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An Approach for Integrating Process and Control Simulation into the Plant Engineering Process

M. Hoyer[a*], R. Schumann[a] and G. C. Premier[b]

[a]Forschungsschwerpunkt AUBIOS, University of Applied Sciences and Arts Hannover
Ricklinger Stadtweg 120, D-30459 Hannover, Germany

[b]School of Technology, University of Glamorgan
Llantwit Road, Pontypridd, CF37 1DL, Wales, UK

Abstract

The generation of plant models for simulation is in general a task for modelling experts which are seldom available during the engineering process of a plant. The paper proposes an automatic model aggregation concept which provides the planning engineer with a simulation model at the end of the plant engineering process, such that he can test and debug the plant functions by simulation before it is built. To demonstrate the feasibility of this approach, a prototype example illustrates the practical realisation.

Keywords: Chemical plant, process engineering, control engineering, model catalogue, graphical user interface

1. Introduction

Testing of chemical plants is done mainly during the start-up and commissioning phase and in general requires a considerable amount of time and money to correct hardware and software problems. This costs could be considerably reduced by testing the simulated plant in advance before the plant has been built. Many developments in modelling and simulation are aimed to reduce such deficiencies already during the early engineering phases, see Fig. 1. In this early design stage, generic process models must be used and parameterised by modelling experts. An alternative to these bottom-up methods is the use of model based plant simulation directly at the end of detailed engineering. At this stage all components are completely specified – ready to order – and no degrees of freedom for parameterisation are left as in the early design phases. This paper describes an integrated approach to generate the required plant models automatically from a simulation model catalogue for physical components after completion of the engineering process, not requiring specific modelling expertise of the planning engineer to run the simulation. By this approach the main testing and faults correction could be done by simulation of the virtual plant with small additional effort thus reducing time and cost of the real start-up phase. The paper is organised as follows: First, the need for this approach is established by a critical literature review on current developments in modelling and simulation environments used during the plant engineering cycle. The detected

* markus.hoyer@mbau.fh-hannover.de

deficiencies in supporting planning engineers by plant simulation have motivated this new approach for simulation and testing of the plant at the end of detailed engineering which is based on a simulation model catalogue. Then, the set-up of an integrated simulation environment is described comprising the basic plant-CAE system in which the simulation model catalogue is integrated, the standard process and control simulators and a new module for the automatic aggregation of simulation models using a smart GUI. Finally, an application example illustrates the potential of the new approach by showing the automated procedure guiding the planning engineer from the P&I diagram of the plant-CAE system to the associated simulation results.

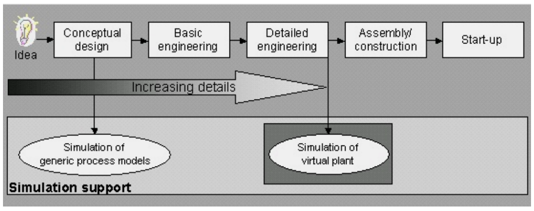

Figure 1. Simulation support for plant engineering process

2. Modelling and Simulation Environments for Plant Engineering

Commercial or scientific modelling tools for the plant engineering process are classified into two groups utilising block-oriented or equation-oriented model descriptions, see Marquardt (1996) or Pantelides and Britt (1995). These tools are tailored to users with appropriate knowledge in their domains (control system engineering, chemical plant engineering, modelling and simulation). In general, the use of these tools requires knowledge from all domains. This makes a permanent presence of experts necessary during all modelling and simulation procedures and is realisable (although at high costs) in large industrial companies or in scientific research. However, in small or medium sized industrial companies (planning and engineering companies) such experts are in general not available at all.

Due to the large variety of chemical process units and physical-chemical phenomena as well as increasing requirements on the sophistication of models, the development in knowledge-based modelling environments has increased in the past decade. The general idea of knowledge-based modelling environments is a methodology to lift the equation-oriented modelling from detailed mathematical representations to the level of process knowledge (in general by using phenomenological building blocks) (Bogusch et al., 2001). The support for the modeller takes place with suitable dialogs, provision of information and modularisation of process models below the model unit level.

The modularisation aspect of process models has been investigated by several authors (Ponton and Gawthrop, 1991; Marquardt, 1996; Perkins et al., 1996 and Preisig, 1996). All approaches contain a general systematic methodology for structuring the model with respect to later reuse and modification. Based on those general structuring concepts modelling languages and tools have been developed which permit a modular and highly structured model formulation. Examples are ModDev (Jensen and Gani, 1999), Modeller (Westerweele et al., 1999), TechTool (Linninger et al., 2000), ProMot (Tränkle et al., 2000) or ModKit (Bogusch et al., 2001). These modelling tools have provided the

development of model libraries based on simple, flexible and reusable modelling units. Furthermore, they are mostly integrated in CAPE (Computer Aided Process Engineering) environments used for modelling procedures and plant analysis as well as for the synthesis of chemical plants or control systems. However, these approaches are dedicated to the conceptual design at the beginning of the plant engineering cycle.
Simulation tools, based on a special web-based platform, such as Jarke et al. (1998) and Köller et al. (2001), use and provide components from different vendors by using a standardised open interface of the Global CAPE-OPEN-project, see Braunschweig et al. (2000). However, for the use of these component stores, expert knowledge is required.
All described methods and tools are designed for modelling and simulation experts and for the early phases of the plant engineering process. In order to provide non-expert users like planning engineers with simulation support during the plant engineering process (in particular at the end of detailed engineering), a new approach has to be taken.

3. New Approach: Integrating Process and Control Simulation into Plant Engineering

The new approach to integrate simulation at the end of detailed engineering is based on an extended CAPE (Computer Aided Process Engineering) concept which comprises the basic plant-CAE system (in the prototype realisation Comos PT by Innotec, 2003) and simulators for the chemical process (gProms by PSE, 2002) and its control system (Simulink by The Mathworks, 2003), Fig. 2.

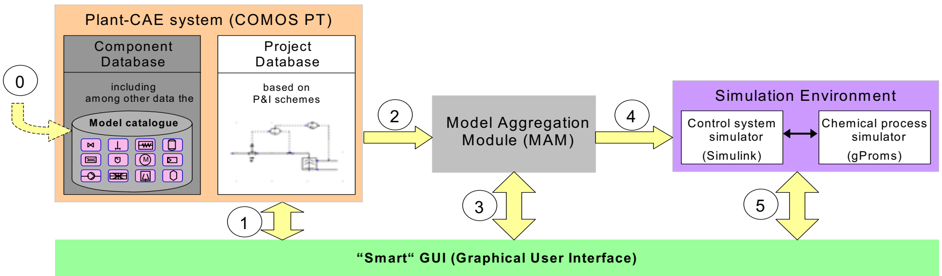

Figure 2. General set-up including essential tasks

These modules have to be linked among each other by the new developed model aggregation module (MAM) and with the planning engineer by the "smart" GUI (graphical user interface) module designed to allow simulation of plant and control system functions without requiring the assistance of modelling or simulation experts.
For setting up a plant model and its simulation the following tasks are accomplished:

3.1 Task 0: Collection of simulation models for the model catalogue in the plant-CAE system

The prerequisite for this approach is the availability of simulation models for all plant components. The component models required for simulation of the fully specified plant at the end of detailed engineering are models of its specific physical components (including the process control system), which will be built into the real plant. These simulation models, which do not have to be parameterised by the user, must become available from the component suppliers (as is the case in electrical engineering for PCB design) – this is a critical assumption – and should be stored in the database of the plant CAE system in a simulation model catalogue. To allow the use of sophisticated and dedicated simulators for chemical process components and control components it makes sense to store and simulate the models separately for the process and control domain, details see Hoyer et al. (2005a).

3.2 Task 1: Extraction of component information from P&I diagram (GUI)

The GUI module realises the interactive selection of an area in the P&I-diagram to be simulated, Comos PT delivers the required component and connection information of the P&I-diagram in a component dataset.

3.3 Task 2: Analysis of P&I diagram and model aggregation (MAM)

From the component dataset MAM detects the selected area to be simulated, the components within this area and their connections. From this information the simulation model is aggregated making use of the simulation model catalogue. For determination of boundary conditions for simulation the relations between the selected part and the rest of the P&I diagram are analysed and missing simulation parameters are detected by MAM.

3.4 Task 3: User dialogue for missing simulation data (GUI)

The missing simulation parameters are specified by the user in a dialogue window collecting boundary conditions for streams, set points etc.. In the actual prototype version the GUI is just able to collect this information, in the final version the smart GUI will provide the non-expert user with assistance functions guiding him through this nontrivial specification procedure.

3.5 Task 4: Generation of simulation scripts (MAM)

The complete simulation information is compiled by MAM into simulation scripts for the process and control simulator. In the prototype realisation a combined simulation script is generated and fed to Simulink (mdl-file) containing besides Simulink blocks for the control part the gProms block containing the gProms script for the process part. In this realisation gProms serves in Simulink as simulation engine for the process part through a standard interface (gOSimulink by PSE, 2002).

3.6 Task 5: Presentation of simulation results (GUI)

In the actual prototype version simulation is still started manually and the simulation results are presented within Simulink. In the final version, the smart GUI will hide the complex simulation environment behind the P&I diagram from which the simulation is started directly, and all simulation results will be directly presented in the context of this P&I diagram allowing easy interpretation of results.

4. Illustrative Application Example

The functionality of the realised prototype is illustrated using an example from a fresh cheese production line, details see (Hoyer et al., 2005b). During detailed engineering of the fresh cheese production line with Comos PT, the component objects were arranged and specified in the P&I diagram and the corresponding object tree as shown in Fig. 3. The red dashed boundary marks the components of the production line to be simulated: the process part contains pipes, the separator with input stream (curd) and output streams (sour whey, fresh cheese), the control valve and the physical parts of the sensors for curd flow and dry matter. The control system part includes the control loop FC 005 for the curd flow to the separator and the cascaded dry matter control loop QC 001.

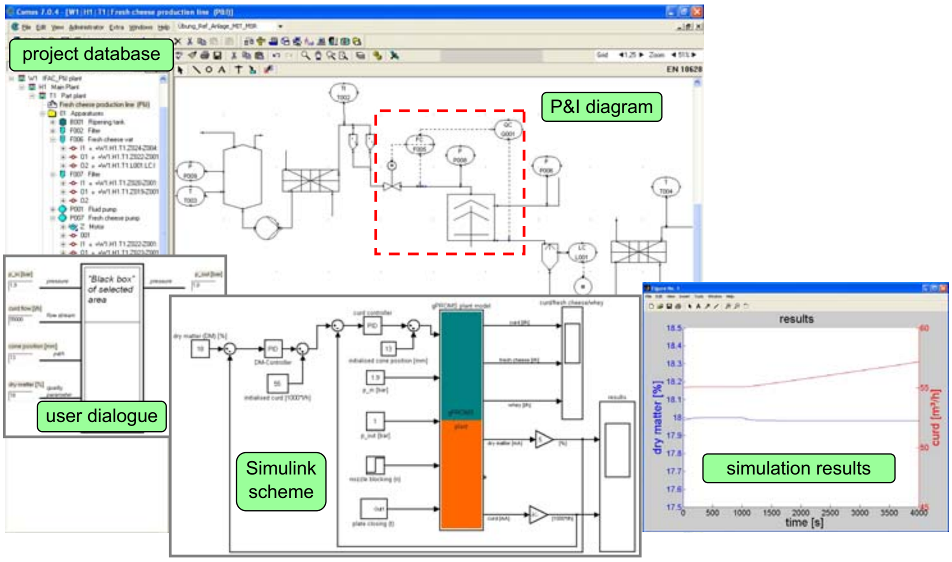

Figure 3. Flow control system in Comos PT (project database, P&I-diagram, user dialogue) and Simulink with gProms block

After selecting the plant parts to be simulated (red dashed lines) (Task 1), the component dataset is analysed (Task 2). Having specified the missing simulation parameters in the user dialogue window (here boundary conditions for input and output streams, set points for flow and dry matter control loop, Task 3), Simulink is started and automatically provided with the generated simulation script as mdl-file (Task 4). The simulation is then manually started by the user from the Simulink scheme (Task 5) and the simulation results are presented in Simulink format. In the application example, the impact of the disturbance "disc fouling" on the dry matter control loop is illustrated with the dry matter and curd flow signal reaction to this disturbance after time t=1000s.

5. Conclusion and Recommendation Aspects

The extended CAPE concept proposed in this paper is intended to support the planning engineer with simulation at the end of detailed engineering and opens a new path to integrate simulation in the plant engineering process. To make the concept work in reality a comprehensive component simulation model catalogue must be accumulated in a combined effort between CAPE system designers and component suppliers, as has already been the case in electrical engineering (e.g. PCB design). Furthermore the question of validation arising within all simulation activities has to be deepened in future. The quality of models may be characterised by the experimental or theoretical conditions under which these models were derived - such modelling conditions must become an integral part of the model description supplied by the model developer (supplier) to allow qualification of simulation results. The general issue how to make sure that non-

expert users can produce reliable simulation results in the absence of experts will have to be addressed step by step – as has been the case in electrical engineering during the evolution of simulation during the last decades with still ongoing discussions.
Having solved the remaining theoretical and technical problems the industrial application of such an extended CAPE system will allow testing and optimisation of the plant by simulation before it is built and thus may help to reduce start-up time and costs.

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