Modeling of the Nuclear Power Plant Life-cycle for "Big Data" Management System: A Systems Engineering Viewpoint

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1. "Big Data" – General Concept

Together with the significant development of Internet and Web technologies, the rapid evolution of "Big Data" idea has been observed since it is first introduced in 1941 as an "information explosion" (OED). Using the "3Vs" model, as proposed by Gartner, "Big Data" can be defined as "high-volume, high-velocity, and/or high-variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization. "[2]

Big Data technologies and tools have been developed to address the way large quantities of data are stored, accessed and presented for manipulation or analysis. The idea also focuses on how the users can easily access and extract the "useful and right" data, information, or even knowledge from the "Big Data".

2. Nuclear Power Plant (NPP) life-cycle model

The life-cycle of NPP development is generally categorized into five main stages, i.e. the pre-project stage, project decision-making stage, plant construction stage, plant operation stage, and decommissioning stage. Within the framework of this study, the decommissioning stage will not be taken into account. The four remaining stages can be further divided into specific phases as illustrated in Fig. 1.

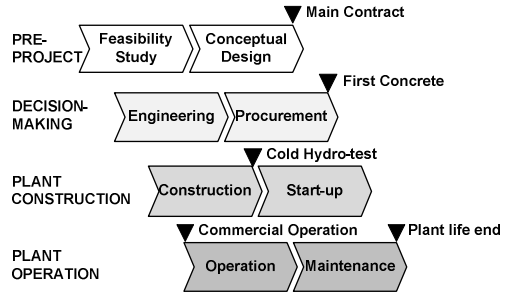

Fig. 1. NPP life-cycle model

Referred to as the NPP life-cycle model, the process in Fig. 1 usually spans 50 – 60 years, depending on plant lifetime design and notwithstanding the possibility of plant lifetime extensions. Given that long-term nature, it is essential that the substantial amount of information and data associated with all the phases and processes in the NPP life-cycle model be managed in a centralized and standardized manner. The application of "Big Data" technologies and tools therefore can be considered as a viable solution to greatly necessitate and improve the management, accessibility, and sharing of data throughout the NPP development life-cycle in a more systematic and effective way.

3. "Big Data" Management System in NPP development

Data, information, and knowledge critical to the development of a NPP, which are generated from the initial phases of research and development across the NPP life-cycle, come from many systems and in many formats. This reality shows the similarity between the data at the NPP and the general concept of "Big Data", with respect to the "3Vs" characteristics.

Since "useful and right" data is vital for NPP developers, the effective management of data, information and knowledge throughout the NPP life-cycle requires understanding and attention in the organizational perspective rather than just the traditional notion of individual perspective. NPP development projects can make this shift by utilizing systems engineering approach and the "Big Data" idea to build a NPP "Big Data" Management System.

This paper introduces the idea of using the "Big Data" Management System with various data models to be built throughout the NPP life-cycle. Visualization and context diagram of the system in the NPP life-cycle are shown in Fig. 2 and Fig. 3, respectively.

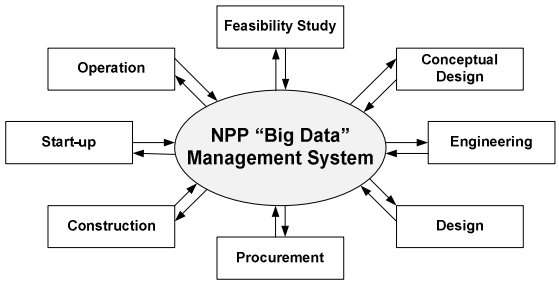

Fig. 2. Big data management system visualization

The purposes of introducing this system to the NPP life-cycle include enabling faster dissemination of data and information to users, reducing the amount of work to be done in all the NPP life-cycle phases by way of having access to "useful and right" data, and having data constantly updated and logged. Consequently, the time, cost, and change management of a NPP development can be optimized.

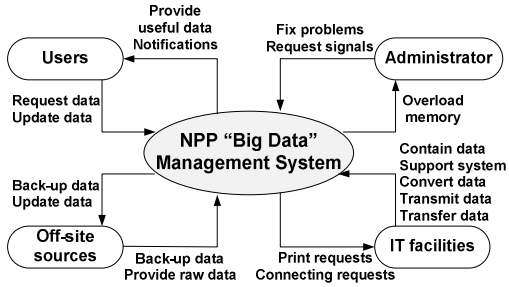

Fig. 3. System context diagram

Structured representation of the functions, activities and processes within the NPP "Big Data" Management System are illustrated using the IDEF0 diagrams (level 0 and level 1) given in Fig. 4 and Fig. 5

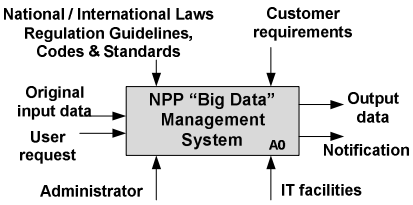

Fig. 4. IDEF0 Level 0

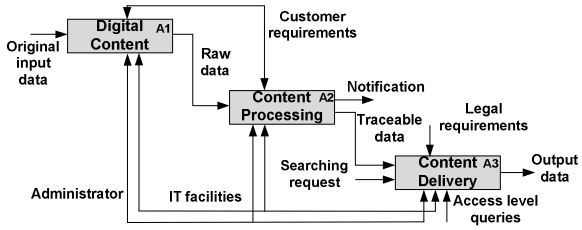

Fig. 5. IDEF0 Level 1

Each function in the IDEF0 Level 1 diagram can be broken down into sub-functions. Fig. 6 shows the IDEF0 diagram for the "content processing" function.

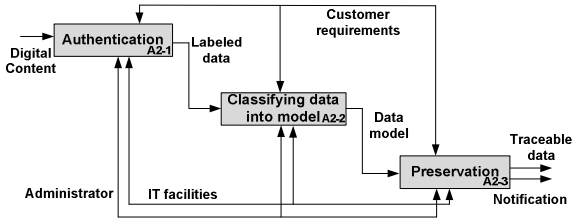

Fig. 6. IDEF0 Level 2 for "Content processing" function

Main functions of the system, which can be derived from the IDEF0 diagrams, are to manage the massive volume, extremely wide variety, and high velocity flow of data in NPP development, as well as to provide useful data and right information for the users during the development of NPP projects.

A functional block diagram, as shown in Fig. 7 below, is built to define how the system works in providing the users with required data upon receiving their requests. The system will also be able to receive digital data from the users, then authenticate, classify, and preserve the data. In other words, the system is designed to allow the users to access and extract their required data, as well as to update data to the database.

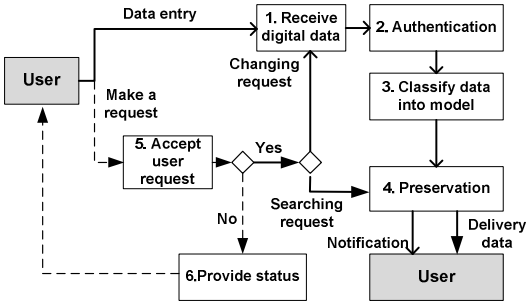

Fig. 7. System functional block diagram

4. Data models map

In order to bring the system to feasibility for application in the NPP development, it is necessary to develop various data models in the NPP life-cycle that will be able to define and classify the data collected in the system. A data model is the collective data from key information domains in a NPP development. These information domains include management, human, social, engineering, technical, and political/legal. The list of these data models for each NPP life-cycle phase can be put in a data models map, organized in a matrix form.

For building each data model, the hierarchy approach with domain, classes, sub-classes, and types is used to allocate the data systematically. All data models across the NPP life-cycle are connected and able to interact with each other. The data models are the central element of the NPP "Big Data" Management System as they provide key information to all the stakeholders in every life-cycle phase in a structured manner.

5. Discussion and further study

The idea of "Big Data" Management System for NPP projects aims to advance the means of managing, analyzing, visualizing and extracting useful information from large, diverse, distributed and heterogeneous data sets. The system can serve as a highly functional and practical tool for the display and collection of such data at a NPP into information and knowledge.

As a further study, the "game theory" will be introduced to develop an advanced search engine to help the user extract the right information from the "Big Data" for the NPP development throughout its whole life-cycle.

REFERENCES

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