A FRAMEWORK FOR FOOD PROCESSING PLANT MODELLING

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Abstract: The paper presents the development of an open, standard based and low-cost framework for large scale food processing plant modeling. The models produced with the support of this framework should be used for Model Based System Engineering activities. The resulted architecture is presented and tested trough the model generation for a practical case, a sugar beet factory. The model is detailed down to the describing mathematical equation. Representatives SysML diagrams are presented. The formal description of a sugar plant crystallization section in SysML proves that the language is expressive enough to capture the structural and functional aspects of the plant relevant to system engineering and process engineering.

Keywords: SysML, Enterprise Systems Engineering, modelling, sugar beet factory

INTRODUCTION

The food manufacturing enterprises must cope with the diversification and increase in complexity of their production processes. At the same time, the enterprise must assure the food quality and safety trough a management system that is conforming to the international standards. The two goals can be achieved simultaneously only trough a systematic and systemic approach of Enterprise Systems Engineering (Allen, 2004). This approach can't be taken without an informatics system to assist and support its activities.
The design process of the support system is based on a plant model. In the past, this model was used only in the conception stage, by few people and, so, was rarely formalised. The extension of the engineering process to the whole enterprise and to the entire life cycle determined the apparition of the Model Based System Engineering approach (Estefan, 2007). This approach is gaining terrain and some provider offer software solutions (Harmon, 2007). The proprietary character of this solution implies less interoperability,

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less standard compliance and a higher Total Cost of Ownership. Supplementary, they are mainly intended for the software and embedded product industry. This makes them less suited for use in the food industry.
In this paper, a framework, that will allow the development and management of food processing plants models for enterprise system engineering activity, is proposed, in order to address the limitation of the existing frameworks trough the design of a standard based and open architecture.

ARCHITECTURE

Beside the design related criteria, the choice of standards and methods presented in figure 1 was determined also by the interoperability with food related standards and the availability of the software tools.

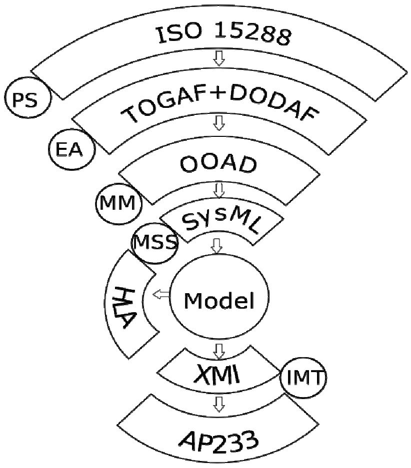

Figure 1 Architecture of the proposed framework

Because of its tight integration with the food quality and safety standards ISO 9001 and ISO 22000, the ISO 15288 was the obvious choice as a Process Standard (**PS**).
For the Enterprise Architecture (**EA**) the combination of DoDAF / TOGAF will be employed to benefit from the synergy of the two architectural frameworks (Dandashi, 2006).
Because the software development tools used are object oriented, the modelling method (**MM**) should also be object oriented so the Object Oriented Analysis and Design (**OOAD**) will be used. The representation of the food plant as a system of interacting systems can be formalised by using

of the System Modelling Language (SysML) as a modelling standard (MSS). SysML is emerging as a standard language for the “specification, analysis, design, verification, and validation of systems that include hardware, software, data, personnel, procedures and facilities” (Weilkiens, 2006). Taking into account the scale and complexity of such a plant, the best solution for the simulation of the models is a High Level Architecture (HLA) based simulator (Kuhl, 1999). The interoperability with the existing tools will be assured by the use of XML Metadata Interchange (XMI) (Grose, 2004) and the ISO 10303-233 Application Protocol: Systems engineering and design (AP233), as Interchange and metamodelling tools (**IMT**) (Weilkiens, 2006).

TEST CASE

To prove the functionality of the proposed architecture and the feasibility of the intended workflow, a crystallisation section of a sugar beet factory was chosen as practical test case. The main objective is to produce a model of this plant that can be used in all phase of the plant cycle management.

MATERIAL AND METHODS

Because the whole workflow is XML based, the first object XML Editor was used. The Scalable Vectorial Graphic (SVG) format was used for the graphical representation of the SysML diagrams. SVG is XML based so that the generation of diagram and the export trough XMI are XSLT driven transformation that can be automatised. The free open editor Inkscape was used for the diagram drawing, not at least because it allows the drafting process automation trough Perl and Python scripting.

RESULTS AND DISCUSSIONS

Because the elaboration of the whole enterprise architecture was behind the goals of this research, the design process was started from the SV2 view of the DoDAF architecture framework.

A SysML bloc description diagram was chosen to represent this view. The resulting diagram is presented in figure 2.

Each block represents a major equipment or machinery needed to fulfil the objectives and requirements described for this section in The Operational Views. This diagram allows the depiction of “composition” (black solid diamond) and "association" (arrow) relations between the equipments of the section. The multiplicity numbers are used for the specification of identical equipment.

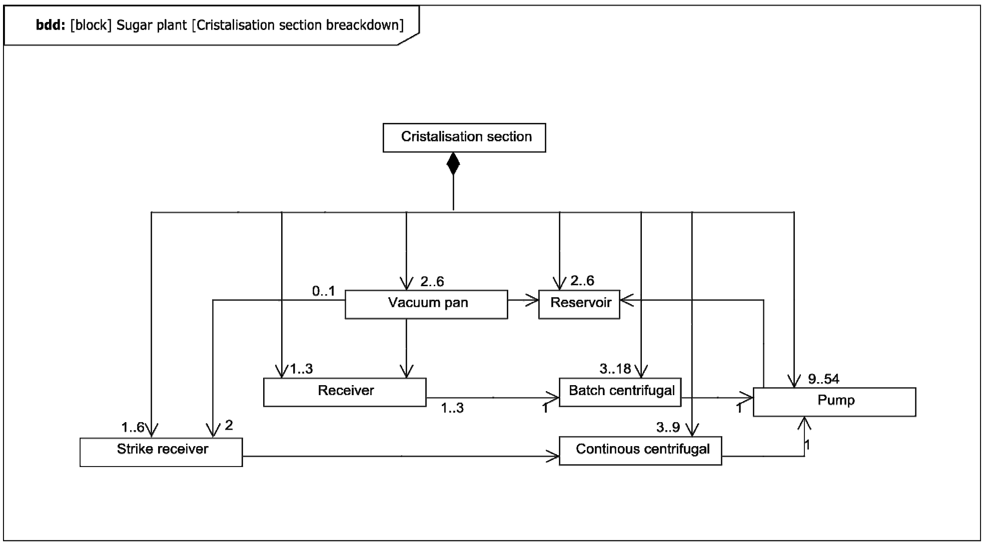

Figure 2 Representation of a Sugar plant trough an SysML bdd

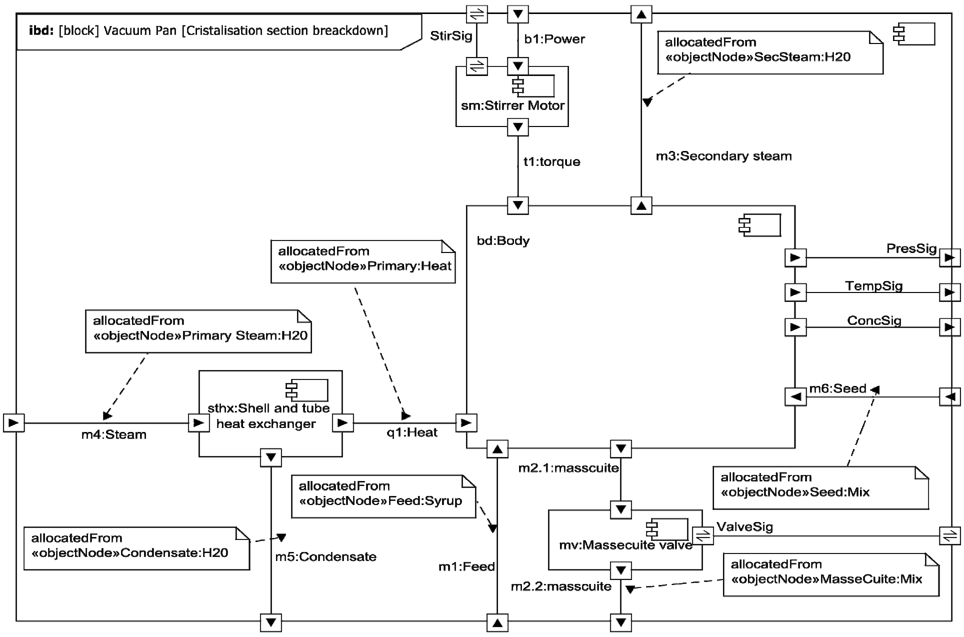

Figure 3 Representation of the structure of an vacuum pan trough an SysML ibd

Each equipment was further detailed trough it decomposition in subsystems connected trough mass, energy and information fluxes. This is best represented trough an SysML internal bloc diagram (**ibd**). Each subsystem is depicted as a bloc with ports trough which the interaction with other components occurs. Fluxes are represented trough lines connecting ports and The allocatedFrom elements permits cross references to elements in other diagrams describing the coresponding fluxes. The ports indicate also the type and direction of the transfer. The diagram resulted for the vacuum pan is presented in figure 3 as example.
A mathematical model relating input output and state variables was written for each subsystem. The resulting DAE system was represented in a SysML parametric (par) diagram. Figure 4 presents the parametric diagram modeling the multiphase processes in the vacuum pan. The equations are represented trough constraints blocks which connects the variables. The variables representing flux parameters are grouped in blocs representing the individual fluxes.

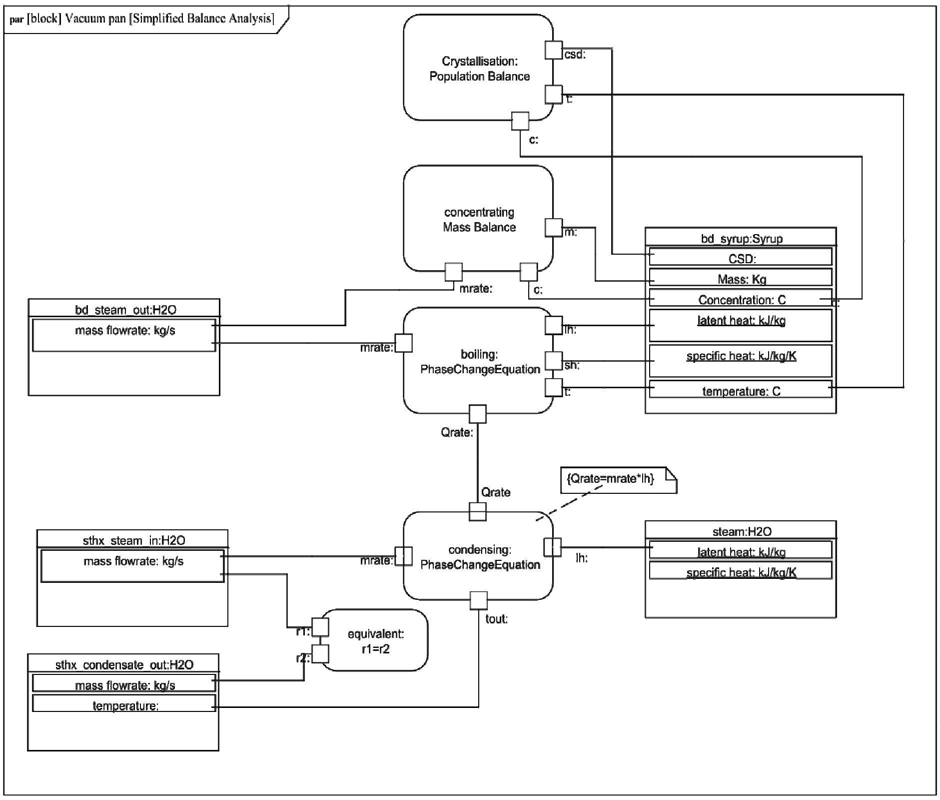

Figure 4 Representation of the mathematical model of the plant

CONCLUSIONS

The formal description of a sugar plant crystallization section in SysML has proven that the language is expressive enough to capture the structural and functional aspects of the plant relevant to system engineering and process engineering. The power of this modelling method resides in the possibility of generating multiple views from the same model and in the use of a visual language that emphasis the old quote "A picture is worth a thousand words".
Further development is needed to transform and integrate the developed software in to a SysML based tool for system engineering. At first the graphical editor must bee improved and made SysML compliant trough add-ons. A second important step is the automation of the translation processes.

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