Plant Modeling Based on SysML Domain Specific Language

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***Abstract*—Successful implementation of Model-based Systems Engineering(MBSE) obviously needs a model supporting efficient communication among engineers of various domains. The system modeling language standard, SysML is designed to create MBSE supporting models. However, SysML itself is not practical enough to be used for real-world engineering projects. As SysML is designed for generic systems and requires specialized knowledge, a model written in SysML has a limited capability to support communication between a systems engineer and a sub-system engineer.**

Our research's main goal is to develop a SysML based plant model integrating most outputs from plant design phases. As mentioned, a standard SysML based plant model is not specific enough to be understood by plant engineers. To make the SysML model more practical, a customized SysML for the plant engineering domain is required. Unfortunately, current researches on SysML Domain Specific Language(DSL) for the plant engineering industry are still on the early stage.

So, as a pilot, we have developed our own SysML-based Piping & Instrumentation Diagram (P&ID) creation environment and P&ID itself for a specific plant system, via widely known SysML modeling tool called MagicDraw. P&ID is one of the most important output during the plant design phase, which contains all information for the plant construction phase. So a SysML based P&ID has a great potential to bridge gaps between plant engineers.

Keywords—MBSE; SysML; SysML Domain Specific Language; P&ID;

I. INTRODUCTION

With the increasing complexity of today's systems, traditional document-based engineering has reached its limit. Systems are becoming too complex to be developed and managed through documents. Model-Based Systems Engineering(MBSE) is considered as a long-term alternative to document based engineering in order to keep correctness, consistency and traceability across all engineering items created through a system life cycle.

In the context of MBSE, a model representing a system and its environment is a basis of communication among stakeholders from different domains [1]. Successful implementation of MBSE obviously requires models supporting efficient information sharing. Systems Modeling Language(SysML) is one of the most actively used language designed to create such a model.

However, SysML itself is not practical enough to be applied to a specific field of industry as it is designed to model general systems. Well-written SysML based model does express various aspects of systems deeply but engineers need professional knowledge and skills to understand the information contained in the model. So, as described in Fig. 1, with a standard SysML based model, information sharing among engineers will be limited as each engineering team needs system engineers who can understand the model. To apply a SysML based model to real-world industries, the model needs to be created by a customized SysML for a specific domain so that corresponding domain experts can easily communicate through the model.

To explore the applicability of customized SysML models for plant engineering industry, we have developed a SysML based Piping & Instrumentation Diagram(P&ID) prototype of the waste-to-solid fuel plant designed by our research institute. P&ID is a key product of any plant design phase, most plant engineering activities are related to P&ID. So, SysML based P&ID can be regarded as the most important step to develop a whole plant model.

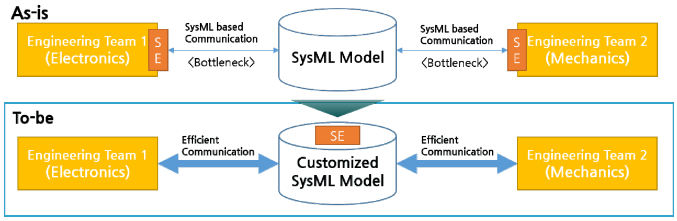

Fig. 1. As-is vs To-be

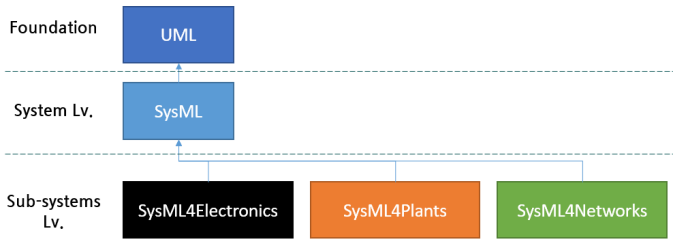

Fig. 2. Hierarchy of modeling languages

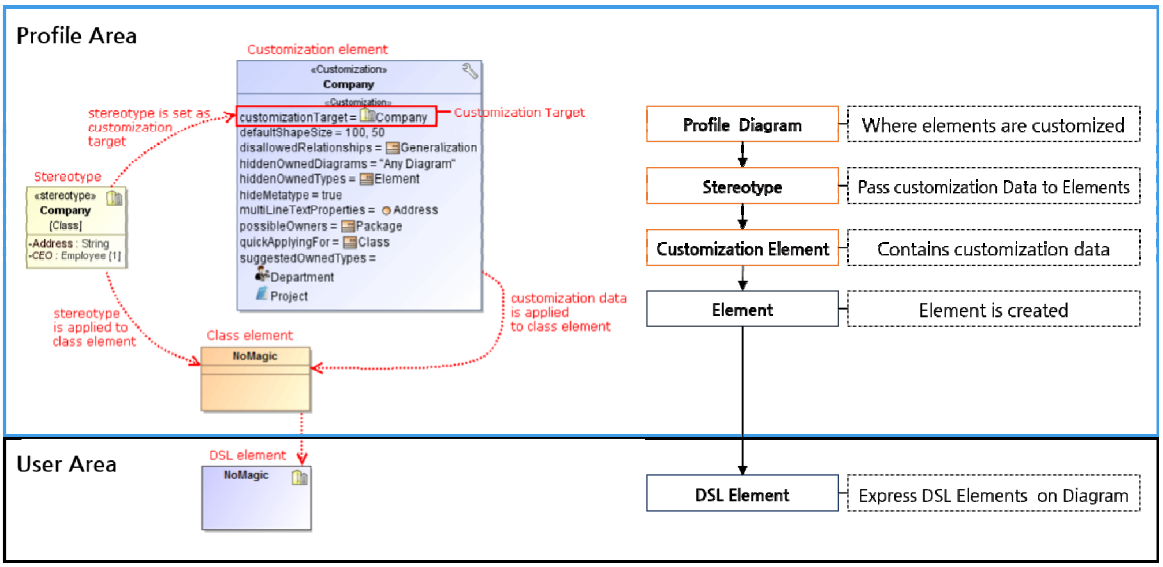

Fig. 3. Concept of SysML Domian Specific Language Realized on MagicDraw [6]

II. SysML Domain Specific Language

A. Definition

The idea of Domain specific languages(DSL) may sound new, but this is a venerable tradition in the field of programming [2]. Both HTML and Matlab are powerful script languages for web presentation and engineering applications but they are limited for developing generic software [2]. This is the nature of DSL. From the viewpoint of Systems Engineering, DSL can be defined as modeling languages modified or extended for user's domains. SysML itself is also a DSL extended from Unified Modeling Language(UML) defined by Objective Management Group(OMG). Fig. 2 shows the hierarchy of modeling languages for better understanding. SysML is extended from UML, and SysML can also be customized for various domains.

B. SysML Domain Specific Language Development

SysML elements can be extended to domain specific elements by using a concept of profile. All customization data – relationships between original elements and DSL elements, changed/added/deleted properties – are stored in a profile and it can be reused for any project. MagicDraw [5], which is one of the most widely used UML/SysML modeling tool provides DSL engine which helps to define profiles. Fig. 3 shows how a profile is composed and how DSL element is realized by a profile.

C. Related Works

Studies on UML/SysML based DSL for various domains from aerospace industry [2] to Computer Aided Design(CAD) model [3] have actively undertaken. These studies put focus on building domain specific schematic vocabulary [2] based on the standard UML/SysML semantics. Our study on SysML based P&ID was also inspired from these works.

III. Plant Modeling : P&ID Prototype Development

A. Scope

A plant is usually consisted of mechanical systems (equipment, valves, pipes, etc.) control systems, electrical line systems and others. And P&ID usually provides information of how mechanical and control system are integrated together. In our case, we limited the scope of the work to mechanical systems of the chosen waste-to-solid fuel plant as mechanical systems are most important parts of a plant that needed to be defined and designed earlier than others.

B. Development Process

1) Define customized element classes

- Mechanical systems of a plant are generally consisted of equipment, valves and pipes. Through the analysis of design data of the waste-to-solid fuel plant, we defined element classes needed to draw P&ID of the plant. Fig. 4 shows elements classes. Equipment needed for the plant was defined with customized properties and data types. Various types of valves were also defined with their own properties. And Pipes, which were extended from "Connector Class" of the standard SysML were defined. Image files of P&ID symbols were also assigned to corresponding element classes.

2) Organize the element classes as a single profile

- Defined element classes were packaged and arranged as a single profile so that it can be reused for any related project. Fig. 5 shows the structure of the created profile.

3) Define SysML based P&ID drawing environment

- Using the diagram customization wizard provided from MagicDraw, defined element classes were arranged to the P&ID palette (Fig. 6). The P&ID drawing environment was created by modifying a SysML Internal Block Diagram(IBD) definition, so relationship rules not customized follow the rules of IBD.

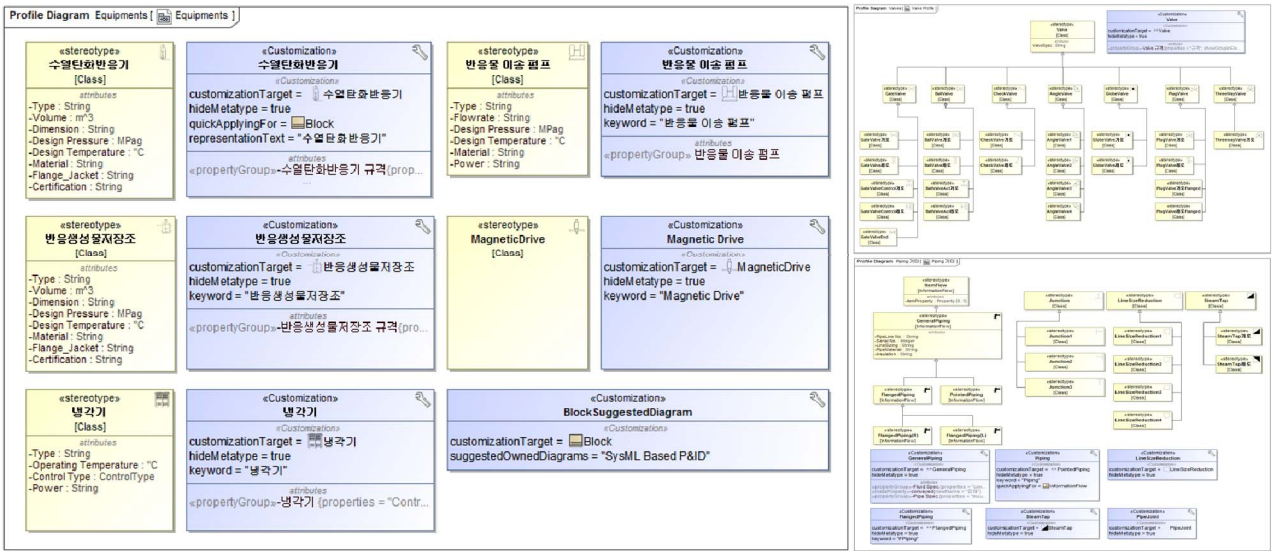

Fig. 5. Defined Plant Equipment, Valve, Pipe (clockwise) Classes

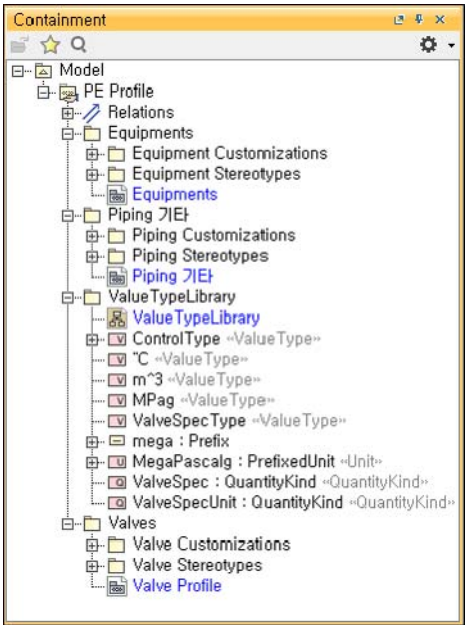

Fig. 4. Plant Engineering DSL profile

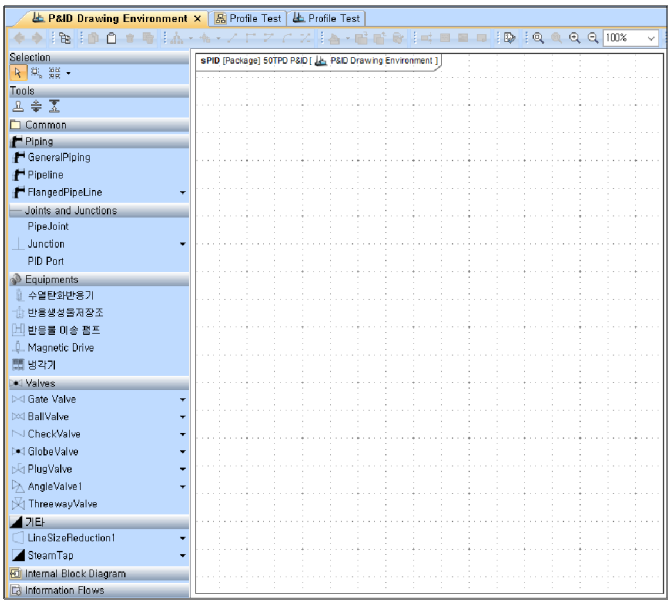

Fig. 6. SysML based P&ID Drawing Environment

IV. P&ID Prototype Examples

As all needed element classes were defined and arranged on the diagram palette, a user can draw a P&ID of the waste-to-solid fuel plant based on SysML even if he/she is not a SysML expert. A user just needs to drag and drop elements from the diagram pallet to the plane and connect them with the right piping connectors Fig. 7 shows the overview of the P&ID prototype. Though only major mechanical systems have been expressed, it is still quite similar with the original P&ID.

Fig. 8 shows what information that each element contains. Each symbol shown on the figure is a modifiable element which contains information needed for plant engineers. Elements' properties from the standard SysML are hidden and only customized properties – defined in the plant engineering DSL profile - needed for plant engineers are shown in each element's specification.

Fig. 9 shows another part of P&ID where the main equipment is connected to external systems. Standard SysML elements and relationships such as block and trace can also be added to P&ID. And defined properties of pipe lines, valves and equipment can be displayed on P&ID to give a better understanding.

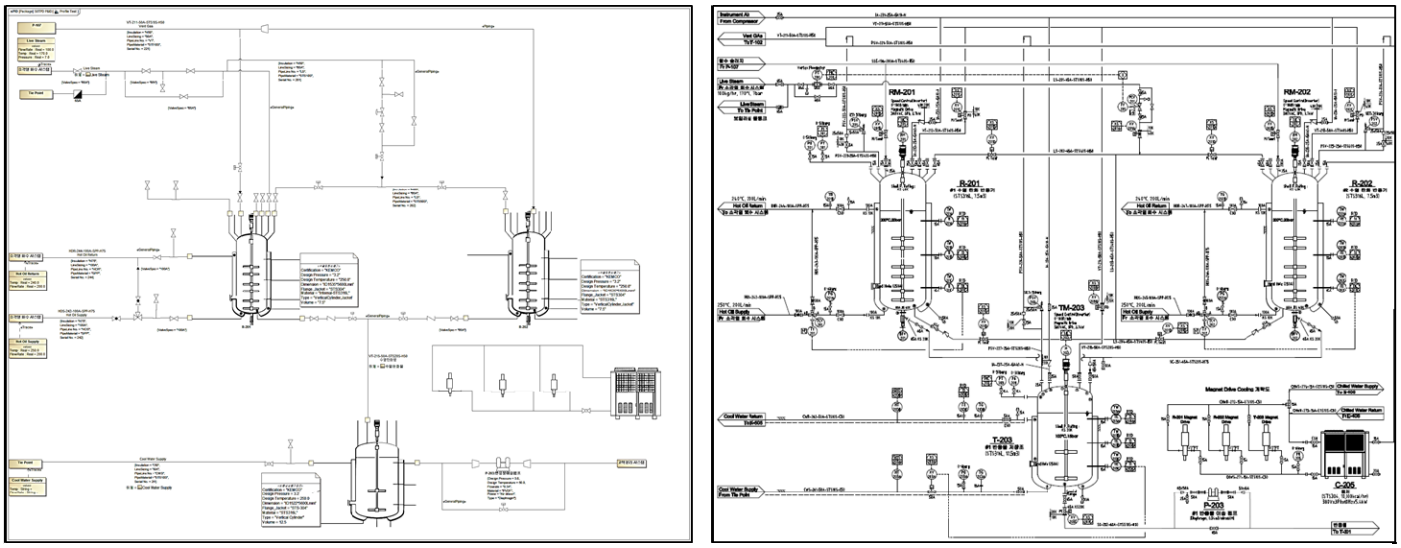

Fig. 7. SysML Based P&ID Prototype(left) and Origninal P&ID(right)

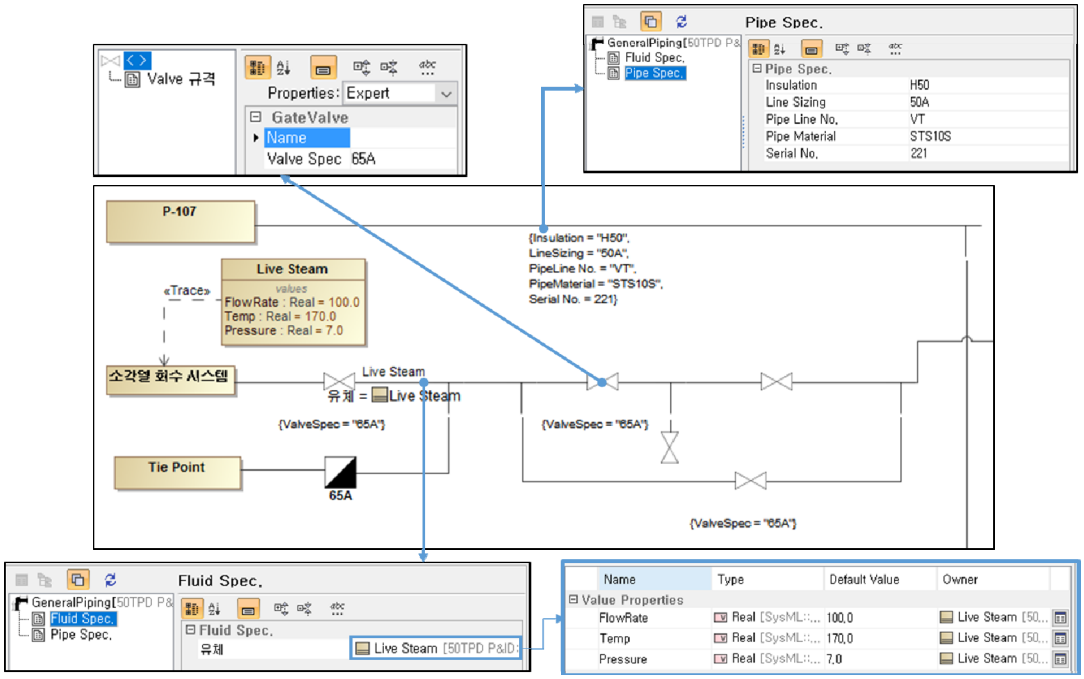

Fig. 8. P&ID Element Properties

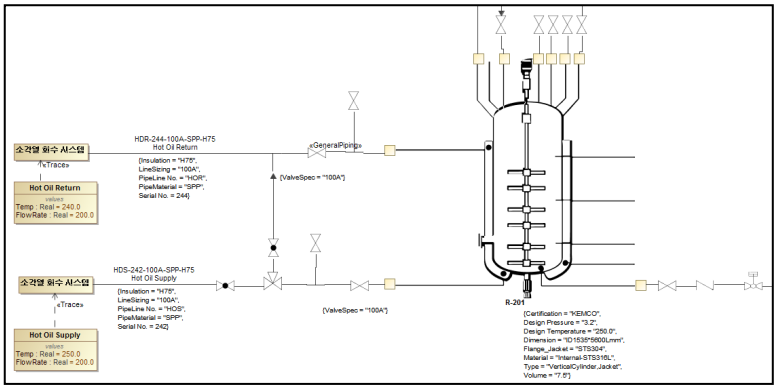

Fig. 9. Displayed P&ID Element Properties

V. Conclusion and Future Work

An example of a plant engineering P&ID prototype has been developed to explore the applicability of customized SysML models to the plant engineering industry. The P&ID prototype developed using MagicDraw was satisfactory as a pilot. However, there are several major issues found during the research and resolving these issues will be our future works to make the P&ID prototype more practical for plant engineers. Future works are followings:

- Resolving Visual Representation Issues: Several issues were found while representing P&ID symbols. In case of MagicDraw, all SysML element shapes are not just images, these shapes are created by JAVA so all conditions (initial size, ratio, boundary shape, etc.) are already defined. But the P&ID prototype's symbols are just vector images so it needs to re-write P&ID symbols with JAVA Open API provided from MagicDraw.
- Model to Model Transformation: Model to Model transformation rules should be developed so that a standard SysML based model for system engineers and a domain specific SysML based model for sub-system engineers should be easily convertible. If a user need to manually draw a SysML based P&ID every time, it is a huge loss of man hours.
- Tool Free Application: In the long run, DSL profiles and diagram creation environment need to function in any SysML authoring tool.

Acknowledgment

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