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Methodology for Developing Standard Schedule Activities for Nuclear Power Plant Construction through Probabilistic Coherence Analysis

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Abstract

Nuclear power plant (NPP) constructions are large scale projects that are executed for several years, and schedule control utilizing various schedules is a critically important factor. Recently Korea independently developed the Advanced Power Reactor (APR) 1400 and is building nuclear facilities applying this new reactor type. The construction of Shin-Kori NPP (SKN) Unit 3, which adopted the APR1400, was completed and commercial operation has begun, while, SKN 4, Shin-Hanul NPP (SHN) Units 1&2, and SKN 5&6 are currently under construction. Prior to the development of the APR1400, Korea built 24 reactors and accumulated the schedule data of various reactor types which provided the foundation for schedule reduction to be possible. However, as there is no schedule development and review system established based on the standard schedule data (standard activities, durations, etc.) by reactor type, the process for developing the schedule for new builds is low in efficiency consuming much time and manpower. Also all construction data has been accumulated based on schedule activities. But because the connectivity of activities between projects is low, it is difficult to utilize such accumulated data (causes for schedule delay, causes for design changes, etc.) in new build projects. Due to such reasons, issues continue to arise in the process of developing standard schedule activities and a standard schedule for nuclear power plant construction. In order to develop a standard schedule for NPP construction, i) the development of an NPP standard schedule activity list, ii) development of the connection logic of NPP standard schedule activities, iii) development of NPP standard schedule activity resources and duration, and iv) integration of schedule data need to be performed. In this paper, an analysis was made on the coherence of schedule activity descriptions of existing NPPs by applying the probabilistic methodology on activities with low connectivity due to the utilization of the numbering system of four APR1400 reactors (SHN 1&2 and SKN 3&4).This study also describes the method for developing a standard schedule activity list and connectivity measures by extracting same and/or similar schedule activities.
Key words: NPP standard schedule activity, Probabilistic Coherence Analysis Method

1. Introduction

1-1. Background and Purpose

During the construction of 24 reactors during the past 30 years, Korea accumulated an extensive amount of data in the unit of schedule activities of several reactor types. However, the data is simply accumulated by project, and there have been no connectivity or data integration have been among the projects; thus, program management recommended by the Project Management Body of Knowledge (PMBOK) is not being implemented. In other words, all construction related information is integrated in the unit of activities, but no assetization has been performed for reference for succeeding projects. In addition, since a standard schedule and schedule activities have not been developed, the efficiency of developing and reviewing the schedule is low and schedule delay events that occurred in preceding units are not being effectively reflected. The target subject of this paper is the Korean reactor type APR1400 (SHN 1&2, SKN 3&4) and a comparative analysis was performed on the Integrated Project Schedule for the construction area of each project. Activities with the same activity number and description from each project were identified. About 50 % of the activities from the projects had the same activity number and description, and the remaining 50 % applied a different numbering system or their descriptions were different. With the objective to develop a standard schedule for NPP construction, this study analyzed the coherence of existing schedule activities and presented methods for developing a standard activity list and activity features (duration, resource, etc.).

1-2. Method and Scope

The scope of this study is the construction activities of NPP construction in Korea, and this paper aimed to present the methodology for probabilistic coherence analysis for the development of the activity list for a standard NPP construction schedule. The following was performed in the provided sequence to achieve this objective.

First, the status of the NPP construction schedule management system in Korea was analyzed, along with incurring issues and areas requiring improvement. Second, automated same and/or similar schedule activities were identified applying the probabilistic coherence method to propose an integration method for standard activity descriptions. And third, the derived method was applied to an actual project to verify whether identification of same and/or similar activities was possible.

2. NPP Schedule Management System in Korea

2-1. NPP Construction Schedule Scheme in Korea

An NPP construction schedule scheme is composed of four tiers according to the purpose of usage and operation characteristics. The Project Milestone Schedule defines the project period and the major milestones; the Project Summary Schedule is a summary of critical activities; the Integrated Project Schedule is the basis for contractual management, being the common communication tool for all project engaged entities; and the Project Detail Schedule provides the detailed schedule of each area[1]. Among the four schedules, the Integrated Project Schedule is the basis used for communication and contractual arrangements, being highly important, and therefore was used as the basic schedule for analysis for this study.

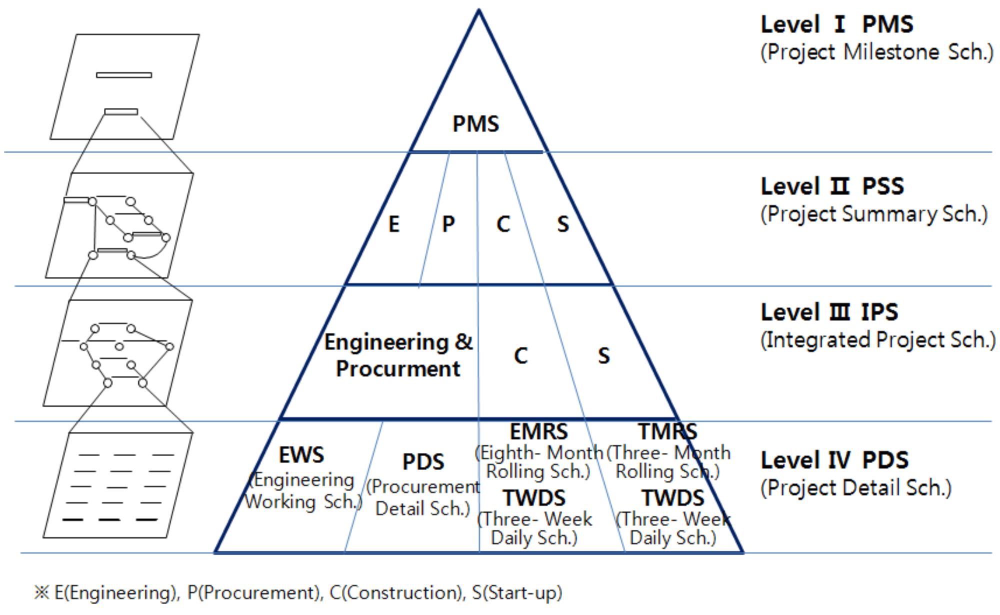

Fig 1. NPP construction schedule scheme hierarhy

2-2. Process for Developing the Integrated Project Schedule

NPP construction projects in Korea are executed based on a “multiple package contract” where supply agreements are individually signed for architectural engineering, nuclear steam supply system (NSSS), turbine generator, nuclear fuel, construction of major facilities, and Balance of Plant (BOP) packages [2]. The architectural engineer (A/E) develops the schedule for NPP construction in Korea, and the project owner and related project entities (construction company and equipment suppliers) review the schedule for finalization. The project owner and related project entities should refer to a standardized activity list and activity features (duration, relation data, etc.) when reviewing the Integrated Project Schedule, but as there is no standardized data at the moment, the review and approval is quite time consuming. Consequently there is a need for standardized activity information that includes all data (quantities, cost, risks, etc.) for each schedule activity.

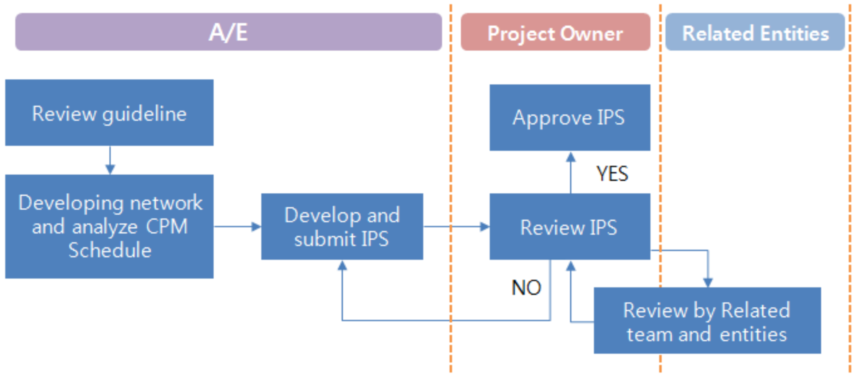

Fig 2. Process for Developing IPS

3. Supplementary Measures to the Standard Schedule Management System for NPP Construction

NPP construction projects in Korea generally have high level schemes for schedule management, but do not have detailed schedule management schemes and the following problems exist. There is i) a lack of connectivity between existing NPP construction schedule activities; ii) a lack of a standard schedule activity list; iii) a lack of standard activity durations; iv) a lack of standard schedule resources; and v) a lack of standard schedule activity relations. Therefore, this study compared the activities of the Integrated Project Schedule of the four ARP1400 reactors mentioned above; and by connecting the existing NPP project schedule activities based on a probabilistic coherence analysis, a method to identify standard schedule activity items was presented.

3-1. Necessity to Develop NPP Standard Schedule Activity Items

The four APR1400 units were compared by unit and by Area (PBS). SHN 1&2 (A) and SKN 3&4 (B) were compared each with 3,712 and 3,588 IPS activities. Mapping was performed based on activity numbers less than one, and the number of activities with the same activity number was identified for each area (Table 1). The number of activities with the same activity was 3,005 (80.95 %) based on SHN 1&2 (A) and 2,995 (83.47 %) based on SKN 3&4 (B). A comparison was made on the appropriateness of the activity descriptions for activities that had the same number. The number of activities where the activity number and the description were the same was 1,717 (total 3,005) based on SHN 1&2 (A) and 1,727 (total 2,995) based on SKN 3&4 (B)—an average of 57 % and this figure rapidly decreases. The analysis results showed that 1,300 out of a total 7,300 activities did not have the same activity number, and among the 6,000 activity items whose numbers matched, the descriptions of 3,444 activities exactly matched and the remaining 3,556 activities had to be judged on their alignment. If a different project of the same reactor type has a schedule coherence of about 50 %, this means that the schedule connectivity is not efficient. It also refers that it is inefficient to develop standard schedule activity lists based on the schedule activities of existing projects.

Table 1. Analysis of Activity Consistancy (SHIN1,2 / SKN 3,4)

	Unit	Number of Activities	Area(PBS)							
			General	Multisystem	Site	Power Block (3xx)	Primary SYS	Secondary SYS	Other SYS	I&C SYS
SHN 1,2 **(A)**	0	^{A}558/^{B}789 ^{C}282(50.53%)	^{A} 0/^{B} 0	^{A} 1/^{B} 1	^{A} 359/^{B} 565	^{A} 198/^{B} 203	^{A} 0/^{B} 7	^{A} 0/^{B} 4	^{A} 0/^{B} 9	^{A} 0/^{B} 0
	1	1233/1466 723(58.93%)	0/0	0/0	258/368	975/1030	0/18	0/33	0/15	0/2
	2	1214/1457 712(58.64%)	0/0	0/1	241/362	973/1026	0/18	0/33	0/15	0/2
Subtotal		3005/3712 1717(57.13%)	0/0	1/2	858/1295	2164/2259	0/43	0/70	0/39	0/4
SKN 3,4 **(B)**	0	551/750 282(51.17%)	0/32	1/2	352/509	198/207	0/0	0/0	0/0	0/0
	3	1230/1418 724(58.86%)	0/0	0/0	255/407	975/1011	0/0	0/0	0/0	0/0
	4	1214/1420 721(59.39%)	0/0	0/1	241/408	973/1011	0/0	0/0	0/0	0/0
Subtotal		2995/3588 1727(57.66%)	0/32	1/3	848/1324	2146/2229	0/0	0/0	0/0	0/0

*Legend : ^{A} Number of activities with the same activity No.; ^{B} Total number of activities, ^{C} Number of items where activity No. and DESC are the same.

3-2. Probabilistic Coherence Analysis Method of Schedule Activities

Among the Power Block (3xx) schedule activities of SHN 1 and SKN 3, 975 activities had the same activity number, but 372 of them did not have the same descriptions and these were analyzed. The reasons that these were not acknowledged as having the same activity descriptions were because of i) simple misspelling and word spacing, ii) sentence sequencing, iii) different abbreviations, iv) additional words, v) different schedule levels or building names, vi) different symbols, and vii) synonyms. The activity of SKN 1 “RCB INSTALL IHA PLATFORM CABLE BRIDGE & MISC” and the activity of SHN 3 “RCB ERECT IHA PLATFORM CABLE BRIDGE & MISC” were not recognized as the same activity because of the differently used words “ISTALL” and “ERECT”. Accordingly, in order to solve this issue of not being able to recognize certain activities as the same activity, an algorithm (Fig 3) was developed to analyze sentences by words and acknowledge such descriptions as the same based on the coherence probability of the words.

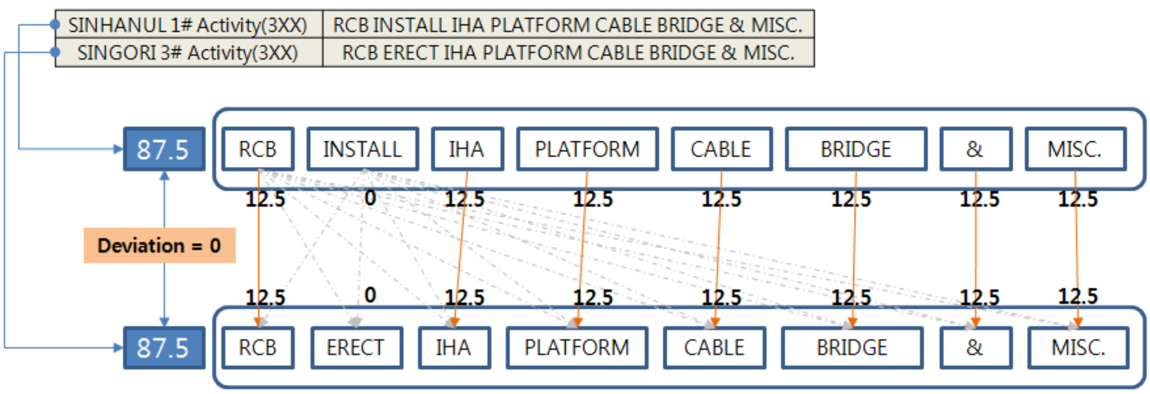

Fig 3. Method of Probabilistic Coherence Analysis

Activity descriptions were separated by words and mapped. Eight words were divided by the premise word number and then allocated (12.5 %) to grant numerical values to the coherence. An algorithm was developed to summon the allocation value (12.5 %) after the words of the sentence being compared is mapped. As a result, the probability coherence of the two activites was 87.5 % and the deviation was 0 %. In order to calculate the probabilistic coherence reliability value, the evaluation range was determined based on the average and deviation of the description coherence rate of 1,198 same or similar activities and the average and deviation of the deviation of the coherence rate of the two activities (Table 2).

Table 2. Analysis of Activity Consistancy

	Average	Deviation	Evaluation Range	Remark
Description coherence rate	82.24	11.76	70.78 or less	Extract (70 or lower)
Deviation of description coherence rate	12.10	9.35	21.45 or higher	Extract (22 or higher)

Applying this method, the coherence of a total of 1,204 Power Block activities of SKN 1 and SHN 3 was analyzed(Fig 4). The results showed 101 activities to have a description coherence rate less than 70 %, and among them, 16 activities with a description deviation of 22 % or higher were extracted. Of the extracted activities, 13 activities had the same or similar descriptions and the remaining three were extracted to be different. When applying the probabilistic coherence analysis method, since only about 8.4 % of activities require judgment, same or similar activities can be effectively extracted and their connectivity can be set.

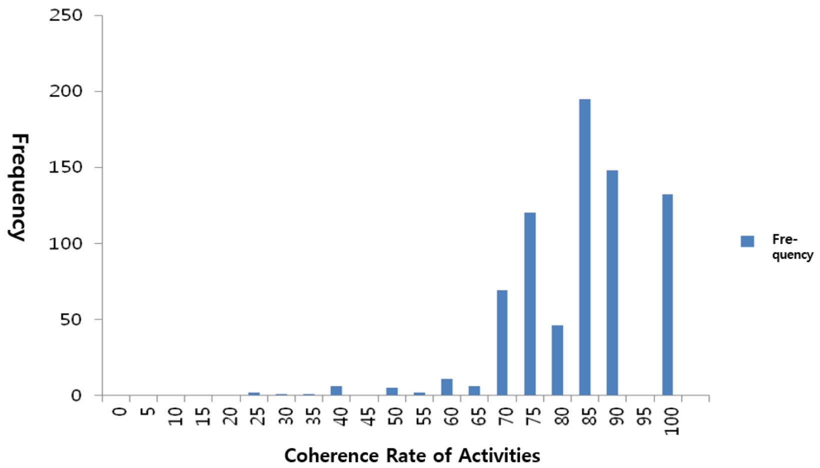

Fig 4. Coherence Rate of Power block Activities

3-3. Verification of the probabilistic coherence of schedule activities

Two activities were selected and analyzed to verify the probabilistic coherence analysis method (Table X). Two same activities, (1) HEAD TENSION, IHA PLATFORM & EXCORE DETECTOR SIPS and (2) RCB INSTALL IHA PLATFORM CABLE BRIDGE & MISC, from two projects (A/B) were chosen and the same or similar activities were extracted. One activity each was extracted with a coherence rate of 70% or higher. Also since the description coherence rate deviances are 0 % and 8.3 %, respectively, they are within the evaluation range, and thus, can be determined to be the same activity.

Table 3. Result of Activity consistancy

No.	Coherence Rate	Deviation	Result of Extraction Activity
1	75%	8.3	RV HEAD TENSION & EXCORE DETECTOR INC. TO SIPS
2	85%	0	RCB ERECT IHA PLATFORM CABLE BRIDGE & MISC.

Additionally, in order to raise the reliability of the verification, one activity (AB MCR AREA ERECT RAISED FLOOR INCLUDE COMPUTER ROOM) which had no same activities between the two projects (A/B) was chosen as the basis and its coherence with all activities was analyzed. As a result, the coherence rates were 0 % (145 activites), 15 % (181), 25 % (38), and 35 % (7); all activities had a coherence rate of 35 % or lower. Resultingly, there was no activity with a description coherence rate of 70 % or higher which verifies that no same activity exists.

4. Conclusion

Up till now Korean NPP construction projects made effort to complete one project and all construction data was collected in the unit of project schedule activity. However, little effort was made to establish connectivity between accumulated data from different projects and utilize the integrated data. This study presented a probabilistic coherence analysis method that can be used to connect and integrate data by extracting similar or same data, regardless of the applied probabilistic numbering system. As a result, the coherence reliability scope was defined and actual data was applied to verify the methodology to obtain reliability. The application of this methodology is expected to increase work efficiency since experience data can be used for integrated data management and new build projects based on the connectivity established among NPP construction data founded on integrated existing activities. The reliability range proposed through this study will be increased in the future by adding more data and coherence rate weighting, and additional research will be made on the issue of synonym usage by applying the word embedding technique[3].

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