Approach for Development of Safety Review Guidelines for Instrumentation and Control Systems of the Proposed Nuclear Power Plant in Nigeria

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1. Introduction

The increasing importance of electricity in future energy systems brings into focus the technology options for low-carbon electricity generation like nuclear power. Nigeria relies on 20 gas plants and three hydropower stations of 12,522MW installed capacity with a generation capacity of about 7,000MW for its growing populace of over 200 million people. Nigeria is currently exploring the possibility of incorporating nuclear energy into its energy mix as a part of its energy policy. Safety concern of nuclear installations necessitates the establishment of the Nigerian Nuclear Regulatory Authority (NNRA), a government agency under the Nuclear Safety and Radiation Protection Act (Act 19 of 1995). The NNRA is responsible for nuclear safety and radiological protection regulation within the country.

Licensees are required to conduct safety assessments of all Structures, Systems, and Components (SSCs) of a Nuclear Power Plant (NPP) to ensure adherence to the regulatory requirements and submit the report of the safety assessments as Safety Analysis Report (SAR) to the Regulatory Body (RB). The RB reviews the SAR to ensure that the designers and the licensee comply with all the requirements for the safe operation of the NPP. The safety review of SAR can only be done by experienced and qualified staff with the help of necessary document for maintaining technical consistency and transparency for safety review, thus requiring the development of Safety Review Guidelines (SRGs).

This research presents an approach for developing NNRA Safety Review Guidelines (SRGs) for Chapter 7 of SAR (I&C System). The Instrumentation and Control (I&C) systems include sensors, alarms, displays, and actuators that aid operators' decisions and automate protective actions during normal operations and accident conditions. I&C Systems play crucial roles during normal operation and accident conditions of a nuclear power plant (NPP).

To develop the Nigerian SRGs, IAEA requirements are used for this research because NNRA, as a member of the IAEA, develops its regulations based on the IAEA standards. The United State Nuclear Regulatory Commission (USNRC) has historically held a foremost position as a global nuclear regulator, responsible for formulating and implementing regulations to ensure nuclear safety. Therefore, the USNRC regulations and guides have been globally adopted by developing countries and international organizations. It means the USNRC regulations and guides are closely related to the IAEA safety standards. However, IAEA standards consist of comprehensive technical regulations and guides but there is no specific document on SRGs. Therefore, the SRGs will be developed based on the IAEA safety standards using the format of Standard Review Plans (SRPs), USNRC NUREG-0800[1] as a base document. The scope of this research is limited to the NPP protection systems, encompassing the Reactor Protection Systems (RPS) and Actuation Systems for Engineered Safety Features (ASESF). This study aims to serve as a basis for developing a Nuclear Power Plant's SRG for the Nigerian Nuclear Regulatory Authority (NNRA).

2. Methods

The method used in developing the safety review guidelines for Instrumentation and Control (I&C) systems is described in this section. This involves the review of IAEA standards and USNRC regulations; identification of applicable regulations and guides; comparison of IAEA standards and USNRC regulations; and then the development of the Nigerian SRGs by using the document format of Chapter 7 of the USNRC SRP[1]. Chapter 7 includes the procedures, requirements, acceptance criteria, and associated international standards for the review of I&C systems.

2.1 Review of USNRC Regulations and IAEA Standards

The IAEA standards are structured into three broad categories: Safety Fundamentals, Safety Requirements, and Safety Guides. The Safety Fundamentals, SF-1 provides the fundamental safety objectives and principles of protection and safety and provides the higher-level basis for the safety requirements. The Safety Requirements are divided into General Safety Requirements (GSRs) and Specific Safety Requirements (SSRs) that must be fulfilled to achieve the fundamental safety objectives. The Safety Guides are non-mandatory technical and/or procedural recommendations to achieve

the safety requirements and are subdivided into General Safety Guides (GSG) and Specific Safety Guides (SSG).

The USNRC regulations provide mandatory requirements for the designers and operators of nuclear facilities. The regulations are known as "Title 10 of the Code of Federal Regulations (10 CFR)". The USNRC also provides Regulatory Guides (RG) as non-mandatory recommendations to meet the 10 CFR requirements. SRPs establish criteria that the USNRC staff responsible for the review of applications will use in evaluating the compliance of the licensee's SAR with the USNRC's regulations. The SRPs are developed based on the content of the RG 1.70[2].

2.2 Identification of IAEA standards and USNRC regulations and guides for I&C Systems.

Safety requirements and guides for the design and assessment of I&C systems were identified from IAEA safety standards on NPP systems. The USNRC regulations and guides were also identified. USNRC has an extensive number of RGs that apply to the I&C system while IAEA standard corresponding USNRC RGs is only one comprehensive safety guide, SSG-39. Twenty-one of the USNRC RGs have been adopted for this research. The IAEA safety requirement and guides, similar USNRC regulations, and some examples of the RGs are given in Table I.

Table I: Example of Regulations and RGs of USNRC and IAEA on the design of I&C systems

USNRC	**IAEA**
Regulations/Requirements	
10 CFR Part 50, Appendix A	SSR-2/1
Regulatory Guides/Safety Guides	
RG 1.70	SSG-61
RG 1.53, RG 1.97, RG 1.105, RG 1.180	SSG-39

- 10 CFR Part 50, Appendix A: General Design Criteria (GDC) for NPPs [3]
- SSR-2/1: Safety of Nuclear Power Plants: Design[4]
- RG 1.70: Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition[2]
- SSG-61: Format and Content of the Safety Analysis Report for Nuclear Power Plants
- RG 1.53: Application of the Single-Failure Criterion to Safety Systems
- RG 1.97: Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants
- RG 1.105: Setpoints for Safety-Related Instrumentation
- RG 1.180: Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems
- SSG-39: Design of Instrumentation and Control Systems for Nuclear Power Plants[5]

2.3 Comparison between USNRC Regulation and IAEA Specific Safety Requirements (SSRs) Related to I&C Systems

There are twenty-nine and fourteen requirements in SSR-2/1[4] and 10CFR Part 50 Appendix A, respectively, that apply to the design of I&C systems. The requirements for sub-systems and functions were compared and some examples of similar provisions are shown in Table II.

Table II: Example of SSR-2/1 requirements and 10 CFR Part 50 Appendix A equivalent

10 CFR Part 50 Appendix A	**SSR-2/1**
Criterion 13: Instrumentation and control	Requirement 59: Provision of instrumentation Requirement 60: Control systems
Criterion 20: Protection system functions	Requirement 61: Protection system
Criterion 23: Protection system failure modes	Requirement 26: Fail-safe design
Criterion 24: Separation of protection and control systems	Requirement 64: Separation of protection systems and control systems

2.4 Comparison between USNRC Regulatory Guides and IAEA Specific Safety Guide (SSG)

The USNRC RG 1.70[2] and IAEA SSG-61[6] provide the standard format and content of Safety Analysis Report (SAR) for NPPs. Chapter 7 of both documents provides the information to be included for the I&C system. Some of the USNRC RGs and the technically equivalent paragraphs in SSG-39[5] for I&C systems are shown in Table III. The USNRC also refers to and adopts some Institute of Electrical and Electronics Engineers (IEEE) standards in their RGs while IAEA provides full detail in its guides but listed the applicable IEEE and International Electrotechnical Commission (IEC) standards that can be adopted by the designer or the national regulatory body.

3. Results

The format and contents of the draft Nigerian SRGs, based on the USNRC SRPs, are constituted as follows:

Title: Title of the SRG section (example: 7.3: Reactor Protection System).

Review Responsibilities: Information about the responsible organization for the review.

A. Areas of Review: This section describes the objectives and the scope of this section of SRG. It briefly describes the component of the systems to be reviewed and their functions. The relationships with other SAR sections are also stated.

Table III: Example of USNRC RGs and Equivalent IAEA SSG-39 paragraphs

USNRC RG	IAEA SSG-39
RG 1.53: Application of the Single-Failure Criterion to Safety Systems	SSG-39 Paragraphs 6.10 to 6.19: Single failure criterion
RG 1.97: Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants	SSG-39 Paragraphs 8.19 to 8.35: Accident Monitoring
RG 1.105: Setpoints for Safety-Related Instrumentation	SSG-39 Paragraphs 6.205 to 6.212: Set Points
RG 1.180: Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems	SSG-39 Paragraphs 6.113 to 6.134: Electromagnetic qualification

B. Acceptance Criteria: This section lists the requirements to be met based on the regulations and applicable recommendations from the IAEA safety guides. The related USNRC requirements in SRPs are replaced with the equivalent requirements in the IAEA standards as compared in section 2 of this paper. The USNRC RGs are also substituted with the appropriate sections of the IAEA SSG-39[5].

C. Review Procedures: This section describes the process to be followed by the reviewer during regulatory review. The requirements and recommendations in 3(B) are sectioned based on the subtopics of the corresponding section in accordance with SSG-61[6]. The guides listed in 3(B) are explained in detail with information to help the reviewer during the regulatory review.

D. Evaluation Findings: This section provides the reviewer with the information that should be included in the Safety Evaluation Report (SER). The reviewer verifies that the applicant provides the necessary information and states the bases for the conclusions. The USNRC requirements in this section are substituted with similar IAEA requirements.

E. Implementation: This section briefly describes the applicability of the SRG. The SRPs can be applied also to Combined Licensing and Design Certification but the SRG under development will only be applied to staged licensing in Nigeria.

4. Conclusion

This research has provided an approach for the development of Nigerian SRGs through the identification and comparison of the IAEA standards and USNRC regulations. It is evident from the comparison that the regulations have very close similarities with requirements. Despite the similarities, there are some of the IAEA requirements in SSR 2/1 that are not available in the USNRC 10CFR Part 50 Appendix A, therefore an in-depth technical knowledge of the requirements is needed for developing applicable SRGs with this approach. Review and comparison of the IEEE standards adopted in the USNRC RGs with IAEA SSG-39 is also crucial to the development of the SRGs. The approach introduced in this research can be beneficial to the NNRA and other nuclear-embarking countries for the development of their national-specific SRGs if used properly with additional documents and an understanding of the requirements. The approach can also be used for the development of other sections of the Safety Review Guides.

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