Communication between CAN Bus Control Devices and Virtual Machines

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Abstract: The fluid power industry has seen significant changes in the last decade, following the electrification of hydraulic technologies. By adding intelligence to hydraulic and pneumatic manufacturers' components, designing and testing new fluid power applications require the additional expertise of control specialists. Since fluid power and control specialists use different CAE tools to create and virtually test their respective design, there is a need to create an integrated test environment to better communicate, understand and specify requirements of electro-hydraulic systems.
In this paper, we will demonstrate how virtual components up to a complete machine developed on simulation software can be controlled by physical control devices (joystick, controllers…) using CAN bus communication. Examples of this will be illustrated for virtual systems built according to manufacturers' specifications in Automation Studio™ and communicating with the physical controllers: a hydraulic simulation model (ex.: Eaton CMA valves) communicating with a programmable controller and multiple devices as well as Eaton HFX Controller, Danfoss PLUS+1® microcontroller or HydraForce CoreTek controller.

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1. Introduction

CAE tools and testing tools continuously evolve to meet the needs of OEMs and system integrators in terms of development time, system accuracy and energy efficiency.

Therefore, the industries want simulation tools that allow macroscopic machine simulation without neglecting the realism of simulation models. These tools will improve the understanding of a machine's key functions and help people focus on the important simulation details. The models created must also be adjustable by integrating test or performance data and the know-how. The capability to communicate with controller via CAN bus will help to reduce the gap between different experts involved in the design process, which makes the testing and verification of an electrohydraulic system more efficient.

This paper demonstrates a concept that will reduce significantly this gap and the development time cycle when designing and testing hydraulic circuits by using a fully integrated multi-technology platform and/or co-simulation. The Section 2 explains the hydraulic simulation model and logic of the Eaton CMA Valve developed in Automation Studio™ software. The Section 3 demonstrates how the CAN bus communication is

achieved and set with Automation Studio™ software [Ref. 3]. Section 4 presents two examples of electrohydraulic model with a CAN bus configuration that demonstrate the results of the development of this approach.   We conclude with some final remarks on how this will help the work process between Hydraulics and Control specialists.

2. Electrohydraulic Model and CAN Bus

As mentioned before, the electrification and the control of hydraulic technology have the potential to maximize the flexibility of system for many mobile hydraulic applications. The objective is to be able to modify the valve's operating parameters to adjust the performance depending on an operator's desired operation mode or the machine's operating conditions. Despite the fact that we can reproduce controller model logic in a multi-technology simulation tool, the addition of the CAN bus communication linked to the machine controller will allow verifying directly a specific control scenario with simulation model, said the virtual machine. It is also possible to link control devices and displays to generate input signals. The Fig. 1 illustrates how the different parts of the simulation environment are integrated together and how they contribute to generate this design and validation tool concept (Virtual machine and CAN bus devices).   The figure shows that CAN bus communicates signals from joystick, pedals, screens display with buttons to the simulation software. The mechatronic components or the controllers receive output signals from the multi-technology software which are calculated to generate the response back to the software. The simulation model can integrate hydraulic, pneumatic and electrical component models and mechanism model. Control algorithms can be programed in the software with mathematical block diagram module

in order to validate a specific logic of the controller. Analysis tools such as measuring instruments recorder and plotter allow tracing results of the solution scenarios for validation.
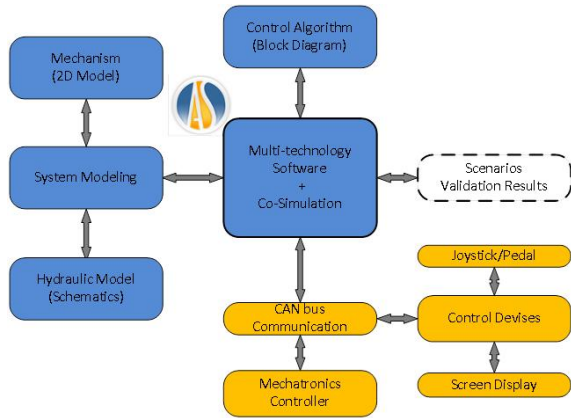

Fig. 1: Virtual Machine - CAN Bus Communication

2.1. CMA Valve Virtual Simulation Environment

In this section, we explain the CMA hydraulic valve model – an innovative Eaton sectional valve that integrates the two stage twin spools independent metering valve concept and the flexibility of control algorithms [Ref. 1],. The valve is equipped with internal sensors and on board electronics that collect data to monitor its states and compute, based on the selected control algorithm and operating conditions, the command signal to obtain the desired system performance.

The hydraulic schematic (Fig. 2) was faithfully reproduced in Automation Studio™ to ensure a proper understanding of the model's components. A simulation model of two work sections has been established by including dynamic parameters influencing the valve movement and responsiveness. As for the spools' hydraulic parameters, a flow gain curve based model has been used and a combination of theoretical relationships and look up tables were used to evaluate the spool flow at each LVDT position. Mechanical and hydraulic parameters can be easily adjusted, according to different configurations, by integrating a maximum of empirical data. This allows hybrid simulation, to have a better matching with reality, using both theoretical models and data that were collected from field experience or from other sources of test. The fix displacement pump inlet option has been used to reduce the model dependency from the pump characteristics. Pressure sensors, located at each work port and in the inlet section, and main stages' LVDT measures provide the actual system state to the control loop.
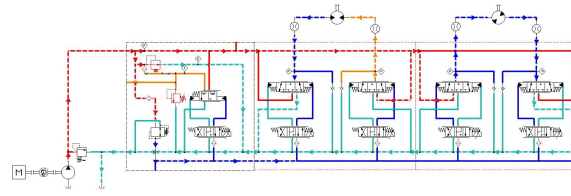

Fig. 2: Eaton CMA Hydraulic Circuit

To simulate and understand the technology of this hydraulic valve, hydraulic knowledge alone is not enough: control engineering aspects must be taken into account. Thus, the control algorithm was implemented using a block diagram environment.
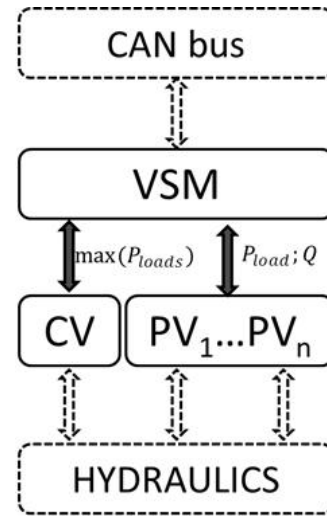

Fig. 3: Valves Control Algorithm Structure

The valve control algorithm is having two levels: the lower one is made of the inlet (CV) and valve sections (PV) controllers that receive their references by the valve system module (VSM). The latter, in addition of its supervisory function, also provides a getaway interface between the valve and the user CAN bus.

The valve section PV controller operates many control strategies depending on the configuration the user selected. In this study, the Intelligent Flow Controller (IFC) has been selected. This twin spool control logic automatically adjusts to the load conditions during machine operation: indeed, it constantly monitors the work ports pressures and, knowing the desired movement direction, detects if the load is resistive or overrunning. The IFC algorithm performs a flow control on one port based on the flow demand received by the VSM and a pressure control on the other based on the user defined desired minimum pressure at actuator ports. When the load is resistive, the flow is controlled upstream while the back pressure is kept to the desired minimum pressure. When the load is overrunning, the control becomes a downstream flow control, to prevent speed increase at the actuator, and an upstream pressure control, to avoid cavitation.

The inlet section CV controller regulates the connection between the inlet and the load signal to recreate a load sense pressure signal. This is the maximum pressure between working ports pressures increased by the section optional margin.

The VSM collects user demands and compute the equivalent flow demand reference for each section controller as well as collecting the working pressures to define the desired load sense signal for the inlet controller. This supervisory element also manages the anti-saturation logic. The maximum flow provided by the pump is communicated to the VSM which compares it with the total user flow demand and thus determines if the saturation condition is reached and applies the desired anti-saturation method. When configuring the valve, the user can define which flow share method to adopt between: none, ratio, cascade and uniform. The ratio method reduces the flow at each section by the same percentage resulting in a performance similar to a traditional post-compensated valve. The uniform method reduces the flow at each section by the same numerical amount (l/min). The cascade method reduces sections flows based on section priority.

Fig. 4 shows black boxes of the control blocks for the CV, the IFC and the VSM programmed in Automation Studio™ software with the virtual control devices.
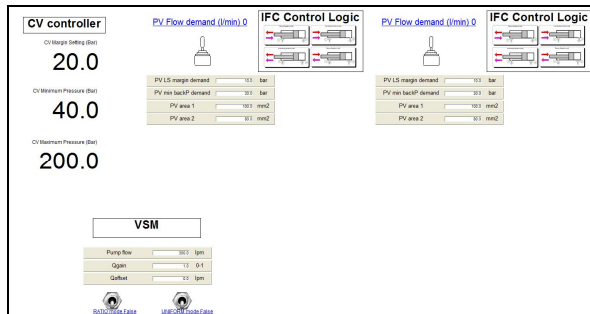

Fig. 4: Black box with embedded control blocks in Automation Studio™

3. CAN bus communication and Controller

As introduced before, this approach allows the multi-technology simulation tool to communicate with controllers and control devices. This section describes the CAN bus technology and the components used for the case studies.

3.1 CAN bus communication

The Automation Studio™ software is able to communicate with a large number of devices via the CAN bus: controllers, valves, programmable displays, joysticks, buttons, sensors, etc. By definition, the Controller Area Network (CAN bus) is a vehicle bus standard designed to allow microcontrollers and devices

to communicate with each other in applications without a host computer. It is a message-based protocol, designed originally for multiplex electrical wiring within automobiles [Ref. 2].

The CAN bus data link layer is defined by the standard ISO 11898 and the application layer by the SAE J1939, CANopen (IEC 62026-3), ISOBUS (ISO 11783), NMEA 2000 (IEC 61162-3), ARINC 825 etc. SAE J1939 is used in heavy-duty vehicles such as trucks and buses, mobile hydraulics, etc. We can also extend the use in many other contexts as well as the construction machinery application and Manufacturers' test cells. Automation Studio™ software exchanges data with devices by using the standard SAE J1939.

In the J1939, each packet has an Identifier and Data. The standard defines the identifiers called Parameter Group Number (PGN). The standard also defines Suspect Parameter Numbers (SPN) to each parameter of a parameter group for identify data.

3.2 Controller and Control Devise

In this case study, five devices have been connected: Automation Studio™, HFX Controller EATON, VFX Display EATON and two Joysticks (Fig. 5). The software is considered here as a device.
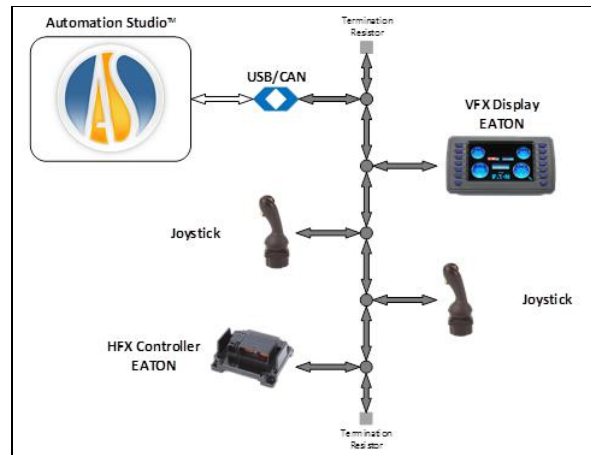

Fig. 5: CAN bus communication with Eaton components

In Automation Studio™, the data from joystick are received by a component Joystick CAN. Each joystick CAN can be associated with the dedicated PNG. Each joystick gives the values in X and Y axis, as well as the state of the buttons. Specific blocs have been created in Automation Studio™ to communicate with the controller and the display: Customizable CAN Transmitter and Customizable CAN Receiver. These items are customizable to give the user the possibility to modify the Identifier number and Data format and to communicate with nonstandard devices (Fig 6).
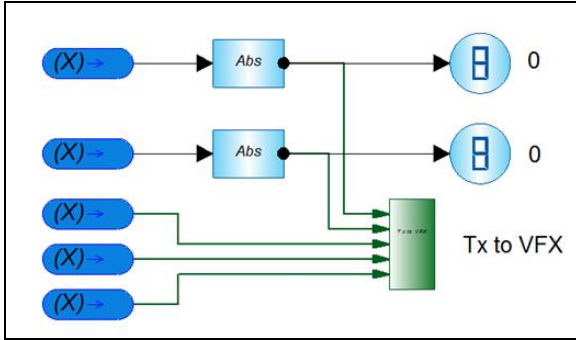
Fig. 6: CAN bus component in Automation Studio™

4 Example and results

4.1 Example 1: Controller interaction with Simulation

The first application example of the CAN bus communication is the connection between a physical controller and the simulation software to achieve a position control. For this, we used the software to simulate a simple hydraulic circuit that contains the virtual cylinder, the controller to implement the PID control and a physical joystick to define the reference. They all communicate via CAN bus.
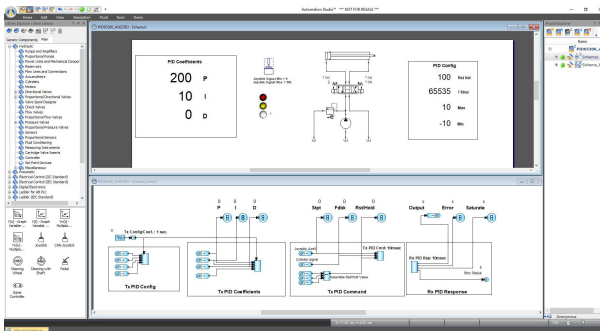

Fig. 7: Hydraulic circuit and variable definition for CAN bus communication in Automation Studio™

When the co-simulation is in progress, the reference signal is generated by the CAN joystick, sent to Automation Studio™ where is packaged using the dedicated transmission blocks and then transferred to the controller. Depending on the controller options, different parameters can be transmitted. The most important are: the reference, the PID gains and the cylinder position feedback signal. These values are sent to the controller which returns the command signal, as well as the error, the saturation and its state, to affect the valve position and thus the cylinder position in the virtual simulation.

This experience has been successfully completed with both an EATON HFX controller and a Danfoss Plus+1 controller.

4.2 Example 2: CMA Simulation

In this application case, the virtual system consists of both hydraulics and control logic. The CAN bus communication is, instead, used to enhance the user experience, who now can interact with the simulation not just via the traditional computer devices (mouse and keyboard) but using real life joysticks and display to monitor the system. Refer to Fig. 2, Fig. 4 and Fig. 5 for this example.

The block diagrams that implement the control algorithm, receive the operator flow demand for each work section from CAN bus connected joysticks; these are the controller set points. The signal is managed by the VSM and redistributed to each individual section PV controller while the load sense pressure signal is transferred to the CV controller. The control loop is then closed by the hydraulic simulation which returns the inlet pressure, main spools LVDT positions and load pressures. At the same time, information on actual system performance, like actuators speeds and system pressures, are sent to a configured CAN bus display that can be read by the operator.

4. Conclusion

This article shows how is now possible to integrate physical hardware with simulation software to perform co-simulation, hardware calibration or to enhance the user experience making it more and more a training environment. The communication between virtual systems and physical devices is now using the CAN bus standard communication protocol, which is compatible with many manufacturers' components. That provides the following benefits: ease of implementation (2 wires, simple parameterization…), diversity of devices, adapted communication speed, reliability.

It allows Hydraulic Specialists to test several numerical parameters in order to perform better parameter adjustments for machine controllers. That enables also Control Specialists to have a better visualization and understanding of the system's operation.

Finally, this approach becomes a possible new design and testing methodology for different specialists from the Hydraulic Engineer to the Automation Control Engineer to make them more work together; therefore, reducing the actual gap of communication between teams.

References

1) Eaton CMA user manual (V1.2) December 13, 2016
2) Source Wikipedia: https://en.wikipedia.org/wiki/CAN_bus
3) Automation Studio™, Famic Technologies Inc., www.automationstudio.com