A Combination of Traditional Control and Hybrid Modeling Methods for Intelligent Fluid Power Systems

Véronique Bader, V. Rémillard and D. Lenoble#

Key Words: Mechatronics, Intelligent Fluid Power Systems, Machine Management Software, Virtual Machine, Integrated Solutions, Power Management, Efficiency, Co-simulation.

Abstract: The necessity for greener and more efficient equipment has led OEMs and manufacturers to bring intelligence into fluid power systems. The integration of electronic controls in key components allow for better power management and safer work environment, which are two major concerns in the fluid power industry. One of the challenges of these new integrated solutions resides in the complexity of the design which involves many different expertise. Fluid Power, Electrical and Control Specialists need a communication platform to develop more efficient systems combining all technologies. Traditional control modeling methods are used to develop performant controllers with the help of equation-based or model-based software. However, more hybrid modeling methods – such as Machine Knowledge Management – are favored to design fluid power systems using integrated mechatronics software. By combining both methods to allow integration or co-simulation, control specialists will be properly integrated in the design and analysis process to build more intelligent machines.

This paper will demonstrate how combining traditional control and hybrid modeling methods with the use of a machine management software facilitates the design of efficient intelligent fluid power systems.

V. Bader, V. Rémillard D. Lenoble: Famic Technologies inc.
E-mail : vbader@famictech.com, Tel : +1 514-748-8050
Sang-Jin Lee : Inroot Co., Ltd, Tel : 82-31-399-5711

1. Introduction

With energy saving and performance requirements being a top priority for OEMs and manufacturers, designing efficient equipment has become a necessity. Consequently, manufacturers are developing electro-hydraulic components that allow for the integration of control algorithms in fluid power systems. However, this recent trend has generated new challenges between Fluid Power, Electrical and Control Specialists.

Part of the issue resides in the absence of active collaboration between experts due to a lack of communication between the different software and tools used to create integrated solutions. Control algorithms, developed with traditional modeling methods (equation-based, model-based), must interact with machine knowledge management software in order to create efficient intelligent fluid power systems.

This paper presents an innovative approach which combines traditional control trends and hybrid modeling methods. The proposed solution helps to establish a more complete virtual system which facilitates communication and analysis of the multi-technology platform and helps to create efficient mechatronic solutions. Section 2 details the characteristics of traditional control technics and hybrid modeling methods and presents their limitations towards building a more efficient complete virtual machine. Section 3 explains 2 case studies on this approach that combines both modeling methods through integration or co-simulation. Section 4 concludes with some final remarks.

2. Traditional and Hybrid Modeling

Intelligent fluid power systems integrate multiple technologies – requiring the contribution of Electrical, Fluid Power, Mechanical and Control Specialists. In order to design a complete virtual machine, two different modeling approaches can be used: traditional or hybrid.

A traditional control modeling method consists more of an upstream design. With this approach, each subcomponent is modeled based on fundamental equations [1]. This allows for in-depth simulation of specific components and functions. It also requires specialists to have a profound understanding of physical parameters and equations governing each components.

Since control algorithms present advanced mathematical relationships, they are often developed using an equation-based or model-based software tool. However, to test the performance of the control system, the model needs to interact with the complete virtual machine. With traditional modeling, it is still difficult to build an accurate model at a complete machine system scale.

The complexity of certain components or the lack of information provided by manufacturers on key parameters can make it difficult to establish the precise relationships needed for upstream design. Moreover, many assumptions and simplifications are often made for more complex phenomena. In these cases, an equation-based model will not describe accurately the behavior of the global system.

With downstream design, components are modeled using available performance curves often based on manufacturers' data. This approach uses empiric data to provide an accurate simulation of components, functions or systems. Designers can then quickly validate and improve the global characteristics and behavior of the machine. However, it may be more difficult to analyze the dynamic performances of individual components in a more microscopic scale.

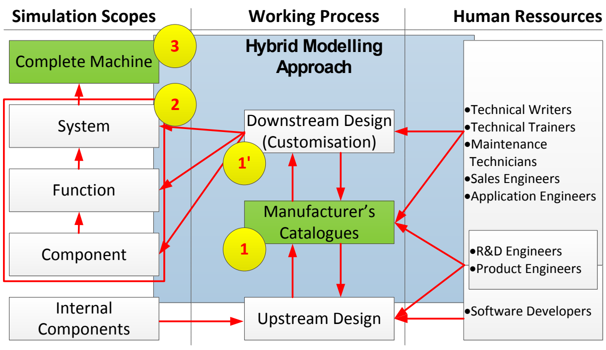

Fig. 1 Hybrid Modelling & Simulation Scope

The solution proposed in V. Rémillard's technical paper [1] is a hybrid modeling method which combines upstream and downstream design. With this approach, upstream design is used to pre-programmed component blocks with differential equations that can be used to create complete systems. Each component can be further customized with the use of performance curves. The combination of both approach enlarges the simulation spectrum, allowing both in-depth simulation of specific components and global simulation of the complete virtual machine, as explained in R. Gagné's technical paper [2].

Hybrid modeling aims to easily integrate all technologies and represent more accurately the behavior of a complete virtual machine. This approach also aims to optimize the entire workflow of a project lifecycle which includes system design engineering, system validation project documentation, start-up, training services, maintenance diagnostics, technical publication and sales support, as shown in Fig.2.

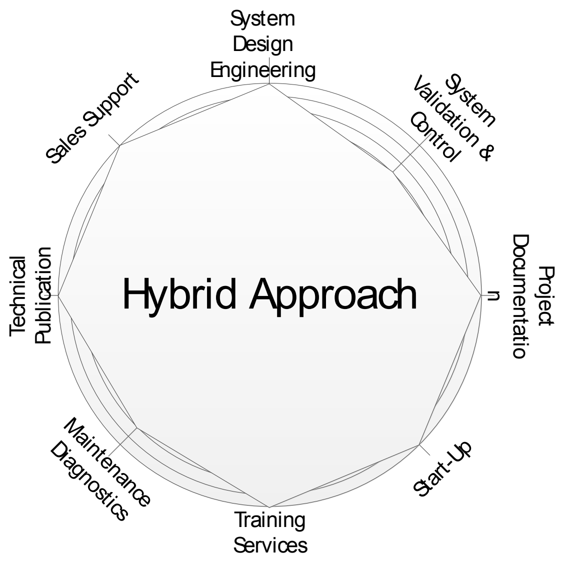

Fig. 2 Hybrid Approach

Fig. 2 illustrates how a machine management software tool helps optimize these different aspects using a hybrid modeling method to design complete mechatronics systems. Although most aspects are well optimized, there are still some improvements to be made on system validation with the hybrid approach.

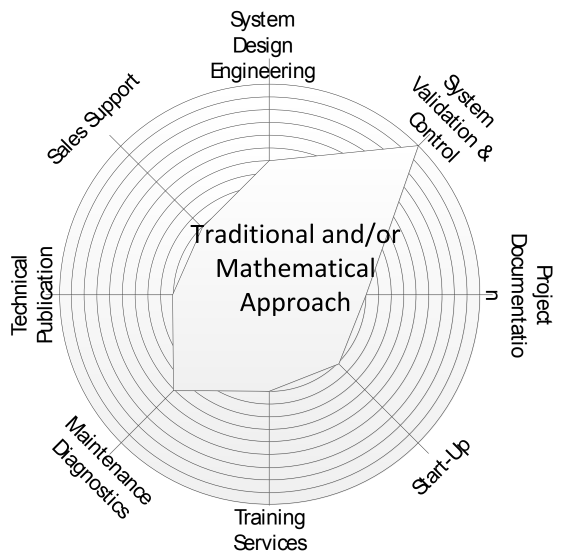

Fig. 3 Traditional Approach

Fig. 3 also shows where a traditional approach is mainly used in an entire project life cycle. The illustration shows that a traditional equation-based/model-based software focuses on system validation, which requires high mathematical and programming skills. This approach among others is used by control specialists to design and test the developed algorithms. Traditional modeling however lacks to optimize the other aspects of a project's entire workflow. It is therefore difficult and highly time consuming to design and simulate accurately the complete virtual machine using only this approach.

Also, since control specialists use different tools than fluid and electrical specialists, it is difficult to integrate their designs and analysis work to the complete virtual machine simulation. This creates many communication challenges in the project and prevents taking full advantage of the hybrid approach for system validation.

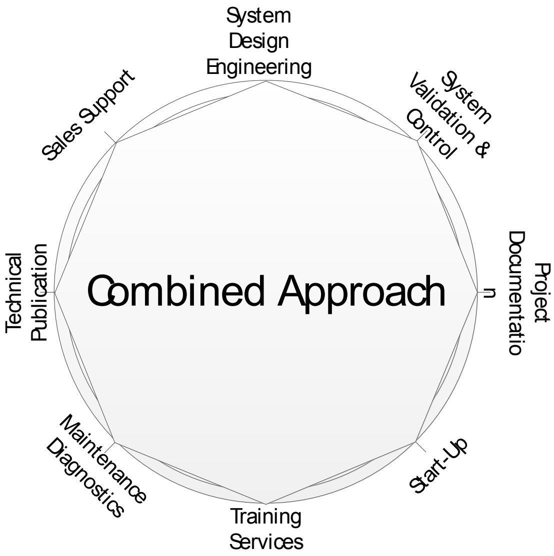

Fig. 4 Combined Approach

The key factor to improve the intelligent machine development life cycle is therefore to combine traditional and hybrid modeling methods in order to fully integrate all technologies and create efficient complete virtual mechatronic systems.

The performance of control algorithms developed with model-based software will be tested with the complete virtual equipment developed with Machine Knowledge Management software. The efficiency analysis of control systems will greatly improve as they will be simulated with complete multi-technological machines that present more accurate global behavior. Overall, by combining traditional and hybrid modeling, the system validation process will be optimized as shown on **Fig. 4**.

3. Combining Traditional and Hybrid Modeling

The combination of traditional control and hybrid modeling can be done in two different ways - by integrating control algorithms in a unique machine knowledge software or by co-simulating with other software and hardware. In this section, examples will show how to take advantage of the proposed working process.

3.1. Integration

The electrification of fluid power systems is a growing trend in the industry. This forces hydraulic and pneumatic manufacturers to integrate electronic components in order to offer programmable components. This adds a layer of flexibility to these

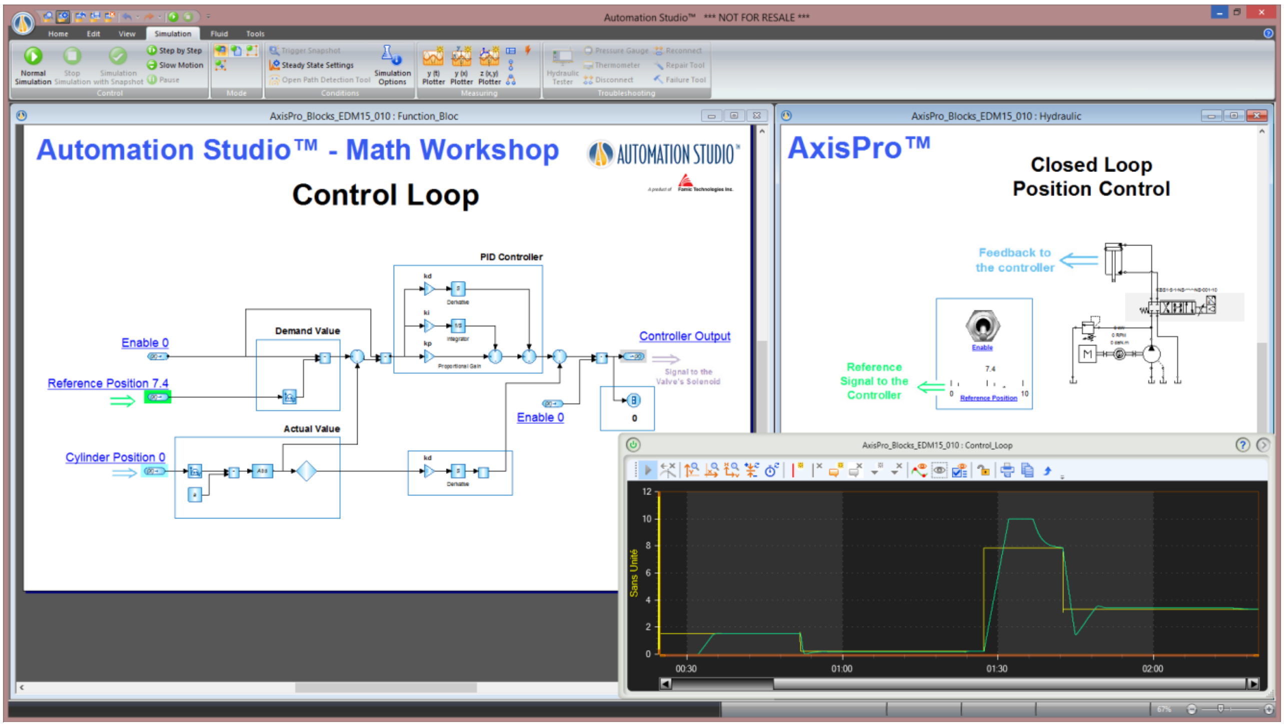

Fig. 5 Integration of Control Algorithm of an Axis Pro™ Valve

components which helps reach the growing performance, energy saving and controllability requirements.

However, as the level of flexibility increases, so does the complexity of integrating these components.

To illustrate this point and demonstrate how to overcome the issue, let us take an example using Eaton's Industrial Valve AxisPro™. This valve consists of an On-Board Motion Control with a CAN Bus communication interface [4].

Although the capacities of this valve are considered to be a Game Changer in motion control, there are still some challenges regarding its implementation in real applications.

This advanced valve is a multi-technological component that involves many different expertise. It requires not only mechanical, hydraulic and electrical knowledge but also system control knowledge. Even with user friendly programmable environments proposed by manufacturers for these types of valves, it remains a challenge to test the performance and robustness of control algorithms with real applications. In many cases, adjusting the control parameters before or during the implementation process generates performance well below the capabilities of such components.

It is important to efficiently be able to integrate all expertise in one common work environment. This will allow to create accurate models which will help understand important development issues of these intelligent electro-hydraulic components, way before testing them on physical test benches.

Fig. 5 shows a simulation model of an Axis Pro™ valve which is completely integrated and simulated using Automation Studio™ software. The right side of the illustration shows the complete hydraulic and mechanical circuit that includes the Axis Pro™ modeled with the hybrid approach. This valve was selected from the manufacturer's catalog of Automation Studio™. It was therefore pre-configured using the hybrid approach and can be analyzed right away within the circuit it was integrated in. The left side of the illustration shows the control algorithm that was designed entirely through traditional modeling, using mathematical block functions.

This virtual test bench therefore allows to test and adjust the system's performances as well as adjust the different control parameters before having to prototype the system.

3.2. Co-simulation

Co-simulation is more and more used to combine traditional control and hybrid modeling methods. This approach was already implemented with great success by IMECA – a company in France that specializes in integrating complete assemblies for pipes and hoses.

IMECA designs electro-hydraulic and pneumatic systems that are usually controlled by Programmable Logic Controllers (PLC). In these type of projects, the problem encountered by the company is the lack of collaboration and communication between the Fluid Power and the Automation Departments. Both teams use different tools and work separately on their designs.

In order to test the performance of their control

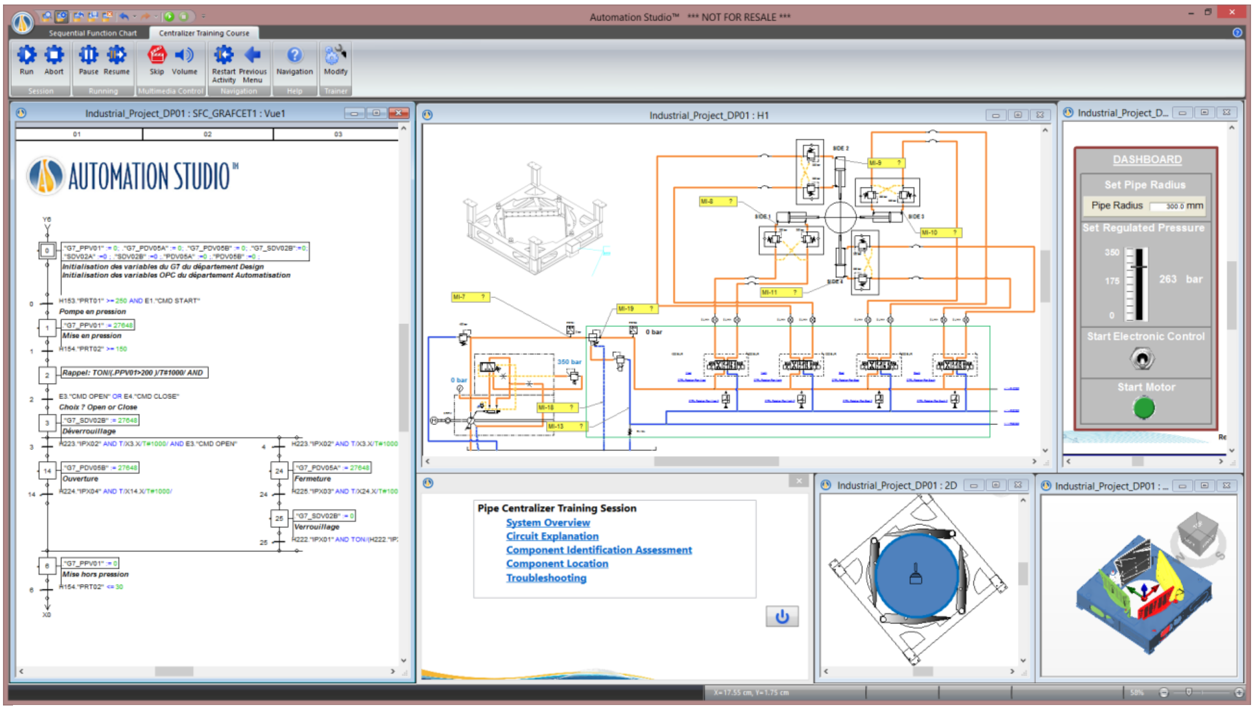

Fig. 6 Co-simulation of a Pipe Centralizing System

algorithms, the Automation Team would recreate a hydraulic system on a second PLC based on the input & output parameters to satisfy according to the Fluid Team. The PLC is therefore not tested with an accurate behavior of the complete machine which in turn greatly impacts the efficiency and robustness of the design.

Fluid Specialists at IMECA modeled their Pipe Centralizing System using a hybrid approach. To do so, they used components from manufacturer's catalog developed by Famic Technology. As shown in Fig. 6, this allowed them to quickly build a complete machine using Automation Studio™.

On the same software platform, control specialists at IMECA were able to create a virtual PLC logic that could be linked to the complete machine. This allowed fluid and control specialists to understand and validate the interaction of the control logic with the modeled fluid systems.

As a second validation process, the implemented program on the hardware PLC was tested with the virtual machine using OPC communication that is supported by Automation StudioTM. This allowed to test the robustness of PLC in real time.

With this new methodology, fluid and control specialists at IMECA gained a better understanding of each other's systems. Both teams can now work together on a common software. Control specialists can also validate their PLC with the complete machine by co-simulating through OPC connection.

4. Conclusions

This article introduced an innovative and combined approach to help design intelligent fluid power by integrating the simulation and analysis work of many specialists. Two different examples were presented to support the proposed working process.

The first example showed how all mechatronic systems can be integrated in a unique software which combines the different working environment of all specialists. On one hand, Fluid Power and Electrical Designers will greatly benefit from standardized components with high fidelity hybrid simulation models. On the other hand, Control Specialists can elaborate complex and modern control algorithms using a pure math environment which can be tested on the complete virtual machine.

The second example showed that sometime, the integration of the expertise is more efficient and valuable by making different development platforms - software and hardware - communicate together and perform what is called a co-simulation.

In both examples, the simulation capability is enhanced and breaks the walls between all engineering expertise. This is an essential step to make in order to follow the electrification and control trends of the Fluid Power industry and keep in line with Industry 4.0 and government instigative such as Horizon 2020.

References

[1] V. Rémillard & al., "Innovative Hybrid Modeling Approach to Enhance Green Design based on Fully Integrated Mechatronic System Simulation", IFPE, 2014

[2] R. Gagné & al., "How to take advantage of a Machine Knowledge Software to enlarge the simulation tool spectrum from the dynamic performances of individual components up to a complete mechatronic systems analysis & monitoring", KSFC Conference, 2014

[3] Rémillard V., Sfeir J. et al. "New Software Generation for Greener Energy Efficient Mechatronic System Design & Analysis", KSFC Conference, 2013.

[4] www.eaton.com/hydraulics

[5] Réjean Labonville, ing. "Conception des circuits Hydrauliques; une approche énergétique", Presses internationales Polytechnique, Montréal, 1999.

[6] Jack L. Johnson, PE. "Designers' Handbook for Electrohydraulic Servo and Proportional Systems, 4th Edition", IDAS Engineering inc., 2008.