment ratings which have been discussed in detail in the main body of this report. I consider that this meets the requirements of the SAP.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

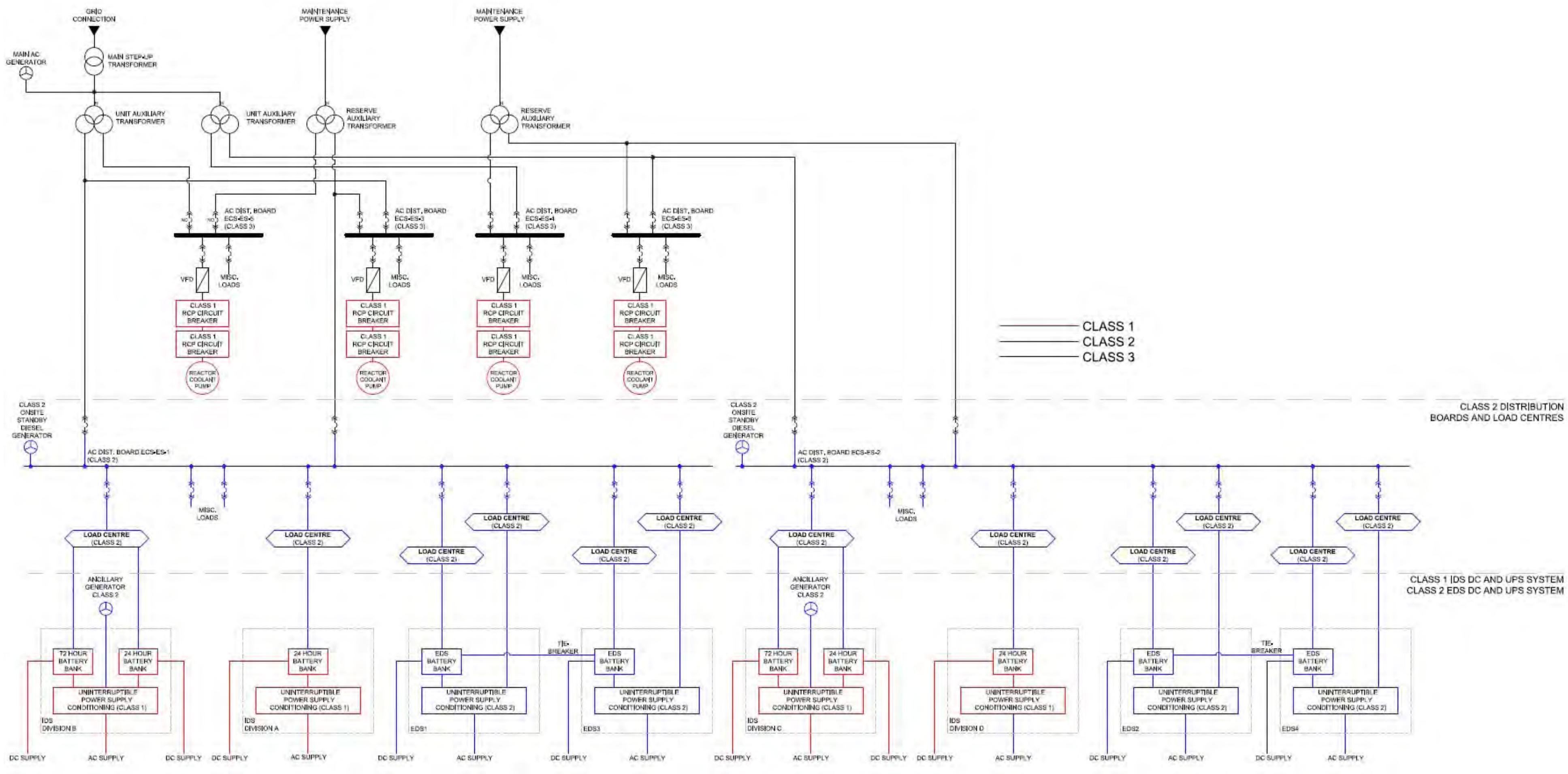
SAP No.	SAP Title	Main Findings/Observations
EES.4	Sharing with Other Plants	I consider that the requirements of this SAP are met since the basis of the AP1000 design is for a single facility with no interconnection or relationship to any other plant. Multiple reactor sites will be covered by a site-specific PCSR.
EES.5	Cross Connections to Other Services	I consider that this SAP has been met by the avoidance of any cross-connections between essential services for safety functions and essential services for non-safety functions.
EES.6	Alternative Sources	I consider that the requirements of the SAP are met by the generic design.
EES.7	Protection Devices	I consider that the protection philosophy described in document APP-GW-E1-004 (Ref. 18) meets the requirement of the SAP.
EES.8	Sources External to the Site	During a long term shutdown of the Main Generator the main source of AC power is the grid supply. As this is a reliable connection with multiple incoming lines for each site the requirements of the SAP can be met.
EES.9	Loss of Service	I consider that the requirements of this SAP have been met by the use of two independent AC divisions and four independent DC Divisions to ensure that the loss of normal service plus one back-up service does not prevent safety functions from being carried out.

Table 8

Assessment of Compliance with Electrical Safety Assessment Principles

SAP No.	SAP Title	Main Findings/Observations
EKP.3	Defence in Depth	I consider that Westinghouse has met the requirements of this SAP. The safety approach at the design level is based on the concept of defence in depth. The defence in depth has a 5-level structure as required by IAEA Safety Guide NS-R-1 (Ref.74). The implementation of the multiple levels of defence to the Electrical System is summarized in the following provisions: • The normal source of supply from the Main Generator or the 400kV point of coupling to the utility grid within the power station main substation connected via UAT. • The reserve auxiliary supply via RAT providing galvanically separate supplies to each of two AC divisions via two main switchboards on the conventional island. • Each emergency power supply system is installed in a separate division. The separation is such that an internal hazard within one division does not affect that in another division. • The nuclear island main switchboards are located in fire segregated areas. Each of the emergency switchboards is supported by an 11kV Standby Diesel Generator. • The Standby Diesel Generators are separated by fire barriers to prevent a fire on one diesel affecting the second. • In each Division on the nuclear island a 24 hour Class I battery and a 2 hour Class 2 battery. In addition Divisions B and C have a 72 hour Class 1 battery. • The 24 hour and 72 hour uninterruptible inverters are provided with a bypass via a transformer regulator. • There are two Ancillary Diesel Generators for supplies to passive containment recirculation pumps and post 72 hour monitoring.
EKP.5	Safety Measures	The requirements of the SAP are met by the provision of the following power supplies • Grid Supply. • Standby Diesel Generator Supply. • Ancillary Diesel Generator Supply. • 2 hour battery supply. • 24 hour batteries supplies. • 72 hour batteries supplies.

Figure 10: Single Line Diagram of Plant Electrical System



Annex 1

Assessment Findings to be Addressed During the Forward Programme as Normal Regulatory Business

Electrical Systems – AP1000

Finding No.	Assessment Finding	MILESTONE (by which this item should be addressed)
AF-AP1000-EE-001	The future licensee shall undertake a load flow study to determine the ratings for all electrical equipment on the AP1000.	Long lead items and SSC procurement specifications
AF-AP1000-EE-002	The future licensee shall carry out a protection study for each power plant to determine the protection requirements and settings for the Electrical Distribution System.	Long lead items and SSC procurement specifications
AF-AP1000-EE-003	The future licensee shall carry out a detailed assessment of electrical cables for each power plant to verify cable sizes, route segregation and loading of cable routes. Segregation criteria between cables to protect against EMI shall be determined as will requirements for mechanical protection.	Nuclear island safety related concrete
AF-AP1000-EE-004	The future licensee shall perform a study to determine battery ratings based on the methodology provided for GDA assessment.	Long lead items and SSC procurement specifications
AF-AP1000-EE-005	The future licensee shall provide details and substantiation of the integrity of the circuit breaker tripping and closing supplies	Long lead items and SSC procurement specifications
AF-AP1000-EE-006	The future licensee shall carry out detail design of the Class 1 inverter fed AC system to calculate actual loadings and to determine adequate grading of protective devices.	Long lead items and SSC procurement specifications
AF-AP1000-EE-007	The future licensee shall carry out fault studies for three phase and single phase faults for each power plant. These studies should also determine the DC components of fault currents to determine switchgear ratings.	Long lead items and SSC procurement specifications
AF-AP1000-EE-008	The future licensee shall carry out studies to assess the consequences of AVR failure for each power plant. This shall assess all possible failure modes and control methods for the AVR utilised	Long lead items and SSC procurement specifications

Annex 1

Assessment Findings to be Addressed During the Forward Programme as Normal Regulatory Business

Electrical Systems – AP1000

Finding No.	Assessment Finding	MILESTONE (by which this item should be addressed)
AF-AP1000-EE-009	The future licensee shall carry out a study for each power plant assessing motor starting performance.	Long lead items and SSC procurement specifications
AF-AP1000-EE-010	The future licensee shall carry out studies of the fast bus transfer system to determine lock-out times, protection settings and protection to prevent M1 and M2 circuit breaker remaining simultaneously closed.	Mechanical, Electrical and C&I Safety Systems - Before inactive commissioning.
AF-AP1000-EE-011	The future licensee shall confirm compliance with the UK Grid Code for each power plant	Long lead items and SSC procurement specifications
AF-AP1000-EE-012	The future licensee shall conduct post-fault recovery studies on the diesel fed system.	Long lead items and SSC procurement specifications
AF-AP1000-EE-013	The future licensee shall conduct studies for each power plant to consider the effects of islanding of the Electrical System.	Long lead items and SSC procurement specifications
AF-AP1000-EE-014	The future licensee shall conduct post-fault recovery studies for the system following grid faults.	Long lead items and SSC procurement specifications
AF-AP1000-EE-015	The future licensee shall conduct a full set of harmonic studies for the Electrical System assessing the effects of RCPs and battery chargers	Mechanical, Electrical and C&I Safety Systems - Before inactive commissioning.
AF-AP1000-EE-016	The future licensee shall determine the fundamental and all relevant harmonic voltage limits for all parts of the Electrical Distribution System at each power plant for incorporation in purchase specifications	Long lead items and SSC procurement specifications
AF-AP1000-EE-017	The future licensee shall define fault ratings for LV switchgear based on fault calculations for the system	Long lead items and SSC procurement specifications

Annex 1

Assessment Findings to be Addressed During the Forward Programme as Normal Regulatory Business

Electrical Systems – AP1000

Finding No.	Assessment Finding	MILESTONE (by which this item should be addressed)
AF-AP1000-EE-018	The future licensee shall prepare detailed specifications for electrical equipment.	Long lead items and SSC procurement specifications
AF-AP1000-EE-019	The future licensee shall ensure that UPS systems complying with US Standards are also compliant with IEC Standards	Long lead items and SSC procurement specifications
AF-AP1000-EE-020	The future licensee shall ensure all relevant purchase specifications define protection against EMI and arrangements shall be made for compliance with the requirements of Directive 2004/108/EC.	Long lead items and SSC procurement specifications
AF-AP1000-EE-021	The future licensee shall identify all Smart Devices to be used in electrical equipment to enable full verification and validation of these devices to be carried out in accordance with their safety classification.	Mechanical, Electrical and C&I Safety Systems - Before delivery to Site.
AF-AP1000-EE-022	The future licensee shall define electrical equipment safety classifications and incorporate the standards and performance criteria relevant to them in equipment purchase specifications.	Long lead items and SSC procurement specifications
AF-AP1000-EE-023	The future licensee shall determine ratings for LV and HV motors to IEC standards.	Long lead items and SSC procurement specifications
AF-AP1000-EE-024	The future licensee shall assess all specialist motors forming integral parts of devices to ensure their suitability for operating on 400V 50Hz supply.	Long lead items and SSC procurement specifications
AF-AP1000-EE-025	The future licensee shall produce electrical specifications for incorporation in the purchase specifications for standby and ancillary diesels.	Long lead items and SSC procurement specifications

Annex 1

Assessment Findings to be Addressed During the Forward Programme as Normal Regulatory Business

Electrical Systems – AP1000

Finding No.	Assessment Finding	MILESTONE (by which this item should be addressed)
AF-AP1000-EE-026	The future licensee shall undertake a study of fast transient disturbances for each system to consider the effects and protective measures to be taken.	Long lead items and SSC procurement specifications
AF-AP1000-EE-027	The future licensee shall demonstrate the protection provisions against the magnetic field levels generated by lightning strikes as defined in IEC 62305-4.	Mechanical, Electrical and C&I Safety Systems - Before inactive commissioning.
AF-AP1000-EE-028	The future licensee shall conduct studies to demonstrate that loss of a line of defence against transient overvoltages will not affect the safe operation and shutdown of the reactor.	Mechanical, Electrical and C&I Safety Systems - Before delivery to Site.
AF-AP1000-EE-029	The future licensee shall determine the voltage limits for all parts of the Electrical Distribution System for incorporation in purchase specifications.	Long lead items and SSC procurement specifications
AF-AP1000-EE-030	The future licensee shall conduct studies to assess the effects of overvoltages following system disturbances. This work should take into account the recommendations from the DIDELSYS task group (Ref. 45)	Long lead items and SSC procurement specifications
AF-AP1000-EE-031	The future licensee shall prepare a set of technical specifications for all electrical equipment taking account of performance requirements and environmental operating limits.	Long lead items and SSC procurement specifications
AF-AP1000-EE-032	The future licensee shall confirm that electrical penetrations meet all relevant IEC Standards.	Nuclear island safety related concrete

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 <u>during</u> 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.

Annex 1

Annex 2

GDA Issues – Electrical Systems – AP1000

WESTINGHOUSE AP1000® GENERIC DESIGN ASSESSMENT

GDA ISSUE

PCSR PRESENTATION OF CLAIMS ARGUMENTS AND EVIDENCE

GI-AP1000-EE-01 REVISION 0

<table>
<tr><td colspan="2">Technical Area</td><td colspan="2">ELECTRICAL ENGINEERING</td></tr>
<tr><td colspan="2">Related Technical Areas</td><td colspan="2">None</td></tr>
<tr><td>GDA Issue Reference</td><td>GI-AP1000-EE-01</td><td>GDA Issue Action Reference</td><td>GI-AP1000-EE-01.A1</td></tr>
<tr><td>GDA Issue</td><td colspan="3">Westinghouse is required to produce, within the PCSR, the claims arguments and evidence to substantiate the design of the complete Plant Electrical Distribution System. The claims made for the electrical system need to be related to the overall safety claims for the plant.
Chapter 18 of the PCSR does not meet the above requirements to demonstrate the safety and integrity of the design of the Electrical Distribution System. Clear safety claims are not presented and there is no structure of arguments and evidence to substantiate the design.</td></tr>
<tr><td>GDA Issue Action</td><td colspan="3">Westinghouse is required to produce a revised PCSR Chapter 18 to substantiate the design of the complete plant Electrical Distribution System. This needs to incorporate a structure of claims, arguments and evidence to demonstrate that the electrical system fully meets the requirements of its safety role as specified in the other chapters of the PCSR.
ONR's expectations are that the PCSR should provide a rigorous justification for the completeness of the electrical Power Distribution System to perform its safety role. The current issue of Chapter 18 does not meet our regulatory expectations as follows:
The PCSR does not provide a clear justification of the safety of the AP1000 Electrical Distribution System. References to other sections of the PCSR do not provide any detail to relate to the overall plant safety claims.
There is no clear structure of claims, arguments and evidence and it is difficult to determine what the actual safety claims are due to a considerable degree of ambiguity.
The electrical chapter of the PCSR principally addresses the reactor; the cooling ponds are not adequately covered.
The description of each constituent part of the electrical system has been presented as a Safety Assessment Principles (SAP) compliance document. The PCSR needs to consider the complete system and needs to substantiate this design rather than only addressing SAP compliance.
With agreement from the Regulator this action may be completed by alternative means.</td></tr>
</table>

Further explanatory / background information on the GDA Issues for this topic area can be found at:	
GI-AP1000-EE-01 Revision 0	Ref. 63.