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A full life cycle nuclear knowledge management framework based on digital system

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ABSTRACT

The nuclear power plant is highly knowledge-intensive facility. With the rapid advent and development of modern information and communication technology, knowledge management in nuclear industry has been provided with new approaches and possibilities. This paper introduces a full cycle nuclear power plant knowledge management framework based on digital system and tries to find solutions to knowledge creation, sharing, transfer, application and further innovation in nuclear industry. This framework utilizes information and digital technology to build top-tier object driven work environment, automatic design and analysis integration platform, digital dynamic performance Verification & Validation (V&V) platform, collaborative manufacture procedure, digital construction platform, online monitoring and configuration management which benefit knowledge management in NPP full life cycle. The suggested framework will strengthen the design basis of the nuclear power plants (NPPs) and will ensure the safety of the NPP design throughout the whole lifetime of the plant.

1. Introduction

Knowledge management (KM) is aimed at providing appropriate information for the appropriate personnel at the right time (Zhao et al., 2012). Just as Arthur Anderson Business Consulting claimed that knowledge management was not only a process of knowledge acquisition, integration, storage, sharing, transfer, application, innovation, etc., but also related to strategy and leadership, organizational culture, performance evaluation and information technology (Consulting, 1999).

Since Polanyi's discussion of the distinction between explicit and tacit knowledge (Polanyi, 1966), researchers developed a set of KM definitions, concepts, activities, stages, circulations, and procedures, all directed towards dealing with objects in order to describe the framework of knowledge management.

IBM claimed that knowledge management structure was composed of knowledge sharing and team collaboration including four models of innovation, skills, responsiveness and productivity (Mentzas et al., 2003). Microsoft discussed that three elements organization, process and technology should be overall considered a necessity to achieve knowledge management through organizational strategy (Chang, 2002). KPMG believed that knowledge management was planning and management methods composed of three basic services—awareness, strategic planning and execution, and knowledge management would rather be an ongoing process composed of a series of integrated projects than a discrete single project.

"Knowledge is power", particularly in the current era. The nature of engineering product development within modern organizations has altered dramatically over the past few decades as products have become more complex. Integrated product group members are not only multi-functional, but likely to work for different companies, have different nationalities and stem from different sites of one company, or even be scattered across the globe (Payne and Deasley, 2001). The significantly increased complexity of products makes the corresponding technology, processes and organization more complex, meanwhile the people more competent. At the same time, due to the large-scale division of labor,

Abbreviations: ASME, American society of mechanical engineers; BIM, building information modeling; DCS, Digital Control System; DKM, design knowledge management; DT, data technology; GB, China's national standard; HVAC, heating ventilation air conditioning; HAF, regulations on the nuclear safety in China; HAD, guidelines on the nuclear safety in China; IAEA, International Atomic Energy Agency; ICT, information and communication technology; IT, information technology; KM, knowledge management; NKM, nuclear knowledge management; NPP, nuclear power plant; O&M, operation & maintenance; R&D, Research & Development; SSC, system structure and component; V&V, Verification & Validation.

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the preservation, transfer and inheritance of knowledge are also faced with big challenges. For this reason, knowledge management has been identified as one of the key enabling discipline for distributed engineering enterprises (nuclear power plant project is a good example) in the 21st century.

The nuclear power industry is highly knowledge-intensive. Therefore, it's very valuable and indispensable to focus on full cycle KM of specific nuclear power plant. Knowledge management will lead to a significant economic and technical benefit for stakeholders during the $60 \sim 100$ years' lifecycle of an NPP. A good knowledge management framework and practice can support the healthy safety awareness and safety culture, reduce the loss of knowledge due to staff turnover, reduce training time for new employees, improve collaboration and access to information, accelerate experience feedback between stakeholders, ensure project quality, and effectively address adaptation issues. Much work has been done by the International Atomic Energy Agency (IAEA) in addressing the knowledge management needs of different nuclear organizations, resulting in many publications(Carroll, 2006; Tecdoc, 2006). Meanwhile, a general concept of designing of a knowledge portal and also a typical content which helps NPP to maintain safety at a high level is introduced (A Kosilov and Pasztory, 2009). Reasons for establishing knowledge management system as a part of new nuclear power programs is provided (Kosilov et al., 2009). Although IAEA-TECDOC-1675 (Tecdoc) provides a general overview of the tools and techniques that might be adopted to gain business benefit in an R&D environment, a full cycle NPP KM framework is absent. This paper introduces a full cycle nuclear power plant knowledge management framework based on digital system and tries to find solutions to knowledge creation, sharing, transfer, application and further innovation in nuclear industry.

2. KM in nuclear power plant life cycle

2.1. Characteristics of NPP life cycle KM

From the viewpoint of the safety a good knowledge management approach can reduce the frequency of near-miss events, to support the healthy safety culture and safe operation. For a specific nuclear project, it covers siting, basic design and detailed design, manufacture, construction, commissioning, operation and maintenance and decommissioning. This full cycle nuclear project requires agreement with regulatory requirements, analysis of site characteristics, information of reference design and its adaptation to the designated country's specific regulations and site data, as well as other supporting knowledge.

From the very beginning of the nuclear project lifecycle, it is essential to recognize the roles of all participating organizations that will generate, or handle data & information that affects the design of a nuclear power plant (NPP), and their involvement in the capture, utilization, transfer, and storage of knowledge. In view of the NPP project particularity, the following characteristics have to be considered when managing nuclear knowledge.

- Complexity of nuclear technology

Nuclear knowledge is highly complex on both the micro and macroscale. The thermohydraulic, material, neutron physics, mechanic, chemical as well as the sociological, economic, political, safety and security aspects must all be considered as a whole.

- Long term

Generally, the full cycle of NPP lasts for 60–100 years. A KM system for a typical nuclear project therefore has to be robust to the best of its capability and pay attention for the information and communication technology (ICT) changes.

- Historical context

The average age of the nuclear reactors globally is about 30 years, which means it is great challenge how to properly record, preserve and transfer information for these old NPPs. The design and also the configuration changes during the life of the plant were collected if they have been followed the international and national requirements. Accordingly, the knowledge management have to take care about each change related to the NPP configuration, documentation and the related information complete and accurate.

- Safety

Safety is the prerequisite for nuclear infrastructure development. Nuclear industry makes lots of effort to emphasize safety by experiment, analysis, V&V, management documents, design basis, safety culture etc. For this purpose, knowledge management needs to make sure that all activities related to the safety design is consistent, not only for each interested party but also between them.

- Quality

Quality management in nuclear is – vitally important because it contributes to both NPP safety and performance. From the aspect of information, quality management is about information inspection and comparison, but for the complicated NPP design, 'know how' enhances quality management to a higher level. The latest version of the ISO 9001 requires the management of organizational knowledge properly and also pays attention for all the organizational context.

- Information overload

Measures have to be adopted to capture the changes in knowledge arising from all the phases and have to reflect the changing state of the plant at all times. With the addition of operating experience, periodic safety reviews, and implemented design changes, the amount of information increases continuously and considerably over the plant lifecycle which will be a challenge for KM.

- Multi-stakeholders

Nuclear knowledge evolves over time along with the life cycle of the nuclear project, involving different stakeholders. Government, regulator, suppliers, Research & Development (R&D) organizations, academic educational institutions, training organizations, vendors, utility and technical support organizations are expected to be closely connected in the complex flows of knowledge among different stakeholders. Due to the characteristics mentioned above, innovative nuclear knowledge management (NKM) approach should be proposed to tackle down the specific challenges of nuclear power.

2.2. NKM framework principles

An overview model will help to fully understand the nature of knowledge management and its importance to an organization. The Fraunhofer Reference Model for knowledge management presented in Fig. 1 has been recognized as one of the holistic KM frameworks for standardization in Europe. The model is a three-layer schema that depicts the relationships between value-adding business processes, four knowledge management core pro-