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A NEW DISTRIBUTED CONTROL SYSTEM FOR THE CONSOLIDATION OF THE CERN TERTIARY INFRASTRUCTURES

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Abstract

The operation of the CERN tertiary infrastructures is carried out via a series of control systems distributed over the two main CERN sites (Meyrin and Prevessin). The scope comprises: ~260 buildings, *2 large heating plants (~50 MW overall capacity) with 27 km district heating network and 200 radiators circuits, ~500 air handling units, ~52 chillers, ~ 300 split systems, ~ 3000 electric distribution boards and ~ 100 000 light points.*

In the last five years and with the launch of major tertiary infrastructure consolidations, CERN is carrying out a migration and an extension of the old control systems dated back to the 70's, 80's and 90's to a new simplified, yet innovative, distributed control system aimed at minimizing the programming and implementation effort, standardizing equipment and methods and reducing lifecycle costs. This new methodology allows for a rapid development and simplified integration of the new controlled building/infrastructure processes.

The basic principle is based on open standards PLC technology that allows to easily interface to a large range of proprietary systems. The local and remote operation and monitoring is carried out seamlessly with Web HMIs that can be accessed via PC, touchpads or mobile devices.

This paper reports on the progress and future challenges of this new control system.

INTRODUCTION

CERN has a large infrastructure of buildings. Most of these are more than 40 years old (see Figure 1). In particular, a large set of buildings (260) are dedicated to tertiary functions. These functions are quite heterogeneous ranging from offices, workshops and warehouse, 2 large heating plants (~50 MW overall capacity) with 27 km district heating network and 200 radiators circuit to 3 restaurants, 3 hotels and a kindergarten.

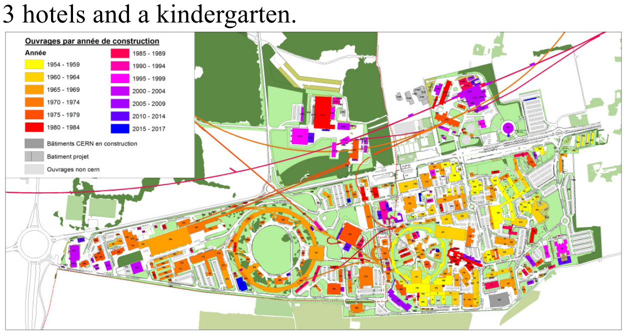

Figure 1: CERN buildings ages in Meyrin.

Throughout the years, different generations of building automation systems have been installed. These systems monitor and control building functions for the heating, cooling, ventilation, air conditioning, chillers, lighting, shading and, in general, functions aiming at optimizing energy usage and building operation and maintenance.

Given the age, some of these installations require substantial refurbishment: at CERN, this programme goes under the name of consolidation. The term "consolidation of infrastructure" identifies the main elements in the buildings and tertiary systems that needed to be refurbished, to be renovated or to undergo a large maintenance intervention. In addition, CERN has embraced the concept that a building doesn't have to be new to be smart and has taken the opportunity when renovating systems to incorporate smart building capabilities. This step-by-step process allows to develop the new smart capabilities along with the improvement of the building infrastructure.

Since early 2009 and as part of the consolidation of the infrastructure, a novel methodology has been applied for the development and the integration of the new controlled building/infrastructure processes. This paper is organised as follows: first, an overview of the methodology is described, second, the basic principles of the new distributed control system dedicated to the tertiary infrastructure is presented. Then, examples of installations deployed in the last five years are presented. Finally, the paper concludes with the most important ideas and future work

METHODOLOGY

In order to fully understand the reasons behind the methodology, it is important to provide some elements to contextualize the motivations:

1. the old systems were built over the years through international call for tenders leading to a large number of heterogeneous manufacturers and architectures;
2. the old systems were built without a remote control and were rarely upgraded with such functions;
3. the local control functions were not networked to improve energy building performances.

In addition to the context, the following facts should also be taken into account:

4. the replacement of the old control systems should allow interfacing with different system manufacturers;
5. new process equipment come with various standard interfaces (not always the same);
6. most of the work on the building control systems is typically subcontracted;
7. there was no interconnection between heating, cooling, lighting and, in general, among various building control functions;
8. the physical distribution of the building.

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In addition, the field of building automation system has suffered since its inception the problem of heterogeneity making the interoperability cumbersome [1].

Finally, the strategy is to upgrade the control systems also to improve the building performance in terms of comfort, energy usage, operational costs and maintainability.

On the basis of the above-mentioned facts, it was decided that the methodology would allow:

1. to interconnect seamlessly with different building systems using standard protocols
2. to reuse pieces of codes for reducing costs and improving maintainability
3. to remotely monitor the various distributed control systems without a centralised SCADA but rather using built in functions allowing access from a multitude of different platforms and locations.

The core of the methodology is to implement an automation layer that is capable of directly interface with the field layer using standards hardware interfaces with standard protocols and avoid the use of proprietary technologies. This will also allow the compatibility with multinational tenders/contracts and increase flexibility for the selection of manufacturers. In addition, the methodology breaks from specific automations platforms (for example, lighting) toward generic automations platforms that allow interoperability among different functions (for example, human presence, lighting and cooling). This is also built on some guaranteed basic functions by predefining data points and naming conventions.

Another core element of the methodology is the reusability of the code [2]. To achieve this goal, a number of software modules have been identified and programmed creating software components that can be further specialized in the individual applications. This piece of the methodology allows to reduce development and validation effort (reusability), facilitates monitoring and maintenance and provides a high degree of standardization in dealing with integrators: the final result is a component-based software architecture. An example of such a component is the building ventilation function. This component is based on a standardized P&ID. Its programming includes the control algorithm, the connection to the sensors and actuators and its control panel interface as shown in Figure 2. Another advantage of software components and component-based design is the possibility to use the actual software components in simulations with the plant model. Hence, this methodology allows a rapid prototyping from the simulation stage to the implementation stage: i.e. the software components can be tested with the actual hardware (aka, hardware in the loop) and then installed on the plant.

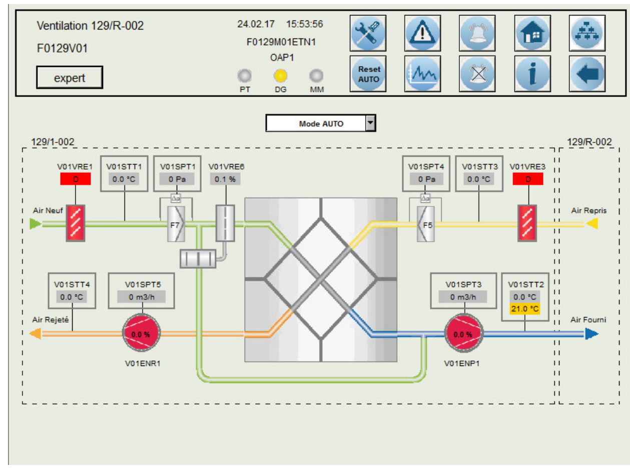

Figure 2: Example of control panel interface component.

The final element of the methodology is linked to the concept of a lean ubiquitous remote monitoring and control: continuous improvement with the aim of increasing value for user and reducing/removing useless functionalities. This element has been implemented by a distributed rather than centralised architecture based on standard web technologies [3]. This provides (1) maximum flexibility to support the constant changes (due to the integration of the new/renovated systems) without compromising the operation, (2) the stability of the elements not affected by the changes and (3) the overall quality since only part of the systems might be affected. This element of the methodology also allows to apply improvements incrementally on a component or system base and, on the basis of the automation of the process described in the previous section, the improvement can be implemented faster than starting from scratch. Finally, the usage of standard web interfaces and secure connections allows a seamless access to the distributed monitoring and control systems from a multitude of different platforms and locations.

NEW DISTRIBUTED CONTROL SYSTEM

The new distributed control system for the CERN building/infrastructure processes is based on an automation model that puts the openness at its centre and, as such, allows the implementation of the methodology described in the previous chapter. This architecture is shown in Figure 3.

This technical solution is based on the Saia Burgess Controls (SBC) product line [4] for the management and automation layer and a multitude of field devices products: all connectable through standards hardware interfaces with standard protocols (DALI [5], KNX [6], MODBUS [7]).

All the building/automation processes are connected to the IP network allowing the remote monitoring and control functions. All connected field devices are based on standards hardware interfaces with standard protocols. The remaining old systems with proprietary technologies are being progressively phased out. In addition, by using the standard software components described in the previ-

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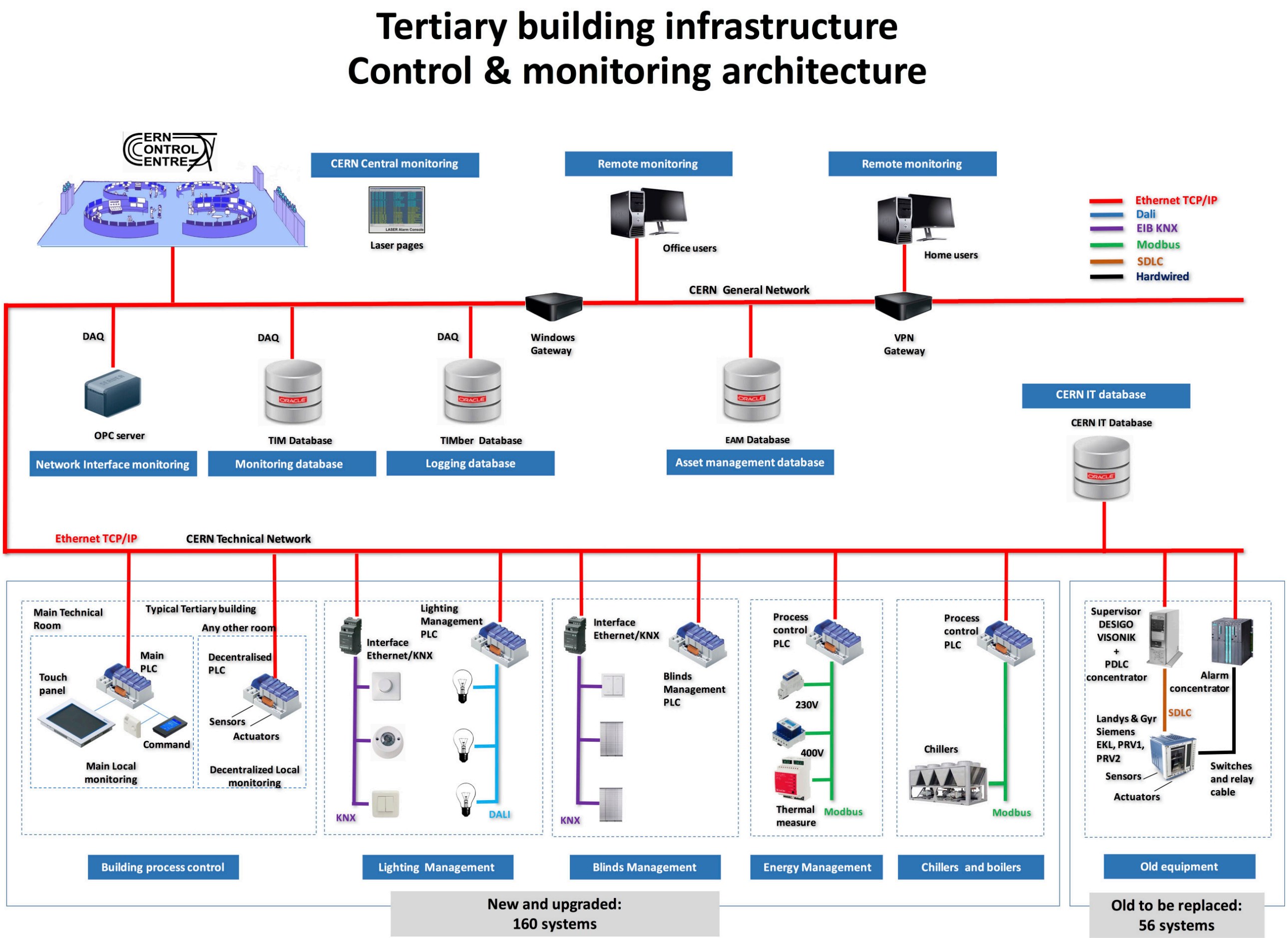

Figure 3: Control & monitoring architecture of the CERN tertiary building infrastructure.

ous chapter, the interoperability between building services is made simple.

Data is integrated in the CERN standard services like the Technical Infrastructure Monitoring (TIM) for the CERN central monitoring, the TIMber database for the CERN central logging, the CERN Enterprise Asset Management (EAM) for the management of the hardware configuration and maintenance and the CERN IT database for the network management and configuration.

Since 2009, all new systems have been designed and implemented following this new concept and old systems are systematically migrated: to date, almost 75% of all the systems are implemented in the new architecture.

This implementation minimizes the effort in the design, the development, the implementation, the testing, the commissioning and the long-term maintenance by using "real" and widely used open standard and reusing optimized software components. Minimizing the effort plays a role in all the life-cycle activities and, finally, results in a reduced cost of ownership. For example, a typical system cost has been cut to almost 70% of the traditional proprietary systems.

IMPLEMENTATION EXAMPLES

This chapter illustrates two examples of implementation of the new distributed control system.

The first example is in the field of lighting management. The main objective of a lighting management system is to deliver the right amount of light where and when needed thus reducing energy consumption while providing greater users comfort, to minimize maintenance cost by monitoring system performances (only replace what is not performing) and to rapidly repair system failures (the system monitors failures and automatically call for a repair). This has been achieved by using KNX compliant sensors and actuators and controlling the lighting directly using the DALI compliant fixtures. Where implemented, the energy consumption has been reduced to about 80%. Thanks to the embedded interoperability, in some areas the information about the presence of people has been used to operate the heating and cooling of that area.

The second example is a building management system for a new construction: the building 774 [8] shown in Figure 4. This building can be defined a green smart building for its integrated functions that allow the real-

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time monitoring and control of its energy management (heating, cooling, lighting and shading). In particular, the building implements an energy concept based on multiple productions (gas district heating, electricity and thermal solar collector) and energy recovery through air circulation [9].

Figure 4: The B774 building.

Heat is used to produce hot water for space heating, for sanitary usage and, when sufficient solar energy is available, for the production of chilled water via an absorption system otherwise a traditional compressor-driven cooling system is started to produce the chilled water. Chilled water is distributed for the cooling of technical installations and some building areas.

Depending of the external weather conditions and the real-time heating/cooling needs of the building areas (technical rooms, conference rooms, etc), the energy flows are managed to maximize the usage of solar energy, hence reducing costs. A schematic diagram of the flow of energy is shown in Figure 5 and the actual implementation of the solar collectors with its control panel interface is shown in Figure 6.

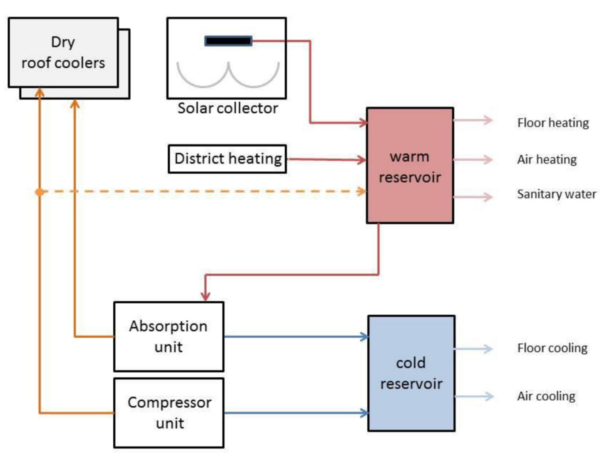

Figure 5: B774 energy flow principle.

Figure 6: B774 Actual implementation of the solar collectors with its control panel interface.

CONCLUSIONS AND FUTURE WORKS

The field of building automation systems is going through a fundamental change with the introduction of smart connected devices. However, when it comes to manage a large number of assets, systems owners either opt for proprietary solutions or to a tailored engineered solution. CERN has decided to move away from proprietary solutions and move to an open, yet controlled, architecture that allows to manage a large number of building automation systems with limited resources. The time from conception to commissioning and a typical system cost has been cut to almost 70% of the traditional proprietary systems.

Future works are on-going to complete the migration of the old systems and to develop additional software components to further reduce the total cost of ownership.

REFERENCES

[1] P. Domingues *et al.*, “Building automation systems: Concepts and technology review”, Computer standard and interfaces, Vol. 45, March 2016, Pages 1-12.

[2] B.H. Het *et al.*, “Software technology for implementing reusable, distributed control systems, IEEE Contr. Syst. Mag., February 2003, Pages 21-35.

[3] G. Bovet *et al.*, "Toward Web Enhanced Building Automation Systems", ISBN 978-3-319-05029-4, Pages 259-283.

[4] Saia Burgess Controls, https://www.saia-pcd.com

[5] DALI, http://www.dali-ag.org

[6] KNX, https://www.knx.org

[7] MODBUS, www.modbus.org

[8] F. Soppelsa, O. Mestre, Fundamental Particles: EA774 at CERN, ISBN 13: 9781940291857.

[9] H.J. Burckhart, F. Audinet, M-L Gabassi, C, Martel, “Application of a Novel, Vacuum-insulated Solar Collector for Heating and Cooling”, in *Proc.* of the 2nd SHC, Freiburg, Germany, Volume 48, pp. 790-795.