Consistent Automation Solutions for Electrohydraulic Drives in Times of Industry 4.0

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Abstract
Electrohydraulic drives are primarily used whenever a low power/weight ratio, a compact build and/or large forces are required for individual applications. These drives are often used together with electric drive technology in machines. However, in terms of automation, unlike electric drives, electrohydraulic drives are still largely connected via analog interfaces and centralized closed control loops today. To compensate for this competitive disadvantage of hydraulic drive technology and, at the same time, significantly enhance its performance and diagnostics capability, a consistent automation solution has been developed that can be configured for both centralized and decentralized solutions. This contribution firstly gives an overview over this complete solution already available and its classification in the automation world. In a second step, the subset of decentralized drive solutions contained therein is presented in more detail and their benefits are explained on the basis of some exemplary applications.

KEYWORDS: Electrohydraulic drives, valves, pumps, Ethernet based bus systems, decentralized axis control, Industry 4.0

1. Initial situation and target
Figure 1 shows both the current situation and a target situation, characterized by the following starting points:

- Actual status of valves/pumps: Today, the majority of valves and control pumps are controlled via analog interfaces (+/-10 Volt, 4...20 mA). For the automation level, suitable interfaces have to be made available.
- Actual status of axis control loops: The control loops are mainly realized centrally in the higher-level control here, control algorithms tailored specifically to hydraulic requirements and an adequate computing capacity have to be available.
Actual status of real-time-capable bus systems: In the field of automation technology, Ethernet-based bus systems are on the rise. The prevalence of various control manufacturers on individual markets and/or regions, results, unfortunately, in a very heterogeneous situation regarding the bus systems to be supported (at present, the solution presented here supports 6 systems) /1/.

Figure 1: Current and future connectivity of electrohydraulic and hybrid drive technology to automation technology

To achieve the full integration of "classic electrohydraulic drives" on the one hand and also take account of "new hybrid systems" such as the "servo-pump" and the "self-contained axis" on the other, the target situation as shown on the left below has been defined, which is realized today by the newly developed, consistent automation system:

- Valves and control pumps can be controlled directly via the bus system.
- With regard to valves, a distinction must be made between an IFB function (Integrated Field Bus) and an IAC (Integrated Axis Control) function:
  - IFB: Analog interfaces are substituted by an Ethernet-based bus system. The integrated bus functionality allows additional data to be exchanged with the higher-level control for configuring the valve or for transmitting internal state variables. The open and closed-loop control task for the drive remains within the higher-level control (central control structure).
IAC: In addition, the axis control loops (position, velocity, pressure and/or force control) are realized in a decentralized arrangement. The higher-level control provides command values and status signals in real time.

- The "servo-pump" system (Sytronix) utilizes the automation connections of electric drive technology.
- The same is valid for the hybrid drive, which consists of an electric servo-drive with hydrostatic transmission ("self-contained axis"). The axis control functionality of the hydraulic subsystems, which is required additionally, is implemented as part of the converter firmware /3/.

2. Demands made on the target system
The requirements can be subdivided into the following three areas:

2.1. Functional requirements (obligatory requirements)
- Implementation of all relevant Ethernet-based bus systems customers can use virtually all automation systems relevant on the market (open interfaces).
- Implemented axis controller algorithms are tailored to suit the special requirements of electrohydraulic drives /3/.
- Integrated safety concept also in the field of valve and pump connections, which receive the bus communication on the one hand and implement the required safety standard on the other (examples of this are press safety or the demands made on the closing axis of plastics machines).
- The bus communication is not only used for transmitting command and feedback values, but also for additional information from components and drives in terms of data, a "Condition Monitor (CM) Ready" situation is realized in the control.
- Tools such as the software oscilloscope functions are essential for commissioning.

2.2. Desirable requirements ("usability") and approaches
- One consistent programming and commissioning tool for all drive forms (electric and hydraulic drives),
- Identical bus connections for all drive forms (state machines),
- Identical parameter designations and scaling of machine data for all drive forms,
- Commissioning (in particular of hybrid drives) is simplified by software-supported tools like "wizards" and automatic optimization algorithms.
Due to the PC-supported programming and parameterization tool IndraWorks (IW), which can be used equally for electric and hydraulic drives, these requirements can consistently be met. Consequently, electric and hydraulic drive technology are treated identically. Due to dialogs in IW tailored specifically to the individual devices, special characteristics of drives are taken into account and commissioning is simplified.

Figure 2: Overview of functions of the IndraWorks tools, which can be used consistently for all drive forms

3. Commercial requirements
- A portfolio of components and drives is required, which is widely scalable with regard to performance and functionality, since customers only pay for what is actually required for the application at hand.
- The extra cost resulting from the digitization of valve and pump electronics has to be justified in the concrete application through added value offered by direct bus integration, reduced commissioning expenditure, lower cabling effort and/or important additional functionalities such as decentralized control and CM functionalities.

4. More detailed description of decentralized drive systems (IAC)
For lack of space only the drive systems in the IAC characteristic (Figure 1) are described exemplarily in the following /4/.

The components available for this can be classified into the following sub-systems:

- In the field of valves, direct and pilot operated proportional and high-response valves of the 4WRPE family are available today in sizes 6, 10, 16, 22, 25, 27, 32.
Figure 3: Valve family with IAC technology (sizes 6, 10, 16 - 32)

- In the field of pumps, control pumps with DFE functionality /2/ of series A10 and A4 in sizes 28, 45, 71, 100, 140, 180, 250 and 355 are available today.

Figure 4: DFE control pump system with IAC functionality

- Digital integrated electronics (OBE=On-Board Electronics) for these valves and pumps are available in the variants IFB and IAC. The functionality of the OBE is described in more detail in the section below.

4.1. Description of the digital OBE

4.1.1. Hardware

The robust IP65 electronics is available in the IFB and IAC characteristics. Both are equipped with interfaces for up to 4 pressure sensors (4 - 20 mA). In the IAC variant, interfaces for position measuring systems (SSI) and incremental interfaces (1 Vpp) are available additionally. For communications, a Multi-Ethernet interface is integrated, which allows one of the following bus systems to be implemented:

- Sercos, EtherCAT, POWERLINK, VARAN, PROFINET, EtherNet/IP.
In other words, every component "speaks six languages". Hardware variances due to different bus systems can thus be avoided. The bus system to be activated is determined by means of software using a corresponding parameter.

Figure 5: Interfaces of the digital OBE

The functionalities of "Safe Halt", "Safe Direction" and "Central Position Monitoring" are realized independently of the bus system via two certified digital inputs and two associated digital output signals. With regard to the valves, they provide a safe shutdown of the output stages for the solenoid(s). This approach allows a safety functionality to be realized without having to design the entire bus system, master included, as safe system.

4.1.2. Software functionality of the OBE

In the following, some functionalities are described in more detail for the field of valve-controlled drives; for control pumps, comparable functionalities are available - where useful in the technical application:

- **Bus communication**: At present, 6 Ethernet-based bus systems can be realized. The selection of the bus system to be used is made by means of a parameter.
- **Valve controller**: The dynamic behavior of the valve can only be modified by the manufacturer. The valve characteristic (curve) can, however be entered by the customer.
- **Closed-loop flow control**: By means of up to 4 integrated pressure sensors in sandwich plate technology, an electronic "pressure compensator function" (load-independent flow) can be implemented. This may be useful in particular for
applications, in which the use of a position measuring system is out of the question for reasons of expenditure or for technical reasons (e.g. core pull function in the field of plastics machinery).

- **Closed-loop pressure control**: Apart from pure pressure control functions (pressure and differential pressure), alternating controls and force limitation modes can be activated.

- **Position controller**: All of the algorithms required for hydraulic drive technology were implemented in this controller. This includes also processes for state feedback and continuous path control /1/.

![Figure 6: Axis controller structure of the IAC (overview)](image)

**Diagnostics and commissioning aids**: Apart from analysis tools such as a software oscilloscope and error log, wizards for the pre-calculation of control parameters as well as automatic optimization tools for axis controllers in the continuous path control mode are provided. In future SW versions, functionalities for **Condition Monitoring** will be offered.

- **Monitoring functions**: In addition to monitoring of the valve functionality, the IAC also offers axis monitoring functions (max. velocities, forces, dynamic following errors, etc.).

- **Integrated PLC**: This option will be offered from mid 2016 on and will allow programming of specific functionalities by the customer such as adjustment of the controllers to individual applications, special motion profiles or also application-specific reactions to errors. Here, the customer can flexibly integrate its know-how and protect it accordingly.
5. Application examples for decentralized IAC technology

This drive structure suggests itself particularly for applications, in which:

- the various axes of the machine can be operated independently of one another, or
- the dependencies of axes only have to be taken into account for the generation of command values (such as, for example, with interpolating axes).

A further criterion for the use of IAC can be a large number of axes to be controlled: As a result of the decentralized control approach, the central control is relieved and, in addition, cabling efforts can be drastically reduced.

**Application 1: Automation of axes in a sawmill**

Examples of axes are shown in Figure 7. A large number of self-contained axes and large physical distances are decisive for the selection of a decentralized drive structure. EtherNet/IP is used as bus system, an AB system as higher-level control.

![Figure 7: Some axis of the “Sawmill application”](image)

The system, which has been employed in three-shift operation for more than one year under these very harsh operating conditions, documents the robustness and reliability of the selected solution.

**Application 2: Axes in the field of rotary indexing machines**

For this application (Figure 8) the demands made on the drive axes and the entire automation solution are extremely exacting:

- Up to 48 interpolating electrohydraulic axes plus electric servo-drives,
- The accuracy requirements with regard to continuous path and positioning accuracies are in the order of a few μm,
The CNC technology utilized for the axes has to realize up to 28 NC channels. Here, the IAC technology is operated in conjunction with an MTX control. The bus system used is Sercos.

Figure 8: Application of rotary indexing machines

Thanks to this technology it was possible to increase the productivity of the machine by 20 % compared with the previous solution. At the same time, system costs were reduced by lower cabling and commissioning costs as well as optimized CNC technology. The machines work trouble-free in three-shift operation.

6. Conclusion

The efficiency of electrohydraulic drive technology and not least their full and "easy" integratability into automation solutions are, apart from the drive cost, essential competitive criteria that speak in favor of this drive technology. The concept presented here is characterized by its consistency in terms of automation. The key aspects are

- The integration of open bus interfaces into the hydraulic components,
- The integration of the "hydraulic know-how" into the drive firmware,
- The identical behavior as that of electric servo-drives when it comes to automation,
- One consistent commissioning and diagnostic tool for all drive types, i.e. valve-controlled, pump-controlled and hybrid systems consisting of electric servo-drive with downstream hydrostatic transmission.
Whether central or decentralized axis controls may be the better concept depends on the application at hand. Such concepts make hydraulic drive technology "Industry 4.0"-capable and maintain its competitiveness as physically compact and robust drive technology that generates high speeds and large forces.

7. References

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