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HAZOP SUPPORT SYSTEM AND ITS USE FOR OPERATION

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Abstract

In their effort to improve safety, process industries have relied on a variety of information systems for managing safety. However, current information systems are limited in their ability to integrate information along the life-cycle.

This paper proposes a Hazop support system, which has three functions as follows.
(F1) An intelligent CAD system (DFD, Dynamic Flow Diagram) to visualize plant structure, operation with process behavior,
(F2) Intelligent user interfaces to make Hazop analysis easer as well as to edit analyzed results
(F3) Interface to generate information models to be used in real-time operation.

Specifically, this paper describes the knowledge management strategy which is responsible for carrying out potential hazard identification and safety protection layer design systematically. Finally, a case study illustrates the proposed system.

Keywords: Hazop, life-cycle engineering, intelligent CAD, knowledge management, logging system

1. Introduction

In their effort to improve safety, process industries have relied on a variety of information systems for managing safety (safety information management systems). One of the challenges in developing such systems is the variety of information. For example, hazard identification requires engineering diagrams such as P&IDs, design specification data, process chemistry, and design information on currently installed/considered protection layers. Furthermore, it is necessary to record, keep and store the hazard identification itself, which is complicated by a number of issues such as:

(1) Because hazard identification results and Hazop in particular are recorded in natural language expressions their degree of fidelity and quality are dependent on the particular scribe.
(2) It takes long time to carry out hazard identification because searching proper

information in the relevant documents tends to be time-consuming.

(3) Contents in current safety information systems cannot be easily reused when revamping its process because investigation processes are not clear.

Two types of Hazop supporting systems have been developed: logging systems and Hazop execution systems (McCoy and Chung, 2001). As most of logging systems have no plant structure models in detail, it is not easy to understand the documents. Execution systems are computer tools for performing Hazop automatically. Automic Hazops requires precise knowledge of process behaviors. Its quality of analysis results is dependent on this knowledge.

In a previous research, we have developed technological information models known as MDOOM/MDF (Batres, Naka and Lu, 1998) which cover a wide range of information along the life cycles of product, process and plant (Bayer, 2003). MDOOM/MDF is an integrated model of characterized by physical structure, operation and process behavior information.

This paper describes the knowledge management strategy of the proposed Hazop support system which supports potential hazard identification and safety protection layer design for plant life-cycle engineering systematically. Finally, a case study illustrates the proposed system.

2. Scope of Hazop Support System

The proposed Hazop support system (HazopNavi) has three main functions as follows.

(1) Facilitates Hazop analysis for chemical plants at various design stages

All Hazop analytical data stored in a database and integrated with PFDs and P&IDs.

(2) Assists in the supervision of process states during the operation of the plant while guiding safety operation

We design operational information to supervise process state in operation with the database and design rationale.

(3) Supports management of change

HazopNavi has been developed based on the MDF concept (Multi- Dimensional Formalism) as shown in Figure 1. HazopNavi provides specific engineering functions for supporting Hazop by using PlantNavi and OpeNavi which are commercially available (Kawamura, 2008). The PlantNavi is an intelligent CAD system (PFD & P&ID) based on the plant structure model of ISO 15926 and include a number of function including searching plant and line queries, equipment specifications as well as drawing expressions. The OpeNavi represents relationships between plant structure and its operating procedures corresponding to CGU (controlled group unit) derived from plant structure (Naka, Lu, and Takiyama, 1997).

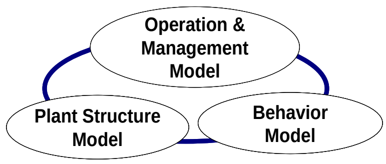

Figure 1 Multi-Dimensional

HazopNavi has the following functions:

(F1) It shows plant areas where failures may propagate and indicates equipment of plant structure where may be changed to other failure. In addition, it lists candidates of sensors to detect failures. It helps Hazop by visualizing the parts of plant, where individual failures propagate. This function clearly defines an area where Hazop is being carried out. These propagations are carried based on whether valves are open or closed, so not only steady state operation but also various transient operations such as start-up or shut-down can be analyzed easily.

(F2) Intelligent user interface: It has two functions to support investigating process of failure propagation and store analysed results and additional evaluation results of likelihood of its failure and degree of its criticality. Its Hazop editor enables users to store Hazop results easily.
(F3) Interface to generate information models to be used in real-time operation: It can transform the stored knowledge to the information models for diagnosing abnormal situations in real-time operation.

3. Methodology

3.1 System Architecture

With use of MDF model, we have developed the system architecture of a technological information infrastructure as shown in Fig. 2, which supports safety engineering information based on 'design rationale'. It is composed of four modules of Dynamic Flow Diagram (DFD), qualitative simulation, library and HAZOP logging system.

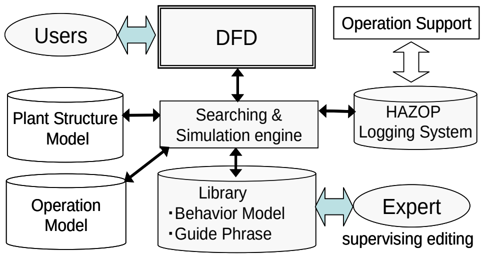

Figure 2 System Architecture

The DFD share functions of other intelligent CAD systems and also has capabilities of visualizing relationships between plant structure and dynamic process behavior. With its visualization, in order to support users, each symbol in DFD has various features of style change in color, line pattern, line thickness and fill pattern. For example, its characteristics distinctly show valve state of open/closes, pipeline with/without flowing/stagnant fluids, pump working state and so on.
HazopNavi has a qualitative simulation engine which can be used instead of existing quantitative dynamic process simulators, thus saving the time it takes to provide various kinds of process models. It is not easy to apply these approaches for entire process hazard identification. HazopNavi can cover entire process plant represented by DFD (PFD and/or P&ID). Safety engineers carry out Hazop by their engineering decisions with qualitative judgment rather than by quantitative simulation. HazopNavi manages kinds of expert engineers' knowledge for process behavior model.

3.2 Information representation

Hazop specific information in the Hazop support system includes: failure propagations, a mechanism that links initiating causes to effects, severity and likelihood, sets of sensors to detect initiating causes or effects.
The Behavior model library has two types of models associated to each piece of equipment: deviations caused by equipment failure modes and new deviations caused by other deviations propagated from other equipment. When choosing equipment failure mode, qualitative simulation starts using propagation mechanism as follows.
Failure modes provide process deviations, d(0,2) in equipment and d(0,3) at a port from the initiating deviation library. It is called internal propagation. Then, port deviation d(0,3) is propagated through piping line to next equipment and raises an effect as shown in Figure 3.

$d(0,2) = f_{etyp,T1}(\text{failure mode})$ ....(1) $d(0,3) = f_{etyp,T2}(d(0,2), pt3)$ ....(2)

$d(i,1) = d(i-1,3)$ ....(3) $d(i,2) = f_{etyp,P1}(d(i,1), pt1)$ ....(4)

$d(i,3) = f_{etyp,P2}(d(i,2), pt3)$ .... ..(5)

where,
d(i, k) is deviation (i=equipment No., k=1 propagation inlet port, k=2 PBE, k=3

propagation outlet port), $f_{etyp,T1}$ and $f_{etyp,T2}$ are initiating behavior model, $f_{etyp,P1}$ and $f_{etyp,P2}$ are propagation behavior model, etyp is equipment type, and pt1 and pt3 are port roles of a liquid inlet and gas outlet, respectively.

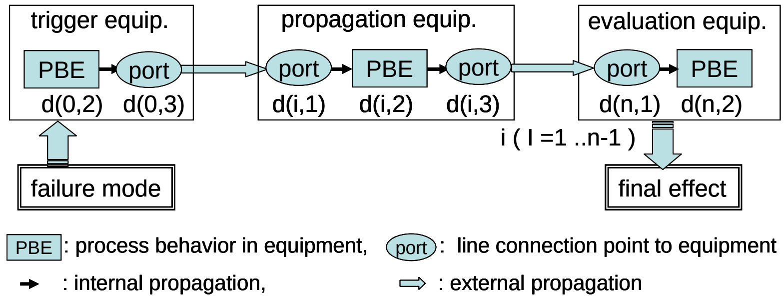

Figure 3 Propagation Mechanism

a. Initiating and propagation behavior models are specified for each type of equipment.
b. Deviations d(,) are shown by “Pmore” (more pressure), “Fless” (less flow rate) etc.
c. If deviation change is required in piping path, some virtual transforming equipment is added between two equipments as a propagation model.

During the design of operating procedures for abnormal situations, engineers require the list of available sensors to detect respective deviations. Each sensor has different sensing capability of propagation mechanism. Figure 4 shows an example for temperature and pressure sensors. HazopNavi’s qualitative model can distinguish between flow and no-flow situations in piping segment.

Hazop results are represented in terms of the following elements: (1) initiating cause and final effect (see Figure 5), (2) criticality evaluation, (3) protection and countermeasure, (4) further study required. In order to ease the scribing efforts as well as to keep consistency in the entries of the Hazop results, users construct sentences using a controlled vocabulary by choosing guide phrases in the guide library (Fig. 2).

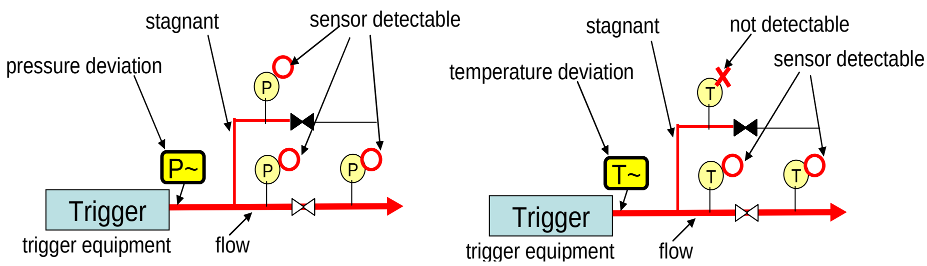

Figure 4 Sensing of Deviation

3.3 Use of HAZOP Database

Hazop results from manually executed Hazop studies are generally recorded in spread sheets, which contain very limited cause-effect information. Hazop database stores not only original causes and final effects but also all intermediate propagation cause-effect chain as shown in Fig. 3. Hazop database has information of all sensors on propagation paths. Sensor information is used to recognize that each deviation can be detected by DCS or local instrument, and to decide whether or not protection control logic and countermeasure against the failure works. If it is not sufficient, further study should be required so as to improve facilities or additional instrument, interlock or alarm system. All these propagation behaviors are confirmed graphically with DFD functions.

Finally, HazopNavi can support operators by using surveillance mechanism based on cause-effect relationships and design rationale.

a. When DCS sends an alarm signal and sets of monitoring data to HazopNavi, it identifies cause-failure relationships and recommendation actions. Its function has been made empirically and is installed already into DCS. The proposed appoach logically designs such function and easily maintains it when a plant revamping situation occurs.

b. When several abnormal signals happened simultaneously, HazopNavi searches Hazop database to find a cause which satisfies all abnormal signal conditions.

3 Case Studies

The above-mentioned approach has been applied to several process plants. Fig.5 shows case studies of typical pump failure in HDS plant.

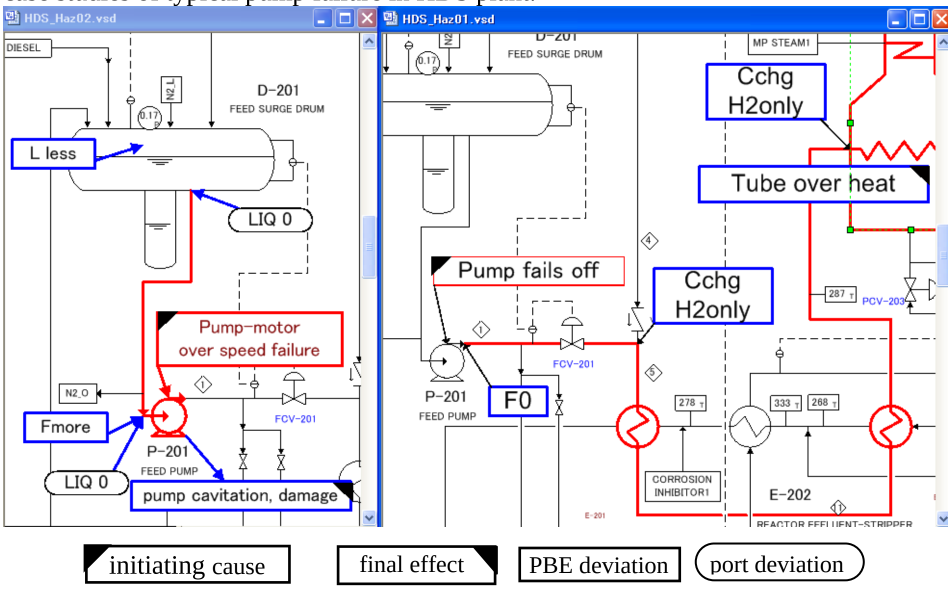

Figure 5 DFD representation
(Left) Pump failure with over-speed (Right) Pump failure stop

Description for Left case;

a. Equipment P-201 failed control and becomes over speed (initiating cause).

b. Initiating behavior model of pump produces deviation 'more Flow' corresponding to eq. (1) and shows it on DFD in Fig. 5.

$d(0,2)$ = 'Fmore' = $f_{pump,T1}$('over speed')

c. All possible propagation paths of normal/reverse flow directions and candidate equipment are highlighted on DFD using plant structure model.

d. When analyzing reverse flow P-201 to tank D-201, its propagation behavior model generates PBE deviations of 'Liquid level down' and 'no Liquid', corresponding to eqs. (4) and (5), respectively.

$d(1,2)$ = 'Lless' = $f_{tank,P1}$('Fmore', 'liquid out')

$d(1,3)$ = 'LIQnil' = $f_{tank,P2}$('Lless', 'liquid out') 'LIQnil':no LIQUID

In this case P-201 is both the initiating cause and the recipient of the final effect. Initial deviation 'more Flow' is propagated to tank and transformed to 'no Liquid', and propagates back to the pump. The right side of Fig. 5 shows more sophisticated example.

4 CONCLUSIONS

This paper proposes an intelligent Hazop support system and describes its core components. The Hazop support system provides the following functions.

1) Integrated information models can support to carry out Hazop with use of DFD interactively.

2) DFD can visualize engineer's creative thinking processes.

3) Hazop database is reusable and understandable because it clearly keeps relationships between plant structure and failure propagation paths.

4) Hazop database which has information sets of sensors and propagation paths can be used for operation support system.

We are develping an information infrastructure to support advanced plant lifecycle engineering by using PlantNavi, OpeNavi as well as HazopNavi. We will support more logical approaches to safety concious production environment as follows.

a. operators protection and countermeasure guidelines against abnormal situations,
b. alarm management and interlock system design
c. preventive maintenance
d. management of change in plant facilities and operation
e. redesign of plant and process engineering activities.

Acknowledgement

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