10th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

REUSE OF HIL SIMULATION MODELS IN LATER PHASES OF PRODUCTION PLANT LIFE-CYCLE

Sven Dominka
Technical University Munich
Boltzmannstr. 15, Garching
Germany

Bernhard Kausler
Technical University Munich
Boltzmannstr. 15, Garching
Germany

ABSTRACT

High dynamic and precise motions are typical characteristics of modern production plants. To control such systems, programmable logic controllers (PLC) or motion controllers are used.
Today, more and more hardware-in-the-loop (HIL) simulations are applied to test these plant controls. That means, that the real plant (without controller) is cloned in a simulation system, and this simulation system is connected to the controller of the plant.
With this kind of simulations, controllers and their integrated software can be tested in an early stage of the development process. However the modelling efforts for such simulations, mainly for large complex production plants are very high., Therefore the technique often is not used consequently in practice.
In order to justify the modelling efforts for these HIL simulations, reuse is an important aim. One possibility is to reuse the simulation in later phases of production plant life-cycles, e.g. the initial start up or ramp up.
Two possibilities of reusing the simulation models are considered in the following paper: the reuse of simulation models for plant diagnostics and for plant optimisation.
By the comparison of the real plant with the plant simulation on the one hand, the condition of the plant and their components can be diagnosed. On the other hand, sensor values of broken sensors could be replaced by calculated values of the simulation till the broken sensors are repaired.
The second possibility for reusing simulation models is plant optimisation. For optimisation a plant or rather the controlling of the plant, the parameters in the controller have to be varied manually. Today, the effects can only be observed on the real plant. For not disturbing the real production process, it’s possible to use the simulation instead of the real plant. The optimised parameters, verified on the virtual system can then be transferred to the real plant.
Keywords: simulation, production plant, reuse, optimization, diagnostics

1. DOMAIN OF PRODUCTION PLANTS

High dynamic and precise motions are typical characteristics of modern production plants. Typical applications are textile-, polymer- and wood processing, the packaging industry and the automotive industry. In all these domains, products are processed, mounted/assembled and transported.

1.1. Requirements on production plants

One common aspect of production plants is the requirement of a high effectiveness. The goal is a maximum of good products, that means no production waste for increasing the profits of the enterprise. One metric for plant effectiveness is called *Overall Equipment Effectiveness* (OEE) (Quelle). It is an overall characterisric of the three factors *plant availability*, the *plant efficiency* and the *quality rate*.

The *plant availability* comprises the productive rate of the plant. That means that the influence of unscheduled plant standstills, caused by troubles, is considered in this factor.

The *plant efficiency* describes the flow-rate of a plant during production. Plant speed and no-load running are considered in this factor.

Defective goods and waste of production, e.g. due to problems in production ramp-up are considered in the third factor *quality rate*. [1,2]

Therefore, the main target is to increase the Overall Equipment Effectiveness (OEE), There's no benefit in increasing one factor, if another factor decrease at the same time.

Below it will be focused on increasing the three factors by using simulation techniques.

1.2. Construction and alteration of production plants

Due to the high requirements in the domain of production plants, an alteration from mechanical to mechatronical plants has been conducted. Mechanical plants mostly consist of an upright shaft, that means the primary shaft, which drives the whole machine. To this input shaft, some output shafts, combined with gears and cam discs, are mounted to drive the different components. One benefit of this concept was the synchronized moves of the plants in former days. Nowadays this concept has been replaced by electrical drives. These intelligent drives facilitate complex and high dynamic movements. Like the upright shift, they offer synchronized movements with other drives, but also give the opportunity to release this kind of rigid coupling, or to change or adapt this linking. This higher functionality and flexibility is partly realized by the increasing rate of software and information technology, which is integrated in modern production plants.

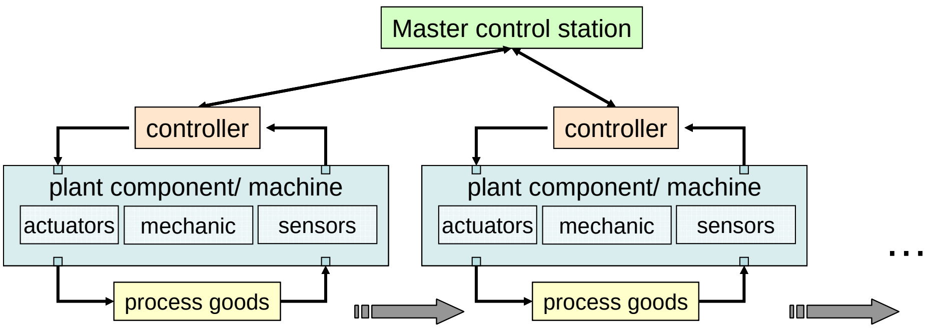

Figure 1: Architecture of production plants

Modern production plants are mostly composed of single parts, the production machines and the intermediary conveyer technique. The single parts consist of a controller and several actuators and sensors.

2. HARDWARE-IN-THE-LOOP SIMULATION

In order to reduce software mistakes during the plant engineering phase different simulation concepts for testing the controller software are established. In these simulation the structure and the dynamic behaviour of the physical part of the plant, consisting of sensors, actuators and other mechanic parts is modelled. The overall goal of these simulation concepts is to provide the same behaviour to the controller interface like the real plant. Thus the software simulation instead of the real physical plant can be connected to the controller in order to test the application software early in the development process. This type of simulation is also termed with hardware-in-the-Loop simulation, wherein the hardware consists of the controller containing the application software interacting with the plant simulation.

3. REUSE OF HIL SIMULATION MODELS IN LATER PHASES OF PRODUCTION PLANT LIFE-CYCLE

There are two kinds of application areas for the reuse of simulation models in later phases of production plant life-cycle, which plays an important role for increasing the availability of plants. On the one hand there's the reuse of simulation models for plant optimisation, and on the other hand the reuse for plant diagnostic.

3.1. Plant optimisation

Mainly in the area of production plants, high flow-rates like several thousand manufactured products per hour are not uncommon. The flow-rate of a plant has a major influence on the advantage in competition. Besides of optimisations in logistic and production planning, the real flow-rate of a plant is an important aspect.

There are different ways to optimise a production plant. First, it's necessary to optimally plan the plant. A well elaborated concept, with topics like, how the single machines work together and which kind of conveyer techniques are used, has a big influence on the plant flow-rate. But also the maximum speed, which is limited by the mechanical dimension and the actuator, affects the flow-rate enormously. An optimal mechanical dimension, can reduce or avoid vibrations, and hence achieve higher velocities. Also the decision for more powerful and robust actuators and sensors can reach higher flow-rates. One example for high-capacity sensors are load cells to find out the weight of the product. There are several load cells with different concepts to provide the functionality available. The simple ones need a certain time for weighting, while the product must not be moved. Better sensors could weight the products in a very short time, while the products need not to be stopped.

An already compounded production plant with integrated actuators and sensors could also be optimized through the controller-software. The velocity of each machine, and thereby the optimal speed of the complete production plant, could be adjusted through the controller. Through an optimal parameterization of the controller software, it's possible to optimize and exhaust a given plant regarding the flow-rate.

The process of optimization through parameter-adjustment is done very often experimentally. Therefore parameters, like drive parameter are changed, and the effects on the plant, and hence on the flow-rate are observed. However experimentation on a real plant has disadvantages.

On the one hand, the process of optimization on the real plant can cause reduced flow-rates or even plant- and production-stops. Particularly the uploading of a changed control program leads to a production stop and a new ramp-up. Repeated stand-stills and ramp-ups lead to a reduced production turnout.

On the other hand, an automatic optimisation of a real plant is a very complex task. For an automatic optimisation, an analyzing-unit is necessary, which calculates the actual plant flow-rate, estimates the new parameter-settings and shifts the new parameters in the plant controller.

Besides, changing of some parameters leads to a restart of the controller, which is very dangerous for the machines as well as for human beings.

If the hardware-in-the-loop simulation of the plant is used for optimization instead of the real plant, the problems, mentioned above, could be reduced or even avoided. By simulation an offline optimization of the controller software is possible, and consequently avoids stand-stills and reduced production during the operation. After optimisation the control program can be uploaded to the controller of the real, operating production plant.

Also the concept of automatic unattended optimisation of the controller software can be fulfilled in the simulated environment without damaging the real plant.

But there's also a big challenge in reusing the simulation model, which originally was used for the controller test. To use a simulation model instead of the real plant, it is necessary to clone the reality exactly. The simulation must have the same behavior at its interfaces as the reality, so the controller realizes no differences between reality and simulation.

3.2. Simulation for plant diagnostics

Another possibility to reuse the simulation model, which was originally used for the functional controller test, is for plant diagnostics.

Similar to the flow-rate-optimisation, the plant availability is another important aspect. Every production-stop leads to high costs. Production-stops could take a long time, when parts are broken and need to be fixed.

To increase the availability and reduce production stand-stills, many different kinds of diagnostic techniques are adopted. By the use of adequate plant diagnostics, defects at the plant as well as defects, which concern sensors, actuators or the mechanics, could be diagnosed and detected at an early stage. Furthermore sources of errors are bugs in the control program and handling/operation errors.

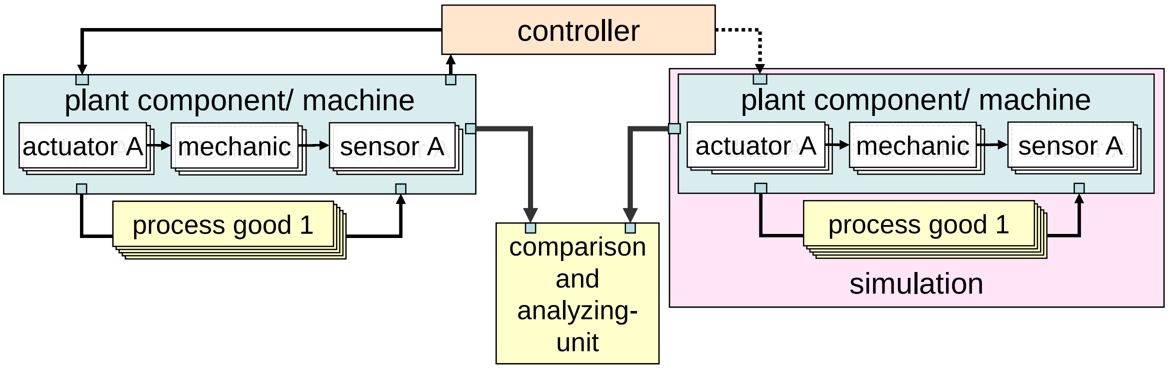

Figure 2: simulation for diagnostic purposes

One facility of diagnostic is to connect a simulation parallel to the real plant (Fig. 3). By a comparison of real and simulated state informations of the plant, its actuators and sensors, and the possible discrepancies, it's possible to conclude to an error or a critical plant state.
To run a simulation parallel to the associated real plant, similar to the plant optimization, a very detailed and accurate simulation model is necessary. In addition, the challenge is to compensate a temporal and local offsets between reality and simulation by synchronization mechanisms. Another challenge is the request to a real-time analyzing, which means that the simulation as well as the comparison of reality and simulation needs to keep up with the real production plant.

3.3. Automatic parameter adaptation of simulation models

The reuse of hardware-in-the-loop simulation models for optimization as well as for purposes of diagnostics postulates very detailed and accurate simulation models. The focus of reusing simulation models for optimization is to achieve optimal parameter-values. The challenge of reusing simulation models for diagnostic is, to run the real and the simulated plant synchronously. So differences between reality and simulation could be concluded as a failure in the operating plant.
The manually modeling of such high detailed simulation models is very time-consuming and expensive. Instead of that the already available hardware-in-the-loop simulation model could be automatically adapted before the actual use. That means that the simulation is connected parallel to the real operating plant. Discrepancies of the simulation respectively to the real plant could be used for adapting the parameters of the simulation model. So a simulation model could be created, which is very similar to the behavior of the real plant.

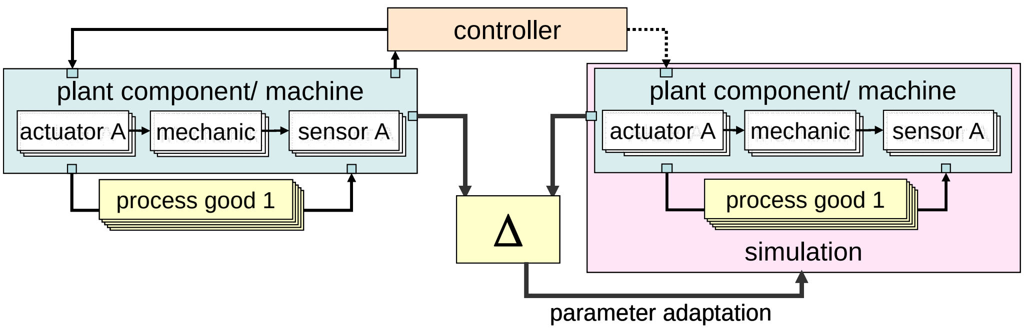

Figure 3: automatic adaptation of simulation models

4. REFERENCES

[1] Kaiser, V.: Asset Optimization - Technik und Beitrag zur Wertschöpfung, ATP, 2000, (12), pp. 28-40.

[2] Perlewitz U.: Konzept zur lebenszyklusorientierten Verbesserung der Effektivität von Produktionseinrichtungen, 1998.