Hardware in the Loop Module to Calculate Production Indicators

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Abstract: Currently Hardware in the Loop (HIL) is a powerful tool in manufacturing planning. A HIL module for manufacturing must include the dynamics of a critical machine, the logical control signals and the production sequence information. By this way Hardware in the Loop can provide a complete set of possible cycletimes, due the module capability to change delays times, sizes of the workpieces and problems in the parts or in the logic states. All this information could be re-used for manufacturers to improve factory designs or by other management modules to improve production indicators under the Virtual Factory Framework European project framework. Due to the level of detailed dynamics required in Hardware in the Loop simulations, it is suggested to integrate information from the multibody dynamic simulations programmed at the design level.

1 INTRODUCTION

In current days the industry has to adapt to the competitive pressures of global economy (Manufuture, 2011). In order to improve process manufacturing, several strategies need to be applied to current industries, and at the same time need to be included in the design for future factories. The ability to achieve cost efficiency, high quality and enhanced robustness with product variability and changing production requirements calls for the application of advanced engineering tools. One way to give advanced design tools to designers and industrial machine providers is to supply them with detailed models of the machines and information about its performance.

HIL shows to the manufacturing providers and end-users the way in which a machine will operate without the necessity to performs real testing and even without having the real machine.

This paper analyzes from the manufacturing point of view the different benefits of HIL used as a functional module, in the framework of the Virtual Factory Framework European project (VFF, 2011).

The structure of this paper is presented as follow: first is described an overview of HIL, next are presented the specifications of the HIL module, where is included the machine model, the control system and the database for the communication. In section three are presented the bases to program the HIL module, followed by specifications of the module. In section 5 is showed the implementation of the module. Preliminary results suggest that random rotations in workpieces could affect the cycle time of a production line. Finally the conclusions are presented.

2 HIL FROM EMERGING TECHNOLOGY TO DESIGN TOOL

This section is not a survey about HIL applications; it is a summary about how HIL has evolved from being an innovative emerging technology in the 50s into a tool used by other innovative solutions to current challenges.

HIL is used since 1950s in Defence and Aerospace Industry where the high cost of equipment and the risk index in trials had required of a new manner to perform testing. However HIL was also an expensive technique due the limited computational performance available at the time. In the 90s with the advances in computer technology and the confirmed functionality of HIL, it was assimilated by the automotive industry. Nowadays, HIL is getting in better implementations and more affordable solutions, which has allowed its expansion to different sectors. It is well known that HIL accelerates product development, increases product quality and minimizes cost in prototypes and tests. All this is making this technique more used every day.

Today, HIL is itself a tool for other emerging technologies like renewable energy, robotics and manu-

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facturing. In energy, PHIL (Power HIL) is used to test the response of smart grids and power components. In this manner, PHIL performs optimization of power supply and prevents dangerous failures see (Lentijo et al., 2010). In robotics, the robot interaction with other robots and/or humans is a growing application, it is generating new challenges in terms of response time, stability and security.

In manufacturing, HIL is providing a tool to analyze production and maintenance capabilities. The information about factory performance is showed by the KPIs (Key Performance Indicators), so HIL must focus in providing the signals needed to calculate determined KPI. (Gu et al., 2007) has studied how HIL could provide reduction in unscheduled downtime and in the KPI MTTR (Mean Time to Repair). Meanwhile (Harrison et al., 2012) has used it in a detailed level for manufacturing systems where real and virtual world could be used simultaneously.

A description of how HIL could be used in production management is described in the next sections.

3 HIL MODULE BASES

In modern factories the continuity of the link design-real machine is broken due the provider-customer relations. Machines that are used in manufacturing processes are designed mostly by Computer Aided Engineering (CAE). The design information is lost when the machine is commissioned in a plant under real conditions, as well as the real performance and behaviour of the real machine is not feedback to designers.

One of the big differences between engineering models and real machines is that in a factory, the behaviour of a machine depends of the industrial control system (PLC), it is a fundamental part of a machine performance and operation.

Therefore, real manufacturing systems need hybrid simulations to represent the combination of dynamics and logical states. A detailed model with logic states, mechatronic and environment systems indicators is fundamental to calculate properly the main production KPIs, like are production and cycle time, reaching even the level of work pieces.

The cycle time is defined as the total time from the beginning to the end of the process. To calculate cycle time, process time and delay time are needed. The performance of HIL module is the combination of the level of detail in the representation of the process and in the real-time hardware (Cai et al., 2008).

Summarizing, HIL module for manufacturing needs three basic elements: a dynamic model of the machine, the PLC control program and the characteristics of the production sequence.

Several ways could be used to obtain the dynamics of a machine, one of them is the mechatronic modelling of final prototypes in multibody dynamics CAE tools, such as ADAMS or ProEngineer. Based on ADAMS *(Multibody Dynamics and Motion Analysis Software)* model, a set of linear state space matrices is exported to MATLAB as the linear representation of the machine. Other way to find the machine dynamics is using the Lagrange-Euler laws of the mechanism, this approach is implemented in mechanic machines and robots (Siciliano et al., 2011).

With the machine model in MATLAB/Simulink it is possible to use StateFlow to model the control program of the machine and perform a hybrid simulation between logic programming and the continuous states.

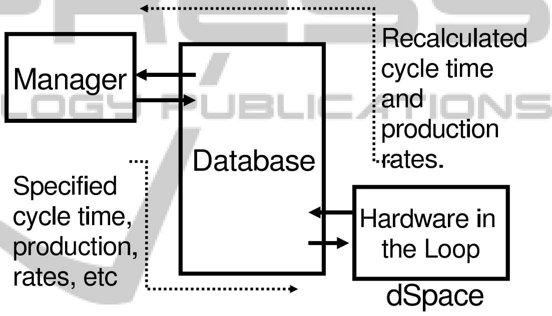

Figure 1: Communication process to read production sequence and write generated KPIs.

The application needs to be loaded to a real-time environment; in this case it has been implemented with dSpace. The processor dSpace rti1006 runs to 1KHz and the results can be transmitted during the simulation thanks the Control Desk application and the connection libraries in C ++/Java. The implemented HIL runs in a PC with Matlab/Simulink (version 2007 or later) and the Control Desk application must be a 2008 version at least.

Finally the production sequence information could be directly introduced by the designer or loaded from a database. Then, HIL calculations could be stored.

The key issue is the HIL configuration as a module that is used by the management actions to improve the factory performance (Sauer et al., 2009). With the modelling of a critical machine in Matlab/Simulink, this module needs to be communicated with other modules (Fig.1). This is the view of VFF, that all modules could exchange information; in other words, that the knowledge produced in one place could be accessible for other modules interested in having it.

4 SPECIALIZED MODULE FOR RECALCULATE KPI

Normally, testing of industrial machines is very expensive and some times it is not possible due the consuming time or because the complete fabrication line is not available. Then becomes imperative to test some parts on a simulation of the actual system. This is the stage where HIL is highly recommended (Fig.2). Besides, this module based in dynamics of a process is better modelled by continuous simulation than discrete event simulations.

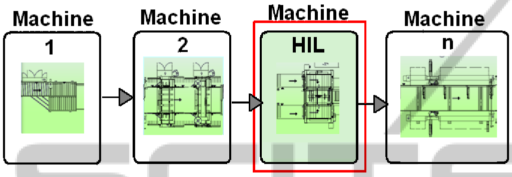

Figure 2: HIL simulation inside the production line.

Since HIL requires a strong modelling effort, a primary approach could be to choose a complex/problematic machine that affects a complete production line and based on its calculate function the main problems in the line and how it is affecting the complete production planning.

The module could calculate the variables needed for some performance indicators that are affected by the critical machine performance.

The module reads the process plan and the production rate information from a database. Then it simulates the given operation in the station/machine in closed loop and calculates the station performance parameters with more precision. The results are more realistic values for the performance indicators.

A designer or provider of production lines could use a machine model to calculate the behaviour of a solution with low development cost, improving the response of the factory design (VFF, 2011); (Bathelt et al., 2010).

The novelty in this approach is to use HIL as a module with the possibility of interacts with other modules. For a multi-component system it is necessary to parameterize the properties that will be exchanged through a remote database or a manager module.

When the machine is working in a real factory, the information about its performance is feedback to the designers to improve the control program or even change the mechanical design.

5 IMPLEMENTATION OF THE HIL MODULE

HIL module contain the information about a specific machine (Fig.3), together with the information about work pieces and cycle times provided by HOMAG (HOMAG, 2011).

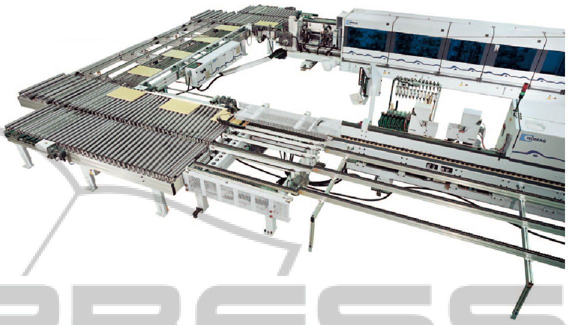

Figure 3: Angular Transfer Machine, provided by HOMAG (HOMAG, 2011).

This critical machine connects two stages into the production line, carrying pieces of wood at the maximum speed from one machine to the next one. Due its shape, this machine saves space in the factory, but also tends to rotate the parts producing unwanted collisions. With this information, the programming of the PLC and the stateflow was carried out. The specific dynamics about the friction and random rotation of the piece of wood are used in HIL to calculate the cycle times. Leading the module prepare to recalculate KPIs under a large range of conditions. The recalculated cycle times are communicated to a central modules manager through a server application.

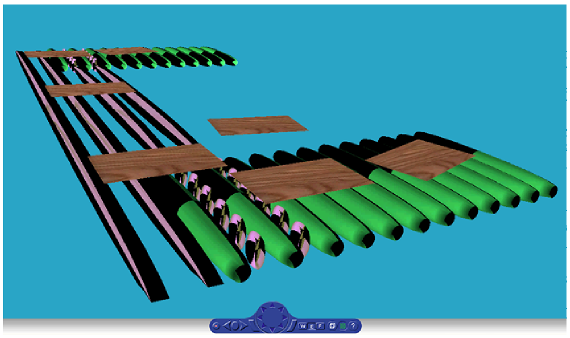

Figure 4: Virtual reality animation of the HIL module.

The parameters that can be changed in the HIL simulation are: the velocity of the line, the wood mass and size, the rolling resistance coefficient and the range of rotation in the wood pieces.

The simulation runs (Fig.4) in a VRML environment. The preliminary results about the cycle time shows that the rotation in the piece of wood affects the necessary gap to avoid collisions in the machine (Figs.5 and 6).

With all pieces of: 2810 mm x 1010 mm, 25 mm height and 65 kg of weight, without rotation, one minute is requeried to transport 24 pieces. With the Poisson distribution applied to the random rotation, simulation shows that 2 or 3 pieces collide. To avoid that it is necessary to increase the gap between pieces from 1.23 s to 1.29 s. The meaning of this time increment is reflected in the new number of parts transported: only 22. The difference of 2 pieces per minute affects the complete production line.

Module validation is required and future improvements in the model are needed, such us the automation in the collisions detection and the simulation of failures in the PLC inputs.

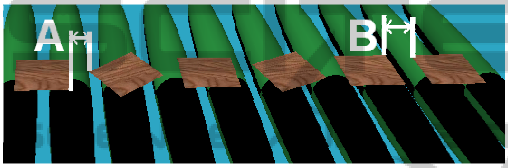

Figure 5: VRLM frame showing a random rotation in the pieces of wood. The calculated necessary space to avoid collision is B, meanwhile A is a shorter space produced by a random rotation.

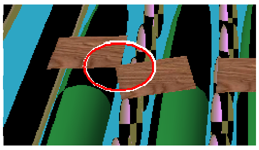

Figure 6: VRLM example of wood pieces collision due the rotation in one of them.

6 CONCLUSIONS

The goal of the HIL module is to investigate the effect of faults, both in sensors and actuators, and the machine itself.

This paper presents how a detailed model of a real critical machine can calculate the production cycle time, this under real conditions for factory production.

The communication of the defined KPI to other modules allows the exchange of knowledge for the factory design or for production improvement. The design of a production line could be optimized even before the line is assembled, increasing productivity even in future factories. The validation of this tool in the VFF framework is still under development.

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