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JÓZSEF HATVANY DOCTORAL SCHOOL FOR
INFORMATION SCIENCE, ENGINEERING AND TECHNOLOGY

Efficiency Questions of the Field Control System Based on Foundation Fieldbus Communication

Summary of
PhD Thesis by

KÁROLY JÓNAP MSC
dr. Univ., Mechanical Engineers

SCIENTIFIC ADVISOR: PROF. TIVADAR SZARKA CSC

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1. Introduction

Control engineering systems have undergone great changes in the past decade due to the development of microelectronic elements, software "tools" and information technology networks. In the period between the appearance of the first Direct Digital Control (DDC) system and the use of Field Control Systems numerous new theoretical and practical solutions were born and since this progress continues to go on incessantly, new solutions have also continued to emerge. In addition to research in control engineering theory, there are conspicuously great changes taking place in the field of technology as well. Microprocessor technology, structured software engineering and high-performance networks constitute the three backbones of technology research. Microprocessors, which constitute the central units of computers, are able to operate in an ever wider ambient temperature range, i.e. technology installed in the field (outdoors) can support instruments that perform measurement, control, and intervention functions and operate practically with ever increasing performance and actually operating as computers themselves. Object oriented programming has facilitated the use of configurable software, which has brought flexibly programmable systems close to reality. The industrial use of computer networks has been a milestone in the process of development, for the distribution of resources both in terms of hardware and in terms of software has become viable, which is a fundamental requirement in the case of industrial technologies requiring reliability and considerable availability in order to ensure redundancy.

The complex systems appearing in an almost uniform configuration – that is containing operating hardware, configurable programs and modules performing long-term data storage and data analysis – were started to be marketed by the various manufacturers under the name industrial process control system. Distributed Control Systems (DCS) brought about a major change in the practical implementation of measurement engineering and control engineering, for the use of these systems has made it possible to perform control tasks outside the traditional instrument room, which made a difference from the previous practice. (The most important achievements in this field have been shown by the companies ABB, Emerson Process Management, Honeywell, and Yokogawa.)

The replacement of centralised, and therefore easily "vulnerable", systems in terms of operational safety by decentralised ones was the first significant step towards the implementation of intelligent field control systems. The Field Control System, FCS, appearing in the literature means in reality a Networked Control System (NCS), i.e. the distribution of resources elaborated in theory and well established in computer networks has become the practice also in industrial control technology engineering. In the development of network communication constituting the "drive" of this system several research units of universities,

research institutes and manufacturing companies have been involved recently. The field application of the industrial communication systems emerging at the end of the previous century was preceded by a stormy standardisation process, which is very vividly described in the paper *Surviving the Fieldbus Wars by D. Marhs (1999)*. The series of publications published by the research units *(J. A. Rehg et al: Fieldbus in the Process Control Laboratory – Its Time Has Come 1999)*, and the deservedly well-known ARC publications *(L. O' Brien, D. Caro: Fieldbus Success Stories and Strategies – 2001)* have given a great impetus to the proliferation of the technology and to speeding up the standardisation process.

Due to the ever-wider spread of DCS and the new process control technologies following it, it has become increasingly awkward to choose the right system for a given task. It has become necessary to formulate the qualification requirements exactly and to explore the integral nature of the systems at scientific level. The method most often used for formulating the requirements set for process control systems and through that for describing them is the hardware-side approach, which is followed by a description of the program *(T. Wallace, M. Peluso: Distributed Intelligence 2002)*. *J. P. Thomesse in a paper Open Issues in Fieldbus Based Systems (2002)* making an attempt at the software-side approach, i.e. creating the 'dream device' for solving the problem. The qualification procedure greatly exaggerating the role of network communication was elaborated by the *Hirschmann* company.

Foundation Fieldbus, as the only industrial communication system to implement a control algorithm among the control engineering networks, has shown an unparalleled arc of development in the past years. The Department of Instrument Development and Information Technology of the Research Institute for Applied Chemistry of the University of Miskolc (Miskolci Egyetem Alkalmazott Kémiai Kutatóintézet Műszerfejlesztési és Informatikai Osztálya) has been involved in industrial communication systems in the past decades, therefore it was an almost compulsory move to begin research into field communication, with particular emphasis on the Foundation Fieldbus system.

2. Scientific objective

The data published and the events in the years following the appearance of the Foundation Fieldbus, and also the controversial interpretations regarding its operation attracted the author's interest to study the characteristics of this new communication system more thoroughly. Following the installation and run-in of the first Hungarian application *(1999, Monitoring System of the Atmospheric Propane-Butane Gas Storage at Algyő)* the author developed definite conceptions so as to investigate industrial control engineering systems, including research into Foundation Fieldbus, with scientific exactitude. Simultaneously with the

proliferation of computer-controlled process control, publication of theoretical works on the operation, and particularly the performance of the programs became also more frequent *(Y. Tipsuwan, M. Y. Chow: Control Methodologies in Networked Control System 2003)*. The computation and estimate processes published are difficult to adapt due to the nature of the operation software. None of the methods applied gives an adequate answer to performance capacity; therefore it was necessary to develop new tests. This finding is particularly true for the Foundation Fieldbus system, for while in the case of other field communication systems – Profibus, CAN – there were publications with scientific exactitude published *(Lee S. Lee KC. Han MC. Yoon JS: On Line Fuzzy Performance Management of Profibus Networks)*, there have been no such publications on the Foundation Fieldbus.

The author set the objective to develop an objective testing method relying on existing research results in order to determine the performance capacity of process control built on Foundation Fieldbus communication, with special regard to issues of performing control tasks that can be implemented in the field. The method developed was to be extended to fields of specialist applications. Formulating the problem was followed by research in the literature, then by tests on the systems and finally by evaluations. Thanks to continuous and constant feedback, newly arising problems required the development of newer methods. The research work made it possible to get acquainted with several systems in operation, as a result it was possible to apply the evaluation not only to a solution linked to one product, but to extend and generalise it.

3. Research methodology

When starting the research work, the original conception was only to investigate timing issues of the Foundation Fieldbus technology linked to control in the field, however, the new problems arising in the course of the research activity led to a decision in favour of system technological investigation, which naturally required a completely different methodology.

Research into a control engineering system cannot be done purely by theoretical methods, for in lack of practical feedback the verifying confirmation is missing, that is the work remains uncontrollable. The Industrial Communication Research and Training Laboratory (Ipari Kommunikációs Kutató Oktató Laboratórium – IKKOL) established by the staff of the Research Institute on site in 1999 created the possibility for the practical examination of Foundation Fieldbus communication systems, thus in addition to the necessary theoretical work a way was provided for an immediate, practical checking of the method developed. The analysis and evaluation of the control engineering application possibilities of Foundation Fieldbus were greatly required by the industry in addition to laboratory

research (the application of this communication technology increased dramatically), as a result it became possible to test the procedure developed on "live" technologies.

In lack of a method suitable for the objective analysis of process control systems, the first step was to devise an intelligent 'instrument' that can be used generally, for any complex system *(PLC network, SCADA, or DCS*). By placing the control task in the focus and rationally grouping the supplementary features it is possible to objectively qualify both a control system of a minimalist configuration and the most complex control system. The greatest advantage of the method is that it takes into consideration all information of fundamental importance and of significance for the client.

The qualification of industrial communication, including the Foundation Fieldbus, and the determination of its performance capacity was performed by the procedure developed by the author. The Foundation Fieldbus function blocks were grouped according to their tasks, and thus the site of the performance of the control tasks was objectively determined. The significance of this becomes clear when the features of the elements to be used in a given system are not interchangeable (poor interoperability factor). The efficiency of the theoretically developed procedures was proved in the laboratory of the Research Institute and in a testing system developed for field communication testing prior to investment in GOK-3 (diesel oil desulphurisation technology at Dunai Refinery).

One crucial point of the quality of control engineering built on communication systems is the time delay pertaining to the performance of the task, which results from the nature of the configuration in the case of networked systems. Although Foundation Fieldbus represents deterministic communication, some tasks are not performed in a scheduled manner, and therefore there may be significant differences in the system in the timing of tasks. The experimental systems, where it was possible to perform these measurements in different combinations of the various devices and elements (sensors and intervention devices), provided assistance in determining the timing differences. In the experimental arrangements created, it was also possible to perform the measurements belonging to the specialist control area and to the performance of the tasks in explosion-hazardous zones.

4. New scientific results

Among the networked control engineering systems, following the appearance of the Foundation Fieldbus communication-based process control systems a long time passed before actual application partly due to deficient knowledge, and partly due to the lack of standardisation. The dissertation, on the

one hand, expounds the new knowledge essential for application, and, on the other, describes the experience gained from the control measurements performed on implemented systems as well as the conclusions. The following is a summary of the research results according to the theses:

Thesis 1

The features characteristics of the qualification of integrated process control systems were systemised: the system can be used for objective qualification, and a generally used descriptive language, UML, can document the performance of the systems.

The methods used for the qualification of process control systems can be used only with difficulty or cannot be used at all in the case of process control based on field communication; therefore it became necessary to elaborate a new system. Describing the development results of the ways leading to field process control gives an exact presentation of the processes and results that provide the foundation for developing the new system structure. An objective method has been elaborated for qualifying process control systems by creating the following groups:

- performing the task,
- efficiency issues of control,
- support required for operation,
- background services connected to control, but not directly bearing on the operation,
- and tasks connected to specialist application fields.

The author presents the qualification parameters, on the basis of which the areas listed can be characterised and can be documented in a standard descriptive language, therefore the method is proposed for use instead of the methods to be found in the literature and currently applied in practice.

Thesis 2

The author elaborated the process control possibilities built on Foundation Fieldbus communication and suitable for use in the field and applied the method developed in practice.

Executing the subroutines serving the purpose of the computer-based performance of process control tasks, that is executing the function blocks, may take place in the central control unit or in the field device, and mixed solutions may also be created. The examinations covered the digital input and output signals, and analogue signals, but mainly the control problems. By examining process control solutions built on field communication and analysing the implementation site of the task, the author determined the tasks to be performed only in the control room,

those to be performed only in the field and those which could be performed in mixed connection. An analysis of the simple and the complex control tasks showed the barriers that had to be taken into account in designing the new systems:

- chaining difficulties in sequence control,
- deficiencies of field solutions in case of complex control tasks,
- advantages of using warning signals.

Thesis 3

The relation between the speed of performing the Foundation Fieldbus communication system tasks and the local control tasks was defined on the basis of modelling data.

The redundant implementation possibilities to be used in the FF system were elaborated and solutions were given for implementing redundancy. As opposed to timing that can be theoretically computed, measurements were used to examine the time requirements of the various control-engineering arrangements. Cycle time investigations were carried out for the different measurement and control tasks.

Starting from simple FF applications (remote transmitter, valves, and other devices) to complicated (splitter control) tasks, various arrangements were examined in order to determine the limits of the performance capacity of operation executed in the field, which can basically be derived from the relation between the control loops performed per segment and the macro-cycle. It was established that in the case of Foundation Fieldbus communication mathematical computations did not produce exact results, the most conspicuous example for which is the effect of the differences arising from changing the sequence of the configuration.

Thesis 4

A proposal is given for the examination of newly developed field control systems (FCS – Field Control System) in the case of their application in intrinsically safe zones.

Since publications in the literature and practical guidelines are non-existent, a method was elaborated for the examination of communication systems in intrinsically safe zones, by using protection methods applied in the traditional process control solutions. The procedure elaborated was checked in 1:1 scale mock-up equipment, and a proposal was made for industrial applications. The limitations that have to be taken into account in the various applications were determined.

The examination procedure to be used in a intrinsically safe zone was elaborated: it is based on the examination of the hardware units (the voltage level and location of the FF supply units, voltage uptake of devices, the lengths of cables to be used, the type of lead closure) and on the communication investigation (the test of instrument describing files, the type of instrument connections, automatic instrument recognition, identification of instruments). The applicability of the hardware and communication examinations was determined and proved by application in practice the implementation of which can be used to check the various solutions (traditional EEx – Entity, limited supply voltage – FISCO, and field protection barrier – Multibarrier).

5. Application of new scientific results

The research results belong to the activities carried out at the Department of Instrument Development and Information Technology of the Research Institute for Applied Chemistry of the University of Miskolc. The research and development results were directly used in the projects included in the publication list under Section 6, the author being the project leader.

It is thanks to the investigations performed in intrinsically zones deserving special attention in the petroleum and chemical industries and belonging to the specialist application fields that it was possible to start designing and implementing the systems that are currently operational and being run-in.

The results of the dissertation are currently utilised in academic work (in courses on Intelligent sensors and Process control in the chemical industry). The qualification method is also continuously used in another highly important area, in the evaluation of tenders submitted to various industrial investments.

The two most important directions for continuing the research involve the elaboration of new, even more efficient examination methods and the extension of the examinations to cover highly specialised technological applications (hazardous technologies, nuclear power industry, etc.) Since in these areas there arises a demand to an ever-increasing extent for the introduction of the new communication technology, the realisation of the tasks is becoming more and more urgent.

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