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Development of a qualitative evaluation method using MFM for abnormal conditions of HPSI pump in NPPs

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1. Introduction

For the past two decades, the nuclear industry has attempted to move toward a condition-based maintenance philosophy using new technologies developed to monitor the condition of plant equipment during operation. Specifically, techniques have been developed to monitor the condition of sensors and their associated instrument loops while a plant is operating. Traditionally, instruments must be recalibrated at each refueling outage in accordance with nuclear regulations. One concern with periodic calibrations is that only the sensor's operating status is checked at every fuel outage, meaning that faulty sensors may remain undetected for periods of up to 24 months. Also, the traditional periodic maintenance method can lead to equipment damage and incorrect calibrations due to adjustments made under non-service conditions, increased radiation exposure of maintenance personnel, and possibly, increased downtime. In fact, recent studies have shown that less than 5% of the process instruments are in a degraded condition that requires maintenance [1][2].

Currently, Korea Atomic Energy Research Institute developed the NSSS Integrity Monitoring System (NIMS) which consists of 4 monitoring systems, Loose Part Monitoring, Internal Vibration Monitoring, Reactor Coolant Pump Vibration Monitoring, and Acoustic Leak Monitoring. So far, most developed monitoring systems are monitoring the specific status of target systems. Therefore, developed monitoring systems cannot evaluate status/integrity of components or systems [3][4].

In this study, the safety-critical components included in safety-critical system are divided into motor-driven valves (MOVs) and pumps as usual. Among the various pumps included in safety-critical components, high pressure safety injection pump is selected and the failure modes of safety-critical components are analyzed to develop the monitoring technology. Also, the integrity evaluation method using MFM (Multilevel Flow Modeling) is suggested in this study [5]. MFM is a methodology in means-end and part-whole way, for automatic real time fault diagnosis of power plant process failure.

2. Multilevel Flow Modeling

MFM is a methodology for functional modeling of complex industrial processes and belong therefore in its thinking and methodology to the branch of Artificial Intelligence (AI) called qualitative reasoning. The purpose of qualitative reasoning is to be able to represent and reason about knowledge of physical phenomena and systems which cannot be done by quantitative approaches based on first principles such as differential equations. An important goal of AI is also to apply computers to automate the reasoning. The MFM modeling language has been developed to realize these aims within the general domain of industrial processes and their automation systems. A particular challenge is here to develop qualitative modeling and reasoning techniques that can handle the complexity of large scale dynamic processes [5].

The concept of means-ends and whole-part decomposition and aggregation play a foundational role in MFM. These concepts enable humans like system engineers and plant operators to cope with complexity, because they facilitate reasoning on different levels of abstraction. The power of mean-end and part-whole concepts in dealing with complexity has roots in natural language. But natural language is not efficient for representing and reasoning about means-end and part-whole abstractions of complex physical artifacts. MFM development draws on insights from the semantic structure of natural language but is designed as an artificial language which can serve modeling needs of complex engineering domains which cannot be handled within the common sense limitations of natural language.

MFM represent goals and functions of process plants involving interactions between flows of material, energy and information[5].

3. Application

The MFM models are applied to develop the integrity evaluation method for HPSI pump. And their systems are shown in the P&I diagram in Fig. 1. P&I diagrams represent the system processing but the information expressed in an MFM models cannot be extracted from P&I diagrams because P&I diagrams does not contain information about goals and functions in an explicit form. Often engineers claim that P&I diagrams are sufficient because they know about the goals and functions and can relate to it in their minds when they read the diagrams. However, the advantage of making this knowledge explicit as done by MFM is obvious because it can be used in the process and automation design or for building knowledge based decision support system for the operators. The blue line represents the transference of the flow from refueling water storage tank (RWST) to HPSI pump in Fig. 1. HPSI pump is in the red box in Fig. 1.

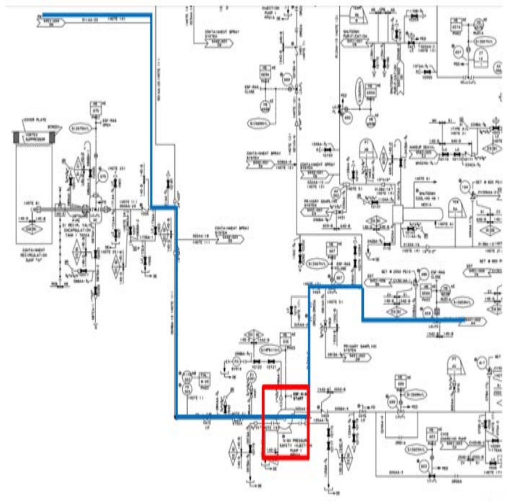

Fig. 1 P&ID for HPSI

3.1 MFM of high pressure safety injection system

Fig. 2 shows the MFM of high pressure safety injection system without control functions. It contains four functional levels comprising a mass flow structure mfs1, an energy flow structure efs1, the mass flow structure mfs2 and mfs3. The process in Fig. 2 explains the modeling from top to bottom. The mass flow structure mfs1 represents the HPSI system. The system process supports the achievement of the objective obj1 which is to deliver the water. The source sou1 represents the water in RWST. The energy flow structure efs1 represents the motor and shaft involved in pumping of the water in pump. The sou3 represents the power supply. The mass flow structure mfs2 represents lubrication system. The purpose of this system is to ensure that the mechanical linkages can compose motor and shaft. The function obj2 is a representation of the lubrication requirement which is related to the lubrication functions shown in the flow structure mfs4 by the means-end relation called maintain. The sou4 in mfs4 represents the source of lubrication oil and the transport tra29 is the transport function performed by a lubrication pump. Finally, mass flow structure mfs3 represents the impeller in pump. The impeller of HPSI pump consists of eight. Therefore, the function sou2 represents the first impeller. Also, mass flow structure (mfs3) is connected to the tra7 representing the HPSI pump. Other functions are omitted in this paper.

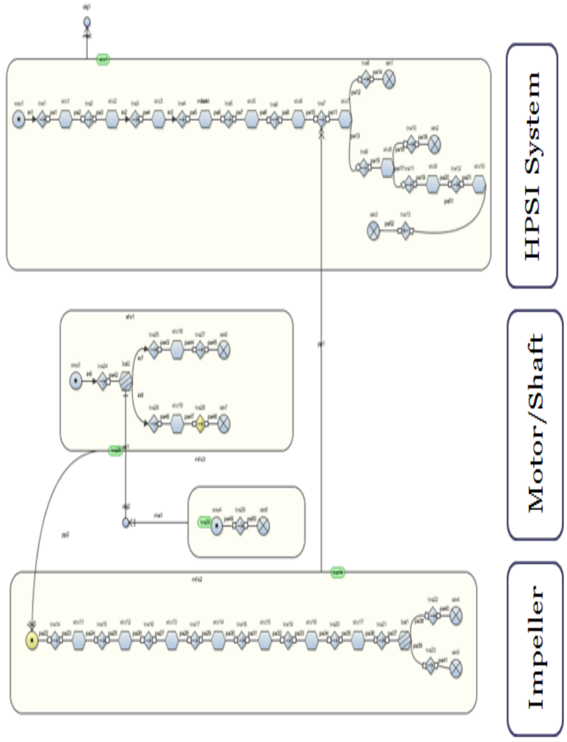

Fig.2 MFM of HPSI system

4. Conclusions

The maintenance strategy of NPPs has been changed from time-based maintenance to condition-based maintenance. So, monitoring systems are needed in NPPs. Also, I developed that MFM is a methodology for functional modeling. This model provides a good basis for diagnostic algorithms. Also, among its advantages are the descriptions of goals and functions, a relatively easy analysis due to the graphical expression.

This paper shows an MFM based fault diagnosis approach for the HPSI pump and system. Also, the possibility of using MFM for the integrity evaluation for HPSI pump was confirmed through this work. But current modeling process in this paper is still ongoing, since control function modeling should be added. Thus advanced integrity evaluation methods will be developed by using MFM. Also, the developed integrity evaluation method will be validated either by comparing with other method or experiments.

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