DEG Strategy for Development and Application of FPGA-based Safety Platform

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1. Introduction

The safety-grade controllers employed in numerous nuclear power plants are typically distinct from both the manufacturer and the operator. This separation arises due to the proprietary nature of the trade secrets held by manufacturers and operators, protected under intellectual property rights. Consequently, actively responding to digital facilities becomes a challenging endeavor.

Our investigation involved a thorough examination of the Digital Engineering Guide (DEG), which draws from system engineering principles studied at Electronic Power Research Institute (EPRI). We sought to adapt and integrate elements of this guide into the development process of an FPGA-based safety-grade controller.

This paper introduces K-DEG basis, a Koreanspecific DEG model tailored for controller development. It is devised by amalgamating segments of the DEG developed by EPRI with insights from the Critical Design Review (CDR) conducted as part of the independent review process for digital facility enhancements at Korea Hydro & Nuclear Power (KHNP).

2. Overview of DEG

DEG serves as a comprehensive technical manual indispensable for engineers engaged in the application of digital technologies within Nuclear Power Plants (NPPs), whether for new installations or existing ones. It encompasses a broad array of topics, spanning systems engineering, ergonomics, data communications, cybersecurity, power plant integrated design, testing, configuration management, and digital product discontinuation management [1].

Among the various domains covered within DEG, system engineering emerges as the paramount area warranting review and implementation. Chapter 4 of DEG particularly concentrates on system engineering, outlining specific targets for analysis and review.

System engineering scrutinizes the elements that must be considered across the entire lifecycle of digital devices to meet the demands of customers. Particular emphasis is placed on evaluating the concept and design in alignment with the primary objective [2].

Although other aspects such as ergonomics, testing, and configuration management are also regarded as

significant, they do not deviate substantially from established technical standards.

3. Overview of CDR

Since 2015, KHNP has been conducting a CDR, which involves an intensive technical review aimed at investigating the potential for unexpected accidents or unacceptable behavior within critical digital facilities. The objective is to recommend mitigation strategies for an independent review of digital facility improvements. To facilitate this process, a Task Force Team (TFT) is currently being formed to conduct an independent review of digital facilities [3].

KHNP's CDR is primarily employed during the Operating and Maintenance (O&M) stage, referencing EPRI TR-1011710 (Handbook of Evaluating Digital Equipment & Systems, 2005). When undertaking digital improvements on critical facilities, it involves forming a task force comprising one (1) leader and two (2) to three (3) technology and system experts. This team conducts an independent review from the initial stages and throughout the entire facility improvement period [4].

The main duties of CDR include reviewing and supporting design specifications, conducting design review and installation assessments, overseeing site acceptance, and managing factory acceptance testing.

Table I: CDI	R Team	Configu	ration
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Division (people)	Responsibilities	Qualification (Required Abilities)
Leader (1)	•Project overall technical review and coordination	 Possess understanding of technical issues Ability to lead discussions and mediate disputes Objectivity (regardless of project, process, budget, etc.)
Applicati on experts (1~3)	•Review of current equipment and interfaces reflected in new equipment	 A person who understands the design of current equipment A person who is familiar with the

	 Operating experience analysis Review of the impact of equipment failure, etc. 	 functional requirements, licensing issues, and design basis issues of new facilities. Power plant system engineers, design engineers, specialists (researchers), etc.
Digital system experts (0~2)	 Review of production documents for new equipment (H/W and S/W documents) Review of digital design adequacy 	 Expert in software, OS, microprocessor, V&V Experts who understand power plant systems and digital (H/W, S/W) best practices

4. K-DEG basis Model

When design, production, and operation are compartmentalized, power generation companies responsible for operations encounter structural barriers to involvement in the design process due to the industry ecosystem. In other words, it becomes very difficult to incorporate DEG or CDR recommendations.

However, the newly developed FPGA-based safetygrade controller has a business structure that enables KHNP, the operator, to oversee the entire lifecycle, encompassing design, production, verification, installation, and operation.

KHNP prioritizes the application of technologies necessary for digital facilities, with a focus on System Engineering outlined in Chapter 4 of DEG. Additionally, it independently reviews aspects such as ergonomics verification, cybersecurity, and more.



Fig. 1. Relation of CDR and Supplier

DEG differentiates evaluations based on product satisfaction goals based on configurability. FPGA-based safety-grade controllers have high goals. In order to review all life cycle processes of digital facility development, we propose to preferentially apply the CDR operated by KHNP as a model.

5. Conclusions

Unlike past controllers, the development and application of an FPGA-based safety grade controller has a development structure that allows everything to be reviewed from the operator's perspective. In other words, a perfect environment is created to apply DEG. Therefore, it is expected that an excellent controller that reflects the opinions of the operator will be developed through the active acceptance of DEG by forming a CDR. Additionally, it is expected that K-DEG will be developed based on development experience.

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