FIELD CONTROL SYSTEMS – THE NEXT STEP?

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Abstract: This paper deals with the field control systems (FCS), which represent state-of-the-art distributed process control systems. The main objective is to present the FCS philosophy, the present state of several major engineering activities and to show possible enhancements improving engineering process which should be developed. While the theme covered by this paper is extensive, the aim was to give an overview and provide references for further study. Evolution of process instrumentation generations which is necessary for understanding following chapters is described in the introduction. The terms like fieldbus, intelligent field device and function blocks for process control are also described. The second chapter contains description of FCS with a simple example of flow control. In the third part the present way of engineering this type of control systems is shown (e. g. configuring control loop, localization of function blocks within field devices, setting control functions schedule). The last part deals with the possible enhancements to the theory of field control systems which could help design such systems.

Keywords: field control systems, fieldbus, intelligent field device.

1. INTRODUCTION

Analysis of process instrumentation evolution is in general based on defining several basic generation of process instrumentation characterized by the changes in solving tasks of processing information, transmitting data and supervisory control. Evolution of digital process automation systems (PAS) structures is shown in the Fig. 1.





Three basic generation change can be distinguished:

- **DDC**: Direct Digital Control
- DCS: Distributed Control System
- **FCS**: Field Control System

The last evolution step of PAS which can be characterized as total functional and spatial distribution of functions for processing information is often designated as Field Control Systems (FCS). They are based on intelligent field devices and industrial digital communication systems used on field level (fieldbus).

While this generation of PAS is relatively new within automation community, right terminology is very important. Here are several most often used terms within FCS:

<u>"Smart" field device</u> is device, which internally works digitally (performs function of processing information) but the transmission of process value to / from superior control system is done in analog way.

<u>Communication</u> can be defined as a process of bidirectional exchange of information between two or more devices of control system. While the analog communication is based on the transmission of amplitude modulated (AM) signals, digital communication is characterized by the transmission of pulse code modulated (digital) data [1].

<u>Fieldbus System</u> (fieldbus) provides a serial digital communication among field devices with one another (horizontal communication) and among field devices and superior control systems (vertical communication) over single pair of wires.

<u>System device</u> is device with serial digital communication capability with the rest of devices within the control system structure.

<u>Intelligent field device</u> represent the combination of smart and system device properties i.e. it is device performing the functions of processing information used in automatic control with ability to communicate (all digital serial communication) with other devices.

2. FIELD CONTROL SYSTEMS

Principle of FCS will be demonstrated on the example of simple (SISO) flow control loop. The Process and Instrumentation Diagram (P&ID) is shown in fig. 2.b. Functions defined in P&ID are in fig. 2b transformed according to function block concept defined in IEC 61804 into function block configuration e. g. function blocks (FB) with information connections. For basic flow control following FB are needed: analog input (AI), PID algorithm and analog output (AO). While FCS represent return to "single loop integrity" where control functions are performed at the field level separately for every loop, possible localization of FB into intelligent field devices is presented in fig. 2c. It's obvious that AI and AO blocks must be performed in flow transducer and actuator. Localization of PID depends on control system designer. Considering effectivity and reliability of control systems, most efficient way is to locate PID into actuator. Interconnections of blocks located in the same device are provided by internal links. Fieldbus system's services are used to connect blocks performed in different devices.

Till now the only Fieldbus system providing communication services indispensable for FCS is Foundation Fieldbus (FF). MAC (Medium Access Control) of FF is based on Abitrator-Producer-Consumer method. The "Arbitrator" function is designated as Link Active Scheduler and can be performed by field device or host system. Example of time schedule of Fieldbus segment so called segment macrocycle is in fig. 2d. Grey arrows represent execution of function block while white arrows mean transmission of data between blocks. Every FB performed in field device and every variable transferred over fieldbus are designated by TAG-s (e. g. AI block is labeled as FT101_AI and output variable of this block is then FT101_AI.OUT). Time in which cyclic communication is not occupying fieldbus is intended for acyclic communication e. g. transmission of alarm messages, configuration and parameterization, diagnosis of field devices and control of fieldbus system.



Fig. 2. Field control systems principle (LAS – Link Active Scheduler)

Example of fieldbus structure of FCS is depicted in fig. 3. Whole flow control strategy is performed by flow transmitter and control valve with positioner.



Fig. 3. Field control systems bus structure

Concept of FCS facilitates to fulfill user requirements like increasing availability and reliability of control system, decreasing of installation costs, increasing flexibility of control system and decreasing engineering, operational and maintenance costs. Further information on FCS can be find in (Berge, 2002). Some notes on engineering are discussed in following chapter.

3. ENGINEERING

Implementation of FCS brings cardinal changes in all engineering activities within the life cycle of the control system and changes processes at all levels of the control system of the factory. Engineering of such systems must be done in way "from up o down" i.e. all intended function must be clear before the engineering phase begins. Design of fieldbus system depends on chosen control strategy (e. g. whether the control-in-the-field will be used or not). Then it is possible to choose number of fieldbus segment and amount of field devices on each segment. Theoretically, application software of control system can be designed independently of the chosen strategy. Control engineer decides where to perform function blocks from function block configuration.

Design of application software consists of:

- Transformation of P&ID to function block configuration
- Localization of function blocks to field devices (or host system)
- Optimization of function blocks execution and data transmission (LAS macrocycle)
- Parameterization of function blocks

While in this area of process automation there is a lag of theory of automatic control, most of engineering tasks are performed according to so called "best practice" and "rule of thumbs" without detailed theoretical analyses. Motivation for analyses is based on increasing user demands for increasing availability, reliability and flexibility of control system and

decreasing engineering, operational and maintenance costs. Some challenges are mentioned in the next chapter.

4. THE NEXT STEP

FCS utilizes properties of intelligent field devices and fieldbus systems. Character of fieldbus system services has a significant influence on quality and stability of control process. To analyze this influence and if needed also eliminate its impact, closer look on functions of communication system is inevitable. In the fig. 4 is depicted a decomposition of generic fieldbus system. It can be decomposed according to seven layers reference model of communication in open systems defined in ISO/IEC 7498 (so called ISO/OSI model). The rest is application specific part i. e. application profile which defines format and meaning of communicated data and functions related to process control.



Fig. 4. Decomposition of fieldbus system

There are several scenarios how to analyze the problem:

1. Analyze the influence of communication system on control process while the process control functions remain unchanged

2. Analyze the needed change of process control functions when functions of fieldbus system are taken as unchanging to achieve defined behaving of controlled process

3. Change the control of fieldbus system to achieve defined behaving of controlled process

Control the fieldbus according to controlled technological process is in the present not very discussed issue. The fact, that fieldbus systems work in deterministic regime (the maximal time in which the device is permitted to transmit its data or in which the information from the device reaches the superior system respectively), doesn't stimulate discussions about the change in their control. In present only the question of reliability of alone FBS is solving i.e. the interest is focused only on process of transmitting data. Possible workflow of this scenario is presented in fig. 5.



Fig. 5. Workflow template for enhancement of FCS

Results of control of fieldbus system could be:

- Maximizing the number of connected field devices or maximizing the amount of data acyclically communicated (e. g. for Asset Management System)

- Increase of control system availability and performance

4. CONCLUSION

Field Control Systems represent so far the last evolution step of process automation systems. Intelligent field devices and digital communication systems, which are the basis for FCS, are in the present in the center of interest of the world of automation. Though FCS exists about ten years there is still lag of usage theory of automatic control within the engineering phase. This paper brought the basic introduction into FCS and proposed the way of their further evolution.

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