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**DISTRIBUTED CONTROL SOFTWARE
FOR
HIGH-PERFORMANCE CONTROL-LOOP ALGORITHM**

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Abstract

The majority of industrial cooling and ventilation plants require the control of complex processes. All these processes are highly important for the operation of the machines. The stability and reliability of these processes are leading factors identifying the quality of the service provided. The control system architecture and software structure, as well, are required to have high dynamical performance and robust behaviour. The intelligent systems based on PID¹ or RST² controllers are used for their high level of stability and accuracy. The design and tuning of these complex controllers require the dynamic model of the plant to be known (generally obtained by identification) and the desired performance of the various control loops to be specified for achieving good performances. The concept of having a distributed control algorithm software provides full automation facilities with well-adapted functionality and good performances, giving methodology, means and tools to master the dynamic process optimization and achieve the required real-time performances.

¹ PID: Digital controller with three functions (proportional, integral, derivative).

² RST: Digital controller with three polynomial (R, S, T) equations.

1 INTRODUCTION

One important consideration in control engineering is that whether the application relates to magnet cooling, accelerator-tunnel ventilation, chilled-water production, cooling for physics experiments, etc., the cooling and ventilation (CV) plants always use complex processes. A good knowledge of the initial goals is essential before starting to detail the engineering control tasks. We must keep that in mind when studying a new and often complex control system; otherwise it will become badly adapted and, in addition, will lose track of the essential objective. So if the process-control architecture is not properly designed, the real performance will be poor and good plant operation will no longer be maintained. Therefore, setting up process-control objectives requires, first, a clear understanding of how the plant operations are determined and, second, a deep study of the plant's objectives.

2 PROCESS-CONTROL ARCHITECTURE

2.1 Process-control design

Process control is expected to cope with a complex process and to provide full automation facilities. It requires complex control algorithms and the application of additional mathematical methods for data-processing plant optimization. An implementation of intelligent controllers is necessary as well. Typically, the starting point for control-system design and analysis is a complete preliminary process design with all components and intelligent controllers, along with specification of the desired process performances. This information enables us to design and build the control architecture according to the essential requirements prescribed during the design.

2.2 Architecture overview (Fig. 1)

CV plants for both LHC and SPS sites are usually spread over kilometres. Therefore, to overcome the geographical challenge, it is of great interest to the CV group operation to provide a client-server architecture to satisfy their requirements.

Moreover, the steadily increasing need for a local supervisory system in modern plant control (enhanced by recent advances in software solutions), has led us after careful analysis of the objectives to integrate a so-called multinode architecture at the plant level. It is based on a full industrial control architecture connecting at the low level Programmable Logical Controllers (PLCs) and input/output Decentralized Periphery through Industrial Fieldbus [1]. At the high level the industrial PC acting as a supervisory and engineering station is connected to the routed Transport Control Protocol-Internet Protocol (TCP-IP) Ethernet network. The multinode architecture is well adapted to gradually integrate new equipment from any other processes as the projects unfold and is in addition bound to gather control equipment from the former G64-Mil1553 structure. This multinode architecture is potentially suitable to move in the next few years toward Object Linking and Embedding (OLE) for Process Control (OPC) connectivity.

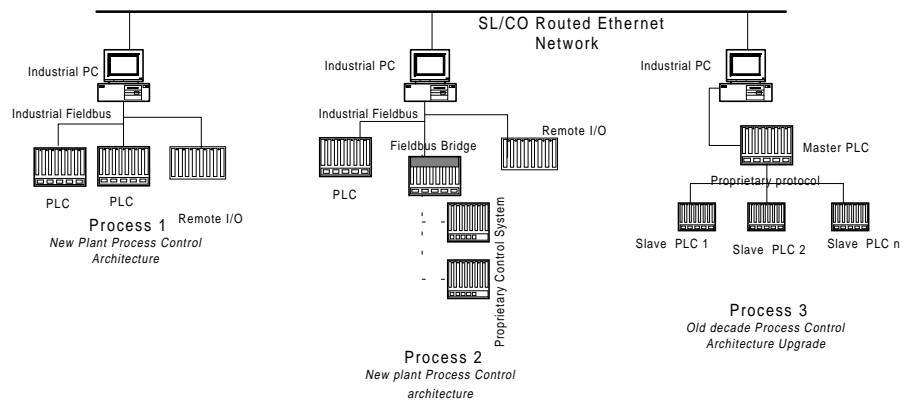


Figure 1: Multinode control architecture combinations.

2.3 Software solution (Fig. 2)

The core software component of the system is the Wizcon Supervisory Control And Data Acquisition (SCADA) software [2] that takes full advantage of Windows NT's 32-bit pre-emptive multitasking. It provides comprehensive graphical and configuration tools to develop rather sophisticated applications. Moreover it enables local operation to view, handle, and control large amounts of data. Through Wizcon, operators can control all the local process parameters (flow, pressure, status of cooling circuit, trend, real-time data analysis, etc.). They can also efficiently handle all types of alarm and warning, and link additional mathematical software (Matlab 'add-ons', etc.).

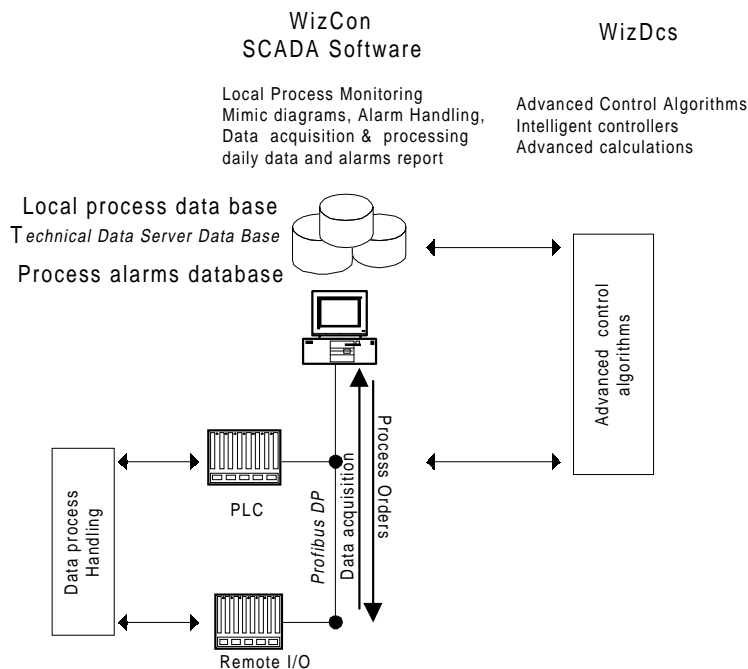


Figure 2: WizCon software architecture for the local station.

2.4 Client-server configuration (Figs. 3 and 4)

The client-server architecture is, on one hand, used for the monitoring of processes located on different sites. Process database might be exchanged under Wizcon-DDE (Dynamic Data Exchange) functionality between the supervisory stations over an Ethernet TCP-IP connection which is opened according to the TCP-IP hostlist file. On the other hand, the local supervisory stations are interconnected through Ethernet TCP-IP to a Wizcon server station not necessarily used as a supervisory station. In this way all the local data, like real-time events, various predefined status and trends, as well as daily reports, can easily be stored for historic data-processing. Moreover, the server station which is fitted with the Web SCADA software also allows users to monitor and control plant activities through a standard Web browser. Thereby, the Wizcon server station is turned into a Web server with state-of-the-art tools for application handling at any location.

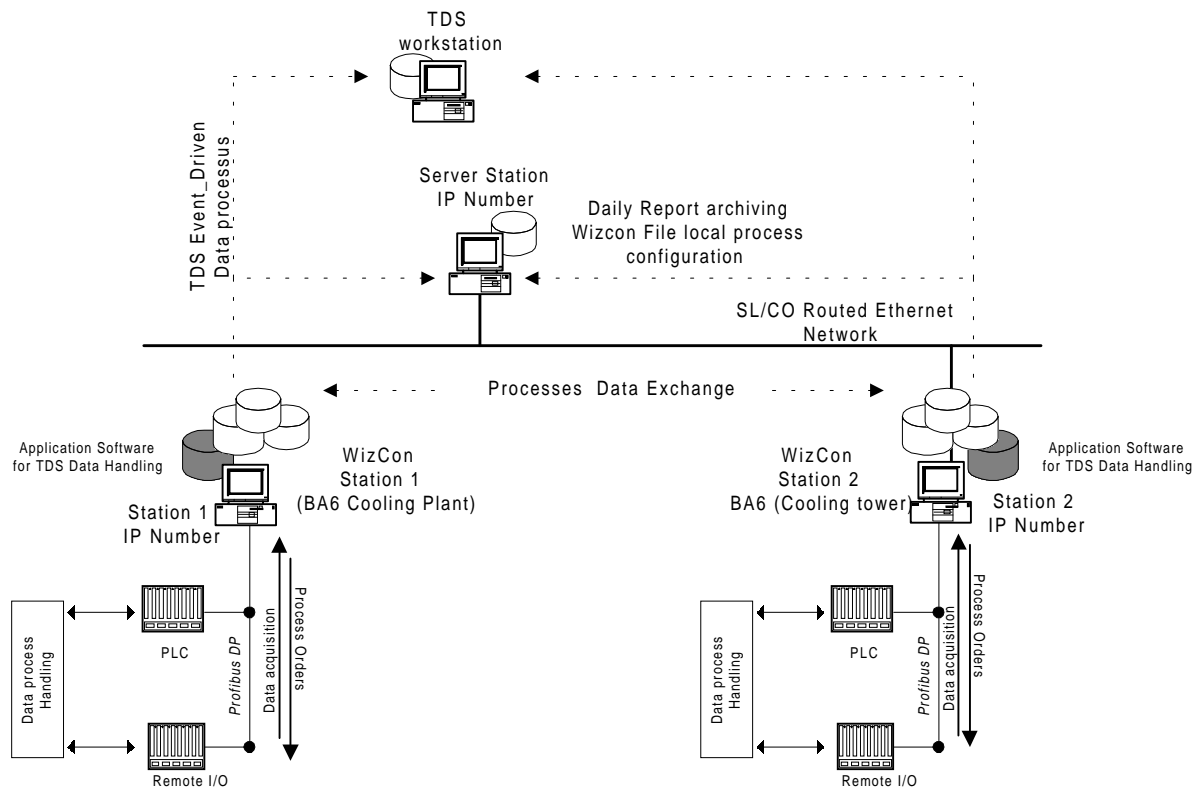


Figure 3: Dynamic data exchange between two WizCon SCADA stations, TCR workstation, WizCon server station.

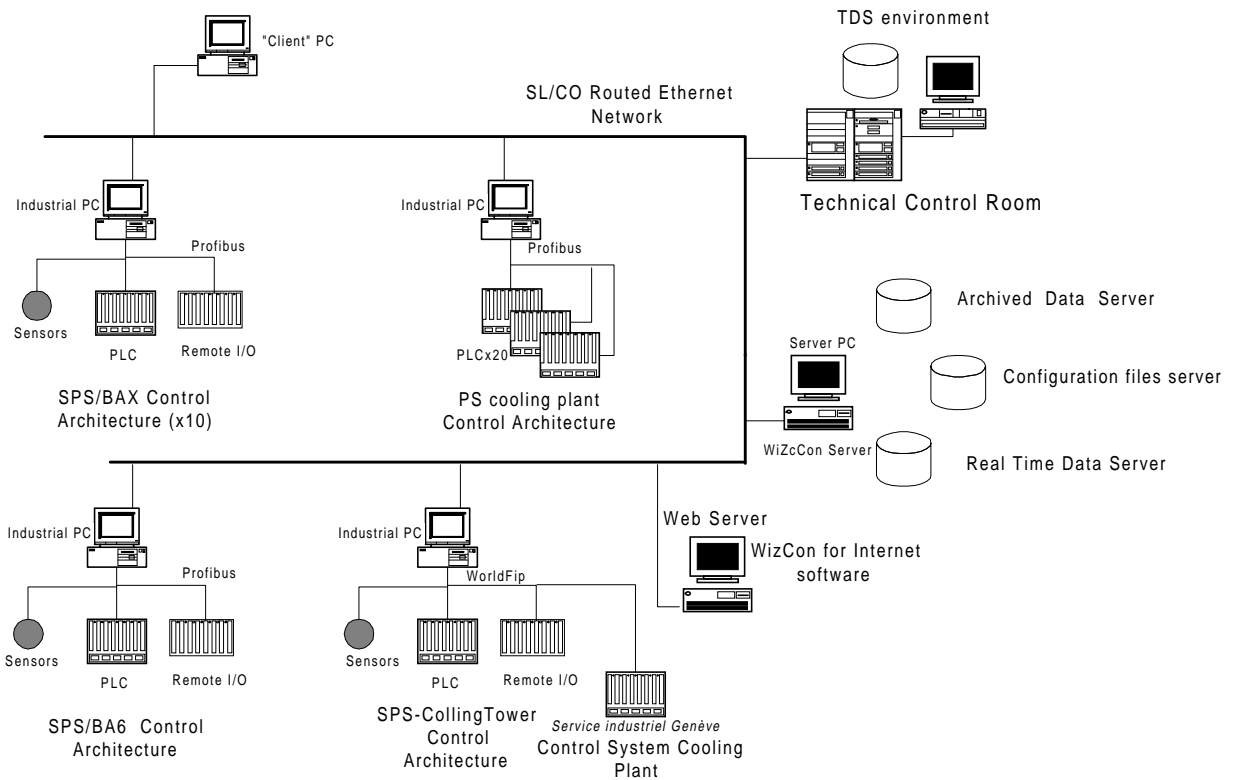


Figure 4: PS cooling-plants control architecture and PS cooling-plant integration.

3 SPS PROCESS-CONTROL PROGRESS

3.1 Introduction

The new concept of cooling the SPS [3] imposes a complete study for the requirements of a Process Optimization System through an improvement of the temperature controllers for the magnet cooling. The study started at the end of 1997 reported in the 1998 ST Workshop [4] has now reached a final stage with the experimental RST ‘Intelligent Controller’ prototype, which is now being tested for performance estimation and dynamic evaluation.

3.2 Plant identification

Identification means the determination of the model of a dynamic system, knowledge of which is necessary for the design and the implementation of a high-performance controller. The objective was to identify a dynamic model of the main magnet cooling system. The most efficient way for the identification of the model was to acquire data in a closed-loop acquisition using a Pseudo Random Binary Sequence (PRBS) signal added to the reference signal. Then after applying appropriate methodology [5] we obtain the required discrete time equation for the plant identification model as follows:

$$H(z^{-1}) = \frac{-0.03228 \cdot z^{-1} + 0.01432 \cdot z^{-2}}{1 - 1.01561 \cdot z^{-1} + 0.17927 \cdot z^{-2} + 0.22166 \cdot z^{-3}}$$

After the evaluation and experimentation of several basic structures taking different noise-disturbance models into account, the initial parametric identification structure proposed to perform the required model plant set out above is the following:

$$A(q^{-1}) \cdot y(t) = q^{-d} \cdot B(q^{-1})u(t) + A(q^{-1}) \cdot w(t),$$

where $w(t)$ is a non-modelled disturbance which is assumed to be of zero mean value, finite power and independent of the input $u(t)$.

The discrete time model of the plant enables us to design the high-performance digital controller. The design of this controller was done in accordance with the Robustness Analysis Methodology. The polynomial equations for R, S, T are the following :

$$\begin{aligned} R(z^{-1}) &= 0.49576 - 0.23703 \cdot z^{-1} - 0.40093 \cdot z^{-2} + 0.22766 \cdot z^{-3}, \\ S(z^{-1}) &= 0.03228 + 0.04661 \cdot z^{-1} - 0.01432 \cdot z^{-2}, \\ T(z^{-1}) &= 1 - 1.51983 \cdot z^{-1} + 0.59929 \cdot z^{-2}. \end{aligned}$$

It is obvious that the high-performance digital controller designed from a discrete time model of the plant requires specific and well-adapted software to be successfully operated. Indeed when such digital controllers are implemented the control and computing of many different parameters are essential for a successful operation and thereby to improve the desired time-response performances. Moreover the idea is in the near future to provide an adaptive process controller algorithm specially designed to create the process model from real-time data acquisition through statistical modelling methods. In this way the predictive algorithm used to compute all these actions will build on the model and continue to adapt and adjust it as long as process conditions change, and therefore to accommodate nonlinear events.

3.3 Advanced control algorithm software

Despite the recent improvement of PLC's functionality, it is still rather difficult to implement high-performance controllers based on mathematical functions as well as knowledge-based decision systems to configure dynamic optimization and control algorithms. All these technical considerations have led us to use a PC-based control software. WizDcs is a software-based control system that combines control, networking, and data-management functions built on a state-of-the-art modular framework. The various tools entirely fulfil these primary requirements. Moreover graphical configuration makes it easy to follow the flow of information through the control strategy. Furthermore the script application tool enables us to customize the system and to perform advanced and specific data-management functions. The availability of such software permits the implementation of the SPS-cooling main-magnet digital controller. In this way we designed and developed the operating procedures and strategies for advanced dynamic process models, data acquisition and accuracy computing,

and advanced graphic construction. Other applications like adaptive process control and training simulation are under way.

4 CONCLUSION

Owing to time constraints in our general schedule, the Cooling and Ventilation group had to cope with new control systems for the new and various industrial plants for the LHC project as well as for the SPS. Even though the advanced technology is applied to the control for the new cooling and ventilation plants, severe problems remain for existing control systems which are based on a decade-old technology. It was not fully clear how to upgrade and integrate rather obsolete control architecture mostly in a limited budget and manpower area. To use a multinode control architecture, allowing special hardware combinations in a rather obsolete Proprietary Network Architecture (or with new Standard Fieldbuses), is the simplest way to satisfy our requirements for the purpose of mixing old and new hardware architectures. Moreover, after thorough investigations of possible solutions from various DCS manufacturers, we have selected WizCon and WizDcs for building our applications. The main factors behind the selection of WizCon were advanced technical features, reasonable price, and simple application development. An important additional argument was its capabilities of online configuration, which enable us to expand very quickly.

References

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