

## A Review on Applicability of Big Data Technology in Nuclear Power Plant : Focused on O&M Phases

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### 1. Introduction

With the rapid growth of information and communication technology (ICT), data has been explosively increasing. It is the most important component of big data concept which derives values from the data [1]. Recently, big data technology has been applied to plant industry such as oil&gas plant, steel&iron plant, and power plant as well as traditional industries including communication, manufacturing, distribution, banking, and so on. [2-8]. It means that the big data technology has a high opportunity to enhance operational performance from tremendous data collected from numerous sensors, which are generally attached to the Structures, Systems, and Components (SSCs). Gartner reported that ‘the big data has high potential opportunities in Manufacturing and Natural Resource industry sector’. Fig. 1 shows the big data opportunity heat map per industry sectors, which referenced from Gartner [9].

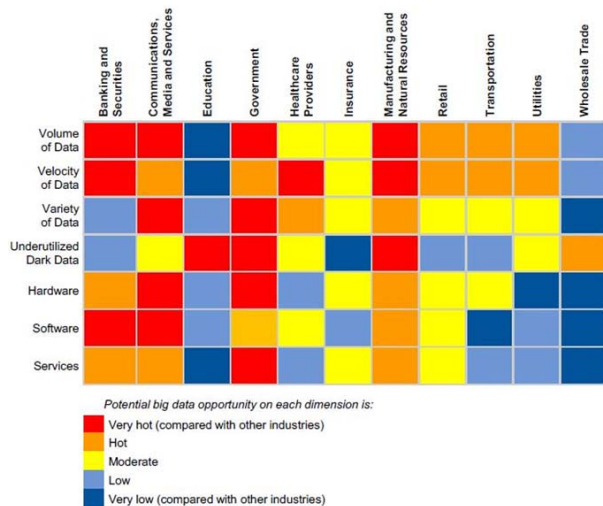


Fig. 1. Big data opportunity heat map per industry [9]

Although increasing interests for the big data technology in plant industry, it is difficult to find the application of the big data technology for the nuclear power plant (NPP) industry. Especially, extension of equipment digitalization and establishment of Plant Information (PI) system in the domestic power plant industry rapidly increase the volume of collected and stored data. Big data industry providing big data services and platforms regard the data collected from

NPP as important potential resource which is able to increase operational efficiency also operational safety.

However, according to interviews with some experts from NPP, the nuclear industry still feels vague on the big data concept; also do not have a clear picture in terms of two factors: 1) why big data is practically required to NPP and 2) how big data can be applied to it. It can be caused by the lack of practical case studies applied to the NPP and researches analyzing the applicability of the big data technology in NPP.

This short paper analyzes needs of big data technology in the NPP from the standpoint of applicability. For this, we analyze the current situation on the data collection and analysis of the operational and maintenance (O&M) phases in the NPP; and then derive the needs of big data.

### 2. Definition of big data and relevant terms

In this section, to decrease ambiguity of big data concept, we define relevant terms in brief. The concept of big data was defined by big data stakeholders' viewpoints. Gartner and McKinsey proposed a data-centered definition as “big data is 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” [10] and “datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze” [11]. However, Oracle proposed the process-centered definition as “big data is the derivation of value from traditional relational database driven business decision making, augmented with new sources of unstructured data” [12]. Unlike the prior definitions, IDC proposed defines big data technologies instead of big data. It is defined as “a technologies describe a new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery, and/or analysis”[13].

As previously described, big data is somewhat differently defined by stakeholder's viewpoints focusing on data/process/technology perspectives each. These diverse viewpoint's definitions are regarded as one of factors to make big data concept vague. To decrease the ambiguity, this paper classifies the big data concept into big data, big data analysis, the big data technology, and big data platform; and defines them.

- Big data is information resources having whole or part characteristics of the three V's (volume, velocity, and variety) which are difficult to be dealt by previous technologies such as store, analyze, process, etc.
- Big data analysis is a technology that derives values from big data
- Big data technology is enabling technologies which support lifecycle activities of the big data analysis from collecting the data to visualizing the analysis results via storing, processing, analyzing, processing, and managing it.
- Big data platform is a high-level system which encompass the detailed big data technologies to enable the data analysis.

### 3. Needs derivation

#### 3.1 Analysis process and methods

To derive the needs of the big data analysis from the NPP, we propose a needs derivation approach. Firstly, As-Is operational concept is derived to analyze the current situation of data store and analyze in the NPP. The operational concept is one of the major outputs in systems engineering (SE) approach which is an approach to develop systematically complex systems requiring multi-disciplined technologies. Next, some major problems faced are derived from the As-Is operational concept. Finally, needs for a To-Be operational concept are derived. The derived needs are mapped with 3V's perspectives to validate it. Fig. 2 shows the schematic diagram of analysis process and methods

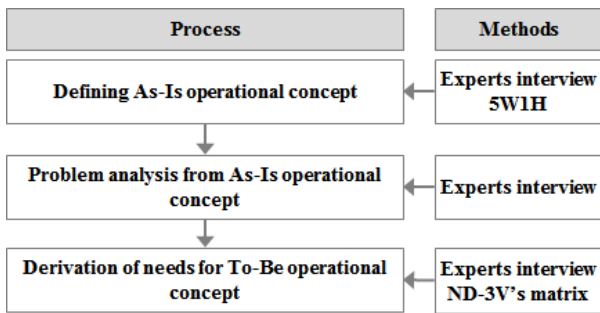


Fig. 2. Analysis process and methods

#### 3.2 Current (As-Is) operational concept derivation

Although there were many standards and researches for the operational concept, we here refer ANSI/AIAA G-043-1992 standard [14] which provides definite process in deriving the operational concept. Core concept used in this standard is to answer 5W1H (Who, What, Where, When, Why, How) questions about the current situation. The lists of 5W1H questions are listed as below.

- **Who:** Who are the stakeholders involved with the system?
- **What:** What are the elements and the high-level capabilities of the system?
- **Where:** What is geographic and physical extent of the system?
- **When:** What is the sequence of activities that will be performed?
- **Why:** What is the problem or opportunity addressed by the system?
- **How:** How will the system be developed, operated, and maintained?

We interviewed experts having in-depth knowledge on the NPP using the 5W1H questions. For reference, main target system of this research is 2<sup>nd</sup> order system of the NPP. Fig. 3 shows the derived operational concept depicted in conceptual diagram. Data is continuously collected from sensors equipped on many machines/equipment through Data Acquisition (DAQ). The Plant Information (PI) server retrieves and stores the collected data from/to Real-Time database. Users who attempt to analyze the data connect the PI client. And, they inquire, retrieve, and analyze the data from the PI server.

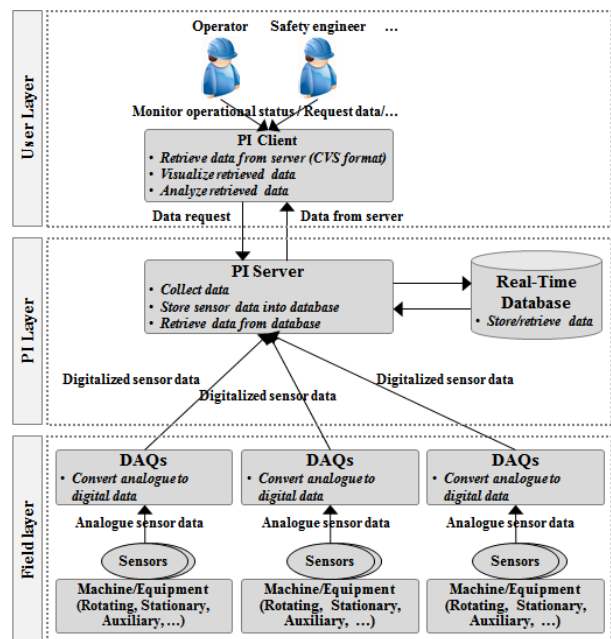


Fig. 3. Simplified illustration of current situation on data collection and analysis in the NPP

#### 3.3 Problem analysis from As-Is operational concept

Based on the derived operational concept, we derive problems with some experts from the perspectives of the big data necessity. Some derived problems are as follows.

- **Problem (PR) #1:** Analysis focusing on unit machine not overall system

Various parameter data collected and stored from numerous machines can potentially affect each other. Therefore, the diverse parameter data should be overall considered and analyzed at the same time as possible. However, currently, data analysis for unit machine is conducted for failure diagnosis and analysis.

● **PR #2:** *Analysis focusing on short-term periods*

When failures occur in any system or machines, symptoms and root causes of failures are mostly existed in the time prior to failures. This time can be a couple of minutes or even several months. The NPP now stores the collected data for several years according to relevant regulations. That is, there are many possibilities to detect the symptoms and root causes of the failures. However, data analysis in the monitoring and diagnosis in the NPP currently focused on around a month data. This can be caused by 1) the lack of understanding about the necessity of long-term data analysis, 2) a lot of time and effort are required to retrieve and analyze the desired data from PI system. For example, several dozen minutes is required to export the desired data in a month period into excel file format from the PI system.

● **PR #3:** *Time difference between failure occurrence and detection*

There are time gap (from a couple of minutes to several dozen minutes) between time when failures occur and are detected. It can be caused by insufficient real-time performance of PI system in retrieving and analyzing the data.

● **PR #4:** *Lack of methods covering various type of data (formal/semi-formal/informal data)*

In the operational phase, sensor data can be collected from the sensors equipped on machines; also data directly/indirectly related with the operation such as documents, standards, drawings, voices, movie clips, etc. are continuously produced. The former is semi-structured data whose data type is different by sensor type or model. The latter is unstructured data having no meta-data which is a regulation for data structure. In the NPP, structured and semi-structured data are mainly treated and analyzed; however, importance of unstructured data is comparatively low. It can be caused by the lack of understanding of the necessity for unstructured data analysis and immature technologies for unstructured analysis

3.4 Derivation of needs for To-Be operational concept

From the derived problems, needs for To-Be operational concept are derived to solve the problems. The derived needs are as below:

● **Need (ND) #1:** In the To-Be operational concept, Unit/overall system/plant as well as unit machine should be analyzed comprehensively. Through this,

detection of root causes of failures and increase of operational safety can be achieved. (to satisfy PR #1)

● **ND #2:** In the To-Be operational concept, long-term period data from several months to years as well as short-term period should be analyzed. Through this, detection of root causes of failures and increase of operational safety can be achieved. (to satisfy PR #3)

● **ND #3:** In the To-Be operational concept, the time difference between the failure occurrence and detection should be minimized and closed to real-time as possible. Through this, damage can be minimized via early response to failures.

● **ND #4:** In the To-Be operational concept, the unstructured data as well as the semi-structured data from the diverse sensors in the operation should be analyzed comprehensively. (to satisfy PR #4)

To validate that the derived needs can be satisfied by big data concept, we map the derived needs into the three major characteristics, called as 3V's (volume, velocity, variety), which Gartner [10] proposed. ND #1 and #2 are consistent in volume perspective, ND #3 and #4 are consistent in velocity and variety perspective each. Table 1 shows the Need-3V's matrix.

Table 1: Need-3V's matrix

ND-3V's matrix	Volume	Velocity	Variety
ND #1	O		
ND #2	O		
ND #3		O	
ND #4			O

4. Conclusion and further works

In the paper, we analyze the applicability of the big data technology in the NPP focusing on O&M phase. For this, the following sequence of process: Operational concept definition, Problem analysis, Needs derivation is conducted. This research has some limitations as follows. 1) Only monitoring and diagnosis part in the operational phase is considered in the whole plant lifecycle activities. That is, the necessity of big data should be derived in the comprehensive and diverse viewpoints. 2) Target interviewee is too small. That is, the more interviewee should be considered to increase the credibility of the research results. In the further study, to overcome the limitations of this research, we plan to validate the necessity via quantitative survey methods with more experts in the various plant cycles. We also attempt to show the practical impacts of big data through the practical application into the NPP.

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