ADVANCED CONTROL FACILITY FOR THE CERN-UNICOS FRAMEWORK

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Abstract

CERN, during last decade, has extensively applied the CERN/UNICOS framework to large scale cryoplant control system. An increase of interested to advanced control techniques and innovative simulation environment applied to cryogenic processes has also occur. Since new control algorithm development into UNICOS framework requires significant time, a control testing platform which can be externally connected can improve and simplify the procedure of testing advanced controllers implementation. In this context, the present paper describes the development of a control testing tool at CERN, which allows rapid control strategies implementation through the Matlab/Simulink® environment, coupled with the large scale cryogenics UNICOS control system or with the CERN PROCOS simulation environment. The time delays which are inherently introduced by network links and communication protocols are analyzed and experimentally identified. Security and reliability issues are also discussed.

INTRODUCTION

During the last few years, CERN has shown increasing interest on the application of advanced control techniques to cryogenics processes [1]. However, the application of such techniques has been limited to the set of controllers which are available in the local automation standard, the UNICOS (UNified Industrial Control System) framework [2]. The integration of a new control technique to the framework can require months of development, what is undesirable when one wants to test a new control technique without guarantees of future use.

In order to provide a universal control testing platform, easy to use and allowing rapid control implementation for testing purposes, the simulation software Matlab/Simulink® was integrated to the CERN control architecture allowing the control of cryogenic process, which typically have large time constants (order of magnitude of minutes), directly from Simulink models. This facility is referred as Virtual Control Platform (VCP).

As one can expect, the VCP introduces time delays due to the network link between Matlab/Simulink and the real processes, and also due to the finite calculation time required by the control algorithm implemented on Simulink. This paper focuses on the study of such delays, identifying and measuring them in real operation. It also discusses how we can assure that the delays will not degrade control performance into unacceptable levels.

Another important issue put in spot is the platform's security of operation. Without precautions, a network breakdown could freeze the control of the process and possibly cause serious damages to the plant. The strategy adopted by the VCP in order to eliminate this risk is also presented in this paper.

FACILITY DESCRIPTION

In normal operation, a programmable logic controller (PLC) is in charge of several control tasks, as sequential operations, security interlocks, alarm triggering and process variables regulation.

Figure 1 describes how the VCP was set up to communicate with an industrial process. A PLC runs the program which is normally used to control a given process.

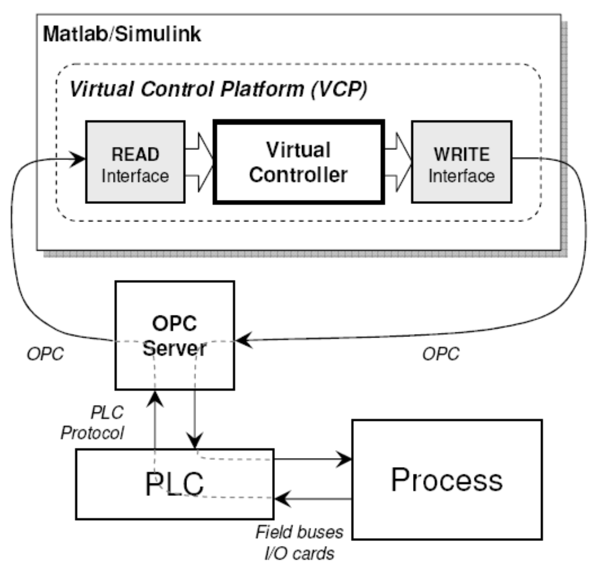

Figure 1: Interface between VCP and process.

A short set of adaptations replaces the original controller's outputs by the outputs of the *Virtual Controller*. The objective is to modify PLC programs as less as possible, only by by-passing the PLC-based UNICOS controllers (commonly PIDs) with the new commands provided by the controller implemented in Simulink. In case of communication or Matlab/Simulink failure, the original controllers are switched on and normal operation is restored. Transitions from VCP to

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PLC control loop algorithm (and vice versa), and tracking mode are not described in this paper. All PLC functionalities are kept unchanged.

The OLE for Process Control (OPC), which stands for Object Linking and Embedding (OLE) for Process Control standard is used as a high-level communication protocol to exchange measurements and commands between the virtual controller and the process.

In order to implement the expected behaviour of a digital control system, a new OPC interface blockset was written for the VCP prototype. The operation sequence is: read controller's input variables with a synchronous OPC transaction; wait for the read values; calculate the control algorithm outputs; write the controller outputs with an asynchronous OPC transaction.

INTEGRATION

UNICOS standard uses typical three-layer control architecture (field, control and supervision layers). In order to integrate VCP to this architecture, a workstation hosting the OPC server and Matlab/Simulink is added to the control layer, as shown in Fig. 2.

COMMUNICATION TIME DELAY

A control-loop which is implemented through the VCP can be theoretically defined as a Networked Control System (NCS), *i.e.* the interface between controllers and processes are done through a network link with associated time delays. NCSs have been studied since 1980's, when first works aimed to determine stability criterions for such systems [3,4]. In recent years, researchers focuses on compensating the network delays with advanced control techniques [5,6].

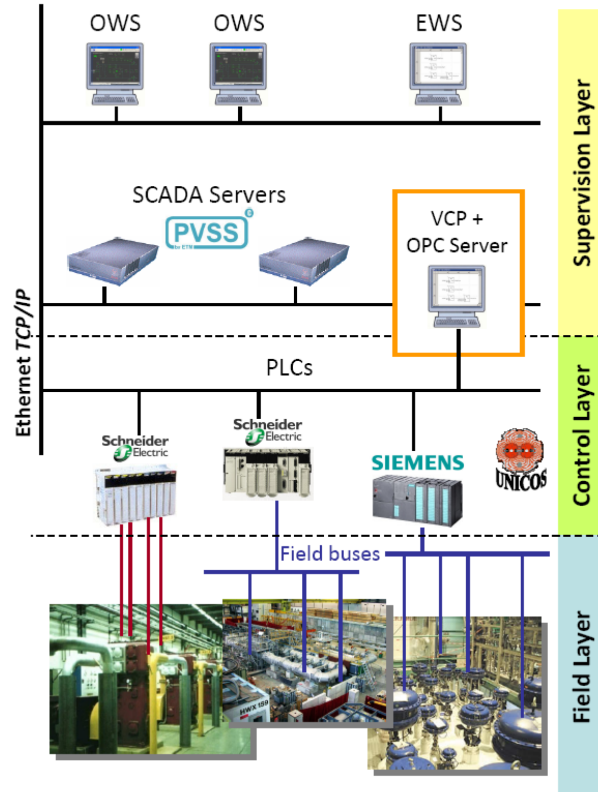

Figure 2: Integration of VCP to the control architecture.

The time between sampling the input variables and writing the corresponding outputs to the PLC is herein referred as *output delay*. Since the read and write time delays can have significant variations due to the network communication, the output delay is modelled as a probabilistic distribution. In addition, equal-distance sampling cannot be guaranteed and thus the *sample time* can slightly fluctuate around the user-specified read period. VCP operation is synthesized as shown in Fig. 3.

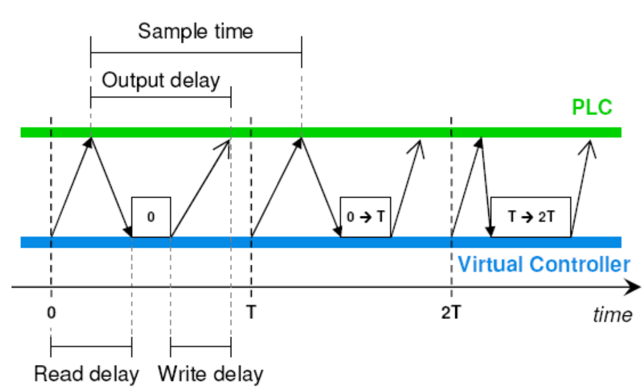

Figure 3: Timeline of VCP operation.

TESTS AND RESULTS

In order to identify experimentally the probabilistic distribution of the output delay and the sample time variation, several tests were run with the VCP prototype inside CERN's control architecture. The scan time of the PLC was set in four different values (50, 100, 150 and 200 ms) and the read period was specified in 0.5 s. The PLC program which was continuously running during the tests was not linked to the real process but in a simulation framework [7] for security reasons.

Basal Output Delay

Since the calculation time required by the control algorithm depends on the complexity of the user-specified virtual controller, it is impossible to determine the VCP's output delay objectively. Thus, we only calculate the basal value of the output delay. It is done by adding the distributions of the read and write delays, which can be obtained experimentally. To find the output delay itself, one has to add an estimate of the algorithm's calculation time to the basal value.

Table 1 shows the mean and the standard deviation of the basal output delay for each hosting approach and each PLC scan time used in the tests. Each distribution is obtained from 8000 measures of the read and write delays.

Table 1: Basal Output Delay Distribution (in seconds)

	Scan time of the PLC			
	50 ms	**100 ms**	**150 ms**	**200 ms**
Mean (s)	0. 167	0. 193	0. 268	0. 320
Deviation (s)	0. 033	0. 047	0. 068	0. 089

We also observe that the scan time of the PLC is a fundamental factor on determining the output delay.

Sample Time Variation

Ideally the sample time variation around the read period should be equal to 0, with standard deviation null. Since Simulink does not operate perfectly in real-time and since OPC read requests can be processed by the OPC server at non-equal-distanced intervals, the sample time of VCP presents some fluctuations. In order to measure these fluctuations, the timestamp information of each OPC read was retrieved for 2000 sample instants of platform's operation. The chosen read period was 0.5 s. Table 2 shows the mean and the standard deviation of the variation of the sample time around the read period.

Table 2: Sample Time Variation (in seconds) When the Read Period is 0.5 s

	Scan time of the PLC			
	50 ms	**100 ms**	**150 ms**	**200 ms**
Mean (s)	0.001	0.017	0.001	0.001
Deviation (s)	0.010	0.040	0.077	0.110

Despite a biased result for the scan time of 100 ms, we note that the sample time variation mean tends to be null (near 1 ms). On the contrary, the standard deviation increases with the scan time of the PLC.

CONCLUSION AND PERSPECTIVES

The main contributions of the work herein presented are (i) an optimized prototype of VCP, which uses OPC communication to interact Matlab/Simulink with large-scale cryogenic processes; (ii) an experimental survey of the time delays which are associated to platform's operation. Further studies will be necessary to define the theoretical criterion to ensure reliability when VCP is applied to real processes. These criterions encompass process time constant and delays, and PLC cycle time.

The Virtual Control Platform is still a concept in development at CERN. The first results show that, under certain conditions, the platform can be safely used to control real cryogenic plants. The experimental campaign focused on the PLC cycle time impact, but it has also emphasized on the correlation between time delay introduced by the VCP use and system time constant, which needs to be the subject of a more detailed approach.

As a testing tool, the VCP can serve as an efficient guide in the development of the UNICOS framework, allowing control engineers to seek promising advanced control techniques for cryogenics with short development times.

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