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Information Model And Techological Information -Infrastructure For Plant Life Cycle Engineering

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Numerous efforts have been made to improve safety in the process industry. Unfortunately, accidents continue to happen, particularly due to inappropriate plant operations. One of the big challenges consists in how to keep updated control and operation instructions along the life-cycle of the plant as changes of process technology and equipment take place. To this aim, we have developed a technological information infrastructure (TII) to support plant life cycle engineering activities, which manages plant information, operation and HAZOP information. The startup of a hydrodesulphurization plant is discussed to illustrate the use of the TII.

1. Introduction

Typically, engineers working in the design of a plant develop process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs) by taking into account normal, abnormal, and emergency operations. During this stage, engineers also develop the standard operating procedures (SOPs). Very often, however, operating policies and design rationale considered at the plant and process design stages fail to be communicated to engineers in the operation and maintenance phases. To complicate things, with current approaches engineers lack the means to integrate PFDs, P&IDs, and SOPs with process behavior information.

To this aim, we have developed a technological information infrastructure (TII) to support plant life cycle engineering activities, which manages plant information, operation and HAZOP information [1]. The objective is firstly to support engineering since the very beginning when early operating procedures and engineering documents are developed. In addition, the TII intends to provide an operational design environment for safety conscious and understandable operations. In a previous research, we have investigated a framework for information models known as MDOOM/MDF to support life-cycle engineering [2]. In this work, information models are built based on this framework, so as to represent and manage engineering information (including design rationale) in the technological information infrastructure (TII). Standards such as ISA S88 [3] have been developed for integrating batch-related information. However, standardization bodies have not yet come up with integration solutions for continuous processes. In this paper, the CGU (Controlled Group Unit) concept [4], which makes explicit relationships between operations and plant structure, is used to break down large sophisticated operation problems to more manageable ones. The CGU allows planning for transient operations, including start-up, shut-down and abnormal situations handling, while improving operations at steady state. PROSEG (Process Operating SEquence Graph) is used to represent the relationship between operations and process behavior in units [5]. The startup of a hydrodesulphurization plant is discussed to illustrate the use of the TII.

2. Plant Life Cycle Engineering and Operational Design

Process industries have recognized the importance of 'Plant lifecycle engineering' which consists of continuous analysis and design tasks enabled through sharing and exchanging of engineering data electronically starting from the very beginning. Also, the process engineering community is recognizing the importance of operating, maintaining, and modifying plants according to a policy of process safety management. For this purpose, the TII provides an engineering activity model (EAM). The EAM is based on three core concepts of MDF namely, plant structural model, operation and control model, and behavior model which have been used in PROSEG and CGU. The PFDs and P&IDs, which are designed during front-end engineering, become one of the views of the plant structural information models when represented with MDOOM/MDF. The resulting electronic data are then used by operation and maintenance activities. When executing the engineering activities, we distinctively recognize not only different unit operation models but also fidelity of behavior models.

2.1 CGU-based Operation

The PROSEG and CGU concepts are used to generate operating procedures as soon as P&ID design activities finish. While traditional process control design strategy leads to flat structure of operating procedures, PROSEG and CGU can be used to create operating procedures for all the operational modes in a hierarchical way. PROSEG is used to represent the relationship between operations and process behavior in units. A CGU defines the relationship of a set of operations and plant structure. The CGU is defined as a part of a plant bounded by control valves, with the ability to keep stationary states using inventory control functions. For a continuous plant composed of several CGUs the plant operation is managed at multiple levels resulting in hierarchical operating procedures. A CGU coordination layer communicates with all of CGUs and sends the operational instructions to the CGUs that participate in the tasks to achieve a given operation objective.

2.2 Operational Design

Operational design is defined as a concurrent design of processing facilities (plant and equipment) to enable operations to be carried out in all the operating modes. In designing facilities for plant start-up, design engineers assume several scenarios in which the objective is to find the series of actions that take the process from some given initial conditions to the steady state. The team then proceeds to designing operating procedures while simultaneously adding extra auxiliary facilities to the PFD. The design process of abnormal operations is carried out in a similar way. The design strategy is summarized in Figure 1.

3. Information Models

In order to carry out operational design, we use the information models as shown in Figure 2. In order to represent CGU operations, a CGU is defined as part of the plant strucuture models based on ISO 15965. Operating instructions are encoded using as PFCs (Procedural Function Charts) which are defined in the operation/control informa- tion models. A PFC is similar to a SFC (Sequencial Function Chart) [6] but PFCs offer hierarchical procedures based on the CGU concept. The behavior models can be linked to the plant structure models. Qualitative design of start-up operating procedures needs bulk process stream models in all of physical components. Those models are similar to water testing models in a CGU. In designing quantitative operations of CGUs, specific temperature trajectories or constraints on concentration are taking into account for which more detailed behavior models are needed including more detailed mass and energy balances. This results in hierarchical behavior models.

		Basic Design	Detail Design
Operation Policy		Operating modes: Procedure	Selected operating modes based on the extent of risks
Normal	Steady State	Unit procedure Operation, Phase	Equipment Control
	S/U	Unit procedure Operation, Phase	Equipment Control
	S/D	Unit procedure Operation, Phase	Equipment Control
Abnormal			Unit procedure, Operation, Phase Equipment Control
Emergency			Unit procedure, Operation, Phase Equipment Control

Figure 1. ISA S88.01Description for Operating Modes

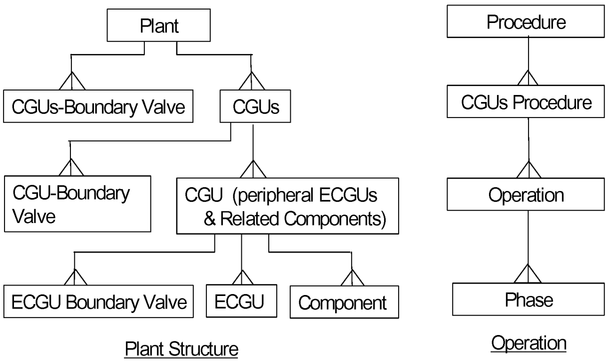

Figure 2 Information models

4. Application to HDS

The above-mentioned approach has been applied to an HDS process as shown in Figure 3. It is composed of four CGUs which have oil feed, hydrogenation, low pressure and stripping functions respectively.

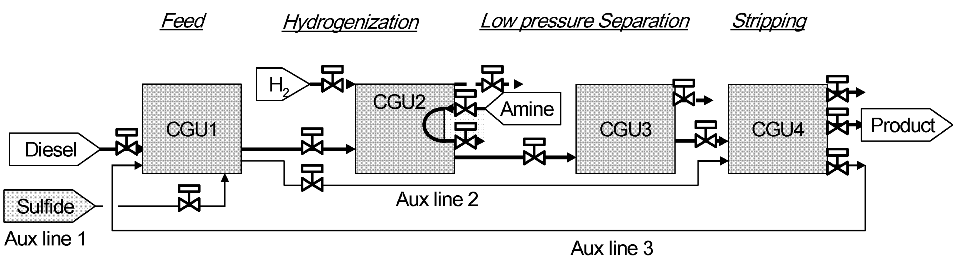

Figure 3. HDS CGU Diagram with Additional Piping System

4.1 Process constraints

Operation of some units is constrained by physicochemical phenomena, safety limits, quality and mechanical properties. Such information is attached to individual unit specifications and considered by the CGU-based operation for each of the operational modes.

Firstly, the 'main process operation' is developed. This operation is the major processing activity that is based on the processing technology that converts raw materials into products. Subsequently, additional operations are added by taking into account the process constraints.

4.2 Auxiliary Facilities

Figure 3 shows a schematic diagram of the CGUs that compose the HDS process which also include additional piping for startup operation. The auxiliary line (Aux line 1) is added to supply a sulphiding agent to activate the catalyst in the reactor at the beginning of the operations in CGU2. Auxiliary lines Aux line 2 and Aux line 3 are added to supply oil into CGU4, and to return off-spec product to CGU1.

4.3 Development of the operating instructions

The first step consists of describing the 'main process operation' in terms of CGU procedures. Then more detailed operations are added. The CGU procedure is similar to the unit procedure defined by ISA S88.01. The difference is that the 'CGU procedure' defines in its entire area where the 'CGU procedure' executes. It consists of an ordered set of operations that causes a contiguous production sequence to take place within a CGU. Only one operation at a time is presumed to be active in a CGU. An operation is carried out to completion in a single CGU. However, multiple unit procedures of one procedure can run concurrently, each in different CGUs. 'Operation' is a procedural element defining an independent processing activity consisting of the algorithm necessary for the initiation, organization, and control of phases. It is an ordered set of phases that defines a major processing sequence that takes the material being processed from one state to another. 'Phase' is the lowest level of procedural element in the procedural control model that can accomplish a process-oriented task. The intent of the phase is to execute a process-oriented action, while the logic or set of steps that make up a phase are equipment specific. Equipment phases are also similar to those of S88.01.

Figure 4 shows the procedure of the cold startup. The phase of 'Ready to supply a material' means that the materials requested by a phase in one of the other CGUs are ready [7]. In the case of catalyst activation, the phase 'Activate catalyst' of the CGU2 procedures is requested. The procedure has a coordination function of CGUs, which manages the execution of CGU procedures in order, identifies executing status of individual CGU procedures and sends the status information to the others. For example, if 'hot bolting' work is needed in CGU2, the corresponding phase has to be added in the operation of 'Heat H2'. If CGU2 and CGU4 start up in parallel, the 'Operation' of 'Fill oil into vessel' in CGU4 procedure needs oil from CGU1.

4.4 Route Search in P&ID

A route searching function in P&ID is used to generate equipment control from 'Phases'. For example, 'Charge oil' of 'Phase' means that diesel oil valve that is between CGU1 and CGU2 should be opened. Before the execution of the phase, the pump and pipe line

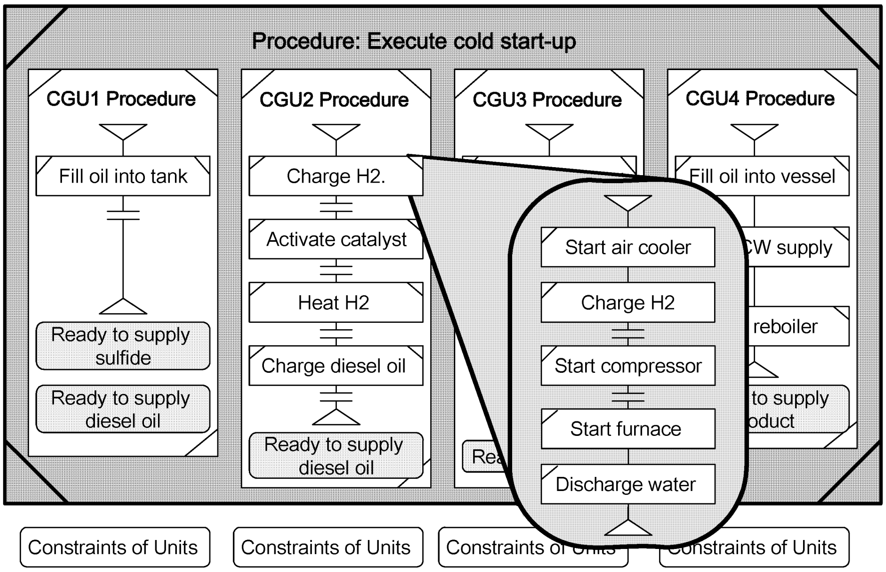

Figure 4. Operating procedure in PFC

around the tank in CGU1 are filled with diesel oil. The pipe line around the tank has several manual valves. Each valve status is determined in terms of valve function in operating. The route-searching function shows the facilities that are to be activated so as to carry out a set of phases in order (Figure 5).

The TII platform supports a user interface that resembles a CAD of PFD & P&ID but which has more functions including PFC modeling, process constraint checking, and the route searching function. Engineers can investigate many different operating procedures and add auxiliary piping to PFD [4]. In general, the resulting operation instructions should be evaluated in terms of safety, elapsed time and cost. For example, if 'a phase' in certain CGU in startup procedure interferes with several 'phases' in other CGUs, the procedure may not be easy to understand by the operations personnel. Quality of operations is dependent on engineers' experience. Ensuring understandable and logical operations may reduce a number of abnormal situation cases.

5. Conclusions

This paper described a technological information infrastructure (TII) for operational design environment based on the CGU concept. TII has the following advantages: (1) It makes clear relationships between 'phase' of a procedure and its location in the plant structure to be executed (P&ID and PFD); (2) it shows the relationships for all 'Phases' in a 'Procedure' individually; (3) it provides hierarchical operating procedures which include the intention of each operation and the order of operations and phases; (4) the object oriented description of operating procedures enables the concurrent construction of multiple operations and plant structure modifications; (5) the support of management of change in a plant.

Finally, in order to quantitatively evaluate operating procedures a dynamic process simulation environment is used which is also integrated within TII.

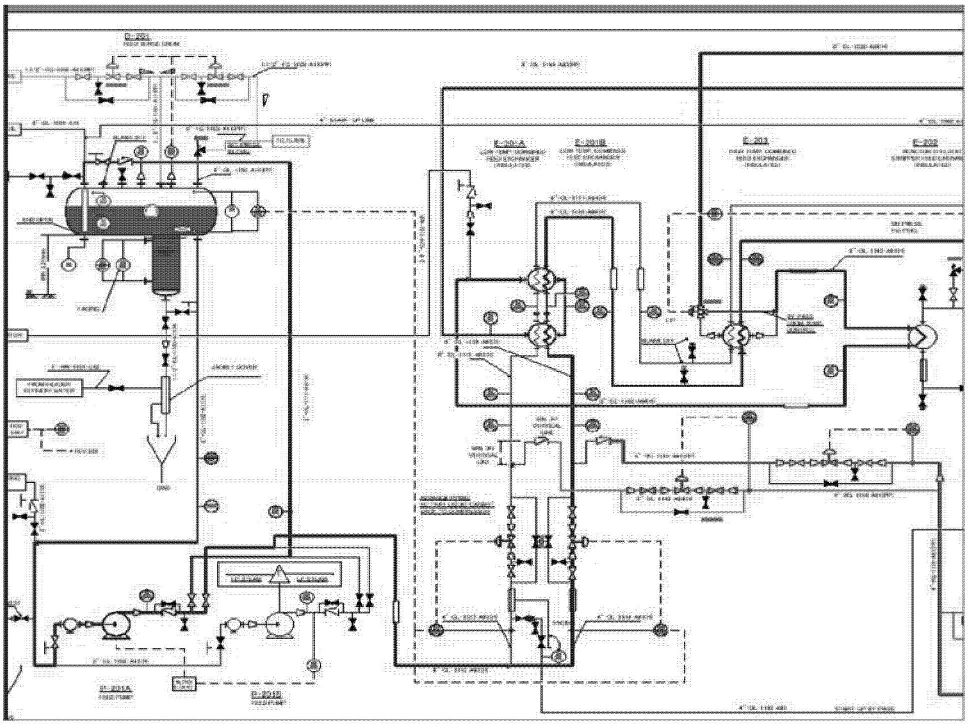

Figure 5. Route searching function in P&ID

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