Development Strategy of the Improved Standard Technical Specification for Wolsong CANDU-6 Nuclear Power Plants

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Abstract

The Wolsong CANDU-6 can be differently treated to a certain extent in terms of operation and safety due to the wide span of commissioning dates between, namely, Unit 1 and Units 2,3,4. This fact resulted in the use of non-unified technical specification (OP&P style in Unit 1 and US standard technical specification style in Units 2,3,4). Thus, it became necessary to improve Limiting Condition for Operations (LCOs) that have been based upon insufficient selection criteria in context of safety standards in the past. The newly developed ISTS for Wolsong CANDU-6 is aimed to achieve the following points, (1) Elimination of unnecessary LCOs that are irrelevant to plant safety, (2) Unification of similar LCOs and relocating them, (3) Application of any improvements gained from operational experiences and/or research works, (4) Reinforcement of technical bases and also placing greater emphasis on human factor principles in order to make technical specification clearer and easier to understand. The goal of Wolsong CANDU-6 ISTS development is to improve plant safety practically by selecting safety significant LCOs, optimise surveillance requirements and reinforce technical bases, in order that the development of the first one for Pressurized Heavy Water Reactor (PHWR) nuclear power plants could be accomplished in the world. Furthermore, it can be utilized as the standard technical specification to prepare Wolsong-1 Improved Technical Specification (ITS) for the continuing operation after the major refurbishment.

1. Introduction

CANDU nuclear power plants generally use Operating Policies and Principles (OP&Ps) instead of a technical specification. The OP&Ps, which are not specifically prescribed by regulatory documents, contain a definition of the authority and responsibilities of managers and operating staff, as well as the principles to be applied for the safe operation of each of the station's systems.

In the United States (US), the licensee is required to operate in accordance with the Technical Specification (TS) document that sets out the fundamental rules for safe operation of nuclear power plants. The nuclear industry in the US recognized a need for technical specification improvement after the TMI accident and an improvement program was initiated in 1984. The ISTSs were developed based on the criteria in the Final Commission Policy Statement on Technical Specifications Improvements for Nuclear Power Reactors [1], which was subsequently codified by changes to Section 36 of Part 50 of Title 10 of the Code of Federal Regulations (10 CFR 50.36) [2].

In the early 1990s, it was recognized that safe operating limits for Canadian nuclear power plants were not defined clearly enough using operating variables that were readily measurable by operations staff. Consequently, Canadian plants initiated improvement projects, called Safe Operating Envelope (SOE) projects, to provide better coordination of design and analysis limits in terms that the operations staff could readily monitor and control. In an effort to improve Korean CANDU-6 plant technical specification, Wolsong Units 2,3,4 adopted a US standard technical specification (STS) style in the operating license stage. But in contrast, Wolsong Unit 1 adopted the Canadian OP&P style. Therefore there are some inconsistencies between CANDU Units. In addition, the following issues still remained unresolved in the current technical specifications (CTSs): excessive surveillance requirements; selection of LCO without objective selection criteria; and lack of consideration for accumulation of operational experience and technological development.

The goal of Wolsong CANDU-6 ISTS development is to improve plant safety practically by selecting safety significant LCOs, optimize surveillance requirements and reinforce technical bases in order that the development of the first ISTS for PHWR nuclear power plants could be accomplished in the world.

2. LCO Selection

The conditions under which it is acceptable to continue operation in a given plant operating state are called "Condition of Operability." It is used to determine the level of severity of an abnormal condition in terms of the impact on safety related performance at the system or functional level. The LCO is one of the conditions of operability, which represents the lowest functional capability or performance level of the equipment or the operating parameters, as credited in the safety analysis. The LCO is related to the Minimum Allowable Performance Standards (MAPS) in the safety analysis.

The selection criteria for LCOs conform to Announcement No. 2009-37 [3], which is based on 10 CFR 50.36. The LCOs should be selected for each item, meeting one or more of the following criteria:

- Criterion 1: Installed instrumentation that is used to detect, and indicate in the control room, a significant abnormal degradation of the reactor coolant pressure boundary.

- Criterion 2: A process variable, design feature, or operating restriction that is an initial condition of a design basis accident or transient analysis that either assumes the failure of or presents a challenge to the integrity of a fission product barrier.

- Criterion 3: A structure, system, or component that is part of the primary success path and which functions or actuates to mitigate a design basis accident or transient that either assumes the failure of or presents a challenge to the integrity of a fission product barrier.

- Criterion 4: A structure, system, or component which operating experience or probabilistic risk assessment has shown to be significant to public health and safety.

The selection criteria have been applied to select the LCOs for Wolsong CANDU-6 ISTS as follows. This selection criteria application guide is established considering the NRC staff's view [4].

Criterion 1

The objective of criterion 1 is to select only the installed instrumentation which is used to detect actual leaks of the reactor coolant. Therefore, the instrumentation used to detect precursors to an actual breach of the reactor coolant pressure boundary integrity or to identify the source of actual leakage is not applicable to criterion 1 (e.g., loose part monitoring system in Wolsong Unit 1, seismic instrumentation of Wolsong Units 1 and 2). The related instrumentations for Wolsong CANDU-6 plants are as follows: annulus gas system to detect pressure tube leaks, D_2O-In-H_2O leak detection system to detect steam generator tube leaks or recirculated cooling water system heat exchanger leaks, tritium in the air monitor to detect reactor coolant leaks into the reactor building, and D_2O storage tank level indicator to monitor reactor coolant inventory change due to leaks.

Criterion 2

This criterion includes active design features (e.g., regional overpower protection system handswitch) and operating restrictions (e.g., pressure/temperature limits) needed to exclude unanalyzed accidents and transients. Initial conditions captured by criterion 2 are not limited to only process variables directly monitored and controlled from the control room. These could also include other features or characteristics that are specifically assumed in the design basis accidents and transient analyses even if they cannot be directly observed in the control room (e.g., channel power peaking factor). Variables that an operator cannot control are not applicable to criterion 2 as follows: geometry factors (e.g., total number of channels, the number of helium bottles in the moderator cover gas system), passive components (e.g., rupture disk) and properties (e.g., gap conductance). The system (or component) which is not credited in safety analysis is not applicable to this criterion (e.g., reactor control system, condenser steam discharge valve, and atmospheric steam discharge valve).

Criterion 3

It is the intent of this criterion to capture into the TS only those structures, systems, and components that are part of the primary success path in the safety sequence analysis. Also those support and actuation systems that are necessary for items in the primary success path to successfully function are captured by this criterion. The primary success path for a particular mode of operation does not include backup and diverse equipment (e.g., the D_2O feed system which is a backup to fill up the D_2O storage tank, and the emergency cooling water supply system which is a backup to the Raw Service Water System for the cooling of standby diesel generators).

Criterion 4

The LCO related to the instrumentation of the Secondary Control Area and those related to operating modes 3, 4 and 5 are selected by criterion 4 through reviewing the operating experience and risk insights.

The process of LCO selection for Wolsong CANDU-6 ISTS is shown in Figure 1.

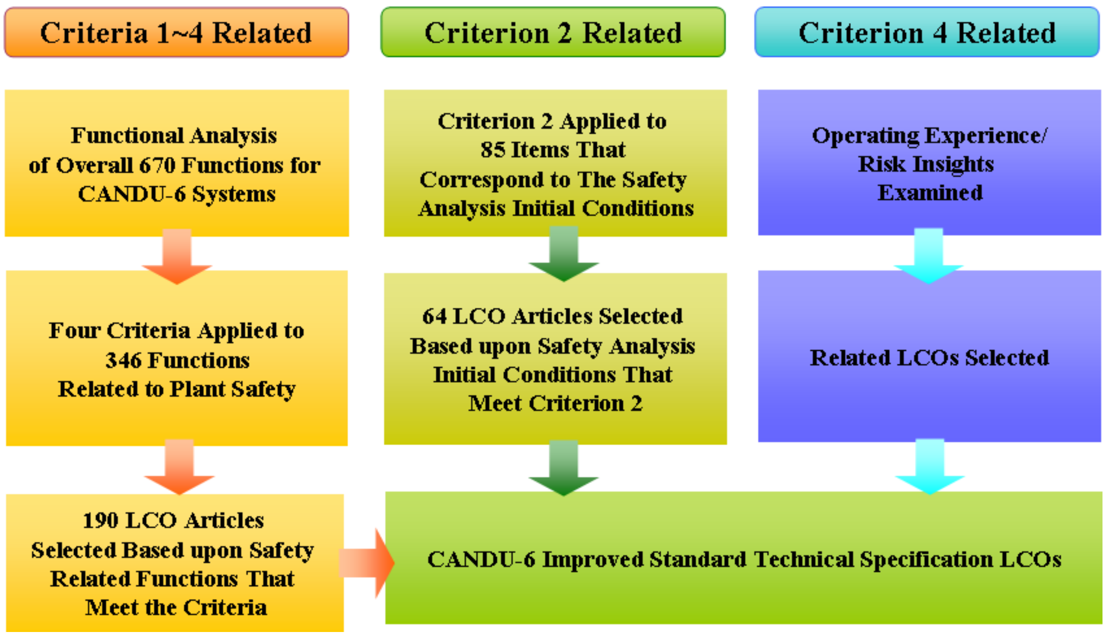

Figure 1. Process of LCO selection

3. Results

On the basis of the other research results [5], of the overall 670 functions for Wolsong CANDU-6 systems, 346 functions were classified as those related to plant safety. Then, after applying the four criteria to the 346 items, 190 functional items that need to be selected as LCOs were classified. Reviewing Safety Analysis Data List [6] and Chapter 15 in the FSAR [7] related to safety analysis, 85 initial conditions were classified. Applying Criterion 2 to those 85 conditions, 64 articles that need to be selected as LCOs were classified. Four items related to operating experience or probabilistic risk assessment insights, which are significant to public health and safety, were selected as LCOs according to Criterion 4.

Classifying and rearranging the LCOs described earlier, 72 LCOs are finally selected as Wolsong CANDU-6 ISTS LCOs. Results of the LCO selection are summarized in Table 1. As shown in the table, the reduction degree in the number of LCO items is ~36%.

The user's comprehension of technical bases for each LCO is enhanced by describing background, applicable safety analyses, LCO, applicability, required actions, surveillance requirements, and references for "Chapter 2.0 Safety Limits" and "Chapter 3.0 Limiting

Conditions for Operation and Surveillance Requirements" in "Part 1: Operation of Reactor Facilities" according to the ISTS writer's guideline.

Table 1. Summary of LCO Selection

Category	*Number (in articles)*
Wolsong Units 2, 3,4 LCO Items	113
Wolsong CANDU-6 ISTS LCO Items	72
Comparison with CTS (Wolsong Units 2,3,4 TS)	
Additional LCO Items	1
LCO Items to be Relocated	33

LCOs are defined considering single failure criterion in case of redundant systems/components in order to preserve minimal redundancy necessary for safe operation. For example, in order to ensure the operability of containment dousing system, the operability of at least 4 downcomers out of the six ones is required. So the LCO is defined as follows: the dousing system shall be operable, with both valves on at least 5 of the 6 downcomers operable by applying single failure criterion.

LCOs are optimized by taking into account the safety analysis initial conditions. For instance, out of 16 Reactor Building (RB) Local Air Coolers (LACs) that are supplied by Class III power, at least 8 LACs shall be operable as safety analysis initial conditions. The LCO is optimized as follows: Out of 16 RB LACs that are supplied by Class III power, at least 8 LACs shall be operable.

Ambiguous contents in LCOs or required actions are described with clarification through the verification process with site staff. For example, the results of natural convection analyses in the operating mode 4 are reflected to the clarification of the necessary number and level of steam generators, which results in the following specification: In each loop, the water level of at least 1 steam generator shall not be less than -1.4 m.

Taking into account of site applicability, the nitrate of gadolinium solution concentration surveillance period is amended from "7 days" to "1 month" regarding poison tanks in Shutdown System Number Two. Relieving of the surveillance period is done through utilizing risk information from system reliability analysis and reviewing performance history on the concentration change trend.

The inter-related LCOs are merged. For example, the shutoff rod drop time is one of the factors that are required to verify the operability of Shutdown System Number One.

Therefore, the two LCOs related to the operability of Shutdown System Number One and the shutoff rod drop time are merged to one LCO.

Some items are relocated after reviewing the Pressurized Water Reactor(PWR) ISTS examples [8,9]. The items related to the release of radioactive effluents are relocated based on GL 89-01 [10]. The equipment list (e.g., RB isolation valve list, etc.) is deleted based on GL 91-08 [11]. Partial items related to instrumentation in the context of non-safety, such as seismic instrumentation and turbine overspeed protection, are relocated based on GL 95-10 [12].

4. Discussion

The description methodology of Wolsong CANDU-6 ISTS has been changed from descriptive to diagrammatic and eliminated confusions by utilizing logical operators. In addition, the significant terminologies are composed of solid gothic characters to offer clear distinctive symbols which contributes to strengthen user friendliness as well as human engineering elements.

The rationalization has been achieved by optimizing ISTS with the elimination of unnecessary LCOs, relocations and unification. The Wolsong CANDU-6 ISTS has been developed as the first one in the world by strengthening LCO selection criteria as well as technical bases according to 10 CFR 50.36.

Wolsong CANDU-6 ISTS has been submitted to the regulatory authority for review and approval and it is expected to be utilized as the improved standard technical specification for the preparation of Wolsong-1 ITS that is required for the continuing operation as well as for the preparation of Wolsong 2,3,4 ITS. Furthermore, Wolsong CANDU-6 ISTS has been laid out according to 10 CFR 50.36 as the first one in the world so that Korea will become with its operation of both PWR and PHWR the first country in the world to have developed the unified version of TS and be regarded as a model nation for the countries with operation of both PWR and PHWR.

5. Conclusion

Wolsong CANDU-6 ISTS has been developed to relocate unnecessary LCOs that are irrelevant to plant safety; to apply any improvements gained from operational experiences or researches; to reinforce technical bases; and to place greater emphasis on human factors principles in order to make technical specification clearer and easier to understand.

Wolsong CANDU-6 ISTS development has several effects such as securing of international competence for CANDU-6 plant safety technology by establishing the ISTS related technical bases, aiming of practical safe operations as well as relieving of utilities and regulatory body load, and improving safety and serviceability for CANDU-6 operations by taking into account human factor engineering.

6. References

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[12] U.S. Nuclear Regulatory Commission, “Relocation of Selected Technical Specifications Requirements Related to Instrumentation,” Generic Letter 95-10, 1995.