A VIRTUAL COMPUTING INFRASTRUCTURE FOR TS-CV SCADA SYSTEMS

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Abstract

In modern data centres, it is an emerging trend to operate and manage computers as software components or logical resources and not as physical machines. This technique is known as “virtualisation” and the new computers are referred to as “virtual machines” (VMs). Multiple VMs can be consolidated on a single hardware platform and managed in ways that are not possible with physical machines. However, this is not yet widely practiced for control system deployment. In TS-CV, a collection of VMs or a “virtual infrastructure” is installed since 2005 for SCADA systems, PLC program development, and alarm transmission. This makes it possible to consolidate distributed, heterogeneous operating systems and applications on a limited number of standardised high-performance servers in the Central Control Room (CCR). More generally, virtualisation assists in offering continuous computing services for controls and maintaining performance and assuring quality. Implementing our systems in a virtual infrastructure, we benefit from services for backup and restoration, deployment, remote access and monitoring. This means lower installation and administration cost, quicker delivery of software architectures as well as higher availability. We mention some of the lessons learnt and give advice for new projects, planning to employ virtualisation technologies.
1 INTRODUCTION

The TS-CV group is responsible for cooling and ventilation systems throughout the CERN site. TS-CV has installed a wide-ranging and complete computing infrastructure, which assists in the development, maintenance and operation of these systems. This computing infrastructure performs three main functions:

- Remote supervision and some levels of process control;
- Alarms transmission to the CERN alarm systems and data publication via DIP;
- SCADA application and PLC program development and testing.

2 SOFTWARE INFRASTRUCTURE

2.1 Architecture

Today, for historical reasons, TS-CV manages a heterogeneous mix of systems and applications. The most important element of the current supervision system architecture is a number of single-user (one user can connect at a time) Wizcon SCADA system installations, each managing a process via one or several Programmable Logic Controllers (PLCs). This architecture is illustrated in Figure 1:

![Figure 1 – Wizcon architecture](image)

In this figure, the Wizcon Server runs an application for a particular CV process, providing a SCADA configuration for monitoring and control, as well as alarms transmission. The server is accessed via Thin Clients, used from the Main Site, accelerator sites (e.g. LHC Site SU buildings), the Control Room (the CERN Control Centre - CCC, and other remote locations, using the standard Microsoft Remote Desktop Client.

Currently, TS-CV is deploying a new SCADA architecture, based on client-server systems, which will also offer redundancy functions as well as local operator panels. Additionally, it will separate the alarms transmission to the CCC from the SCADA systems.

2.2 Systems and software installation

TS-CV operates a collection of configurations, application software and operating systems. Systems are installed for operational purposes, as well as for development and testing. These systems include:

- 55 Wizcon machines (for different versions of Wizcon), on Windows XP and Windows NT;
- 20 PCVue machines for four client-server architectures, on Windows Server 2003;
- 25 OPC Server machines (Siemens and Schneider), on Windows Server 2003;
- 6 PLC development machines for Siemens and Schneider software, on Windows XP;
- 50 Thin Client PCs for remote Wizcon and PCVue connections, on Windows XP;
- 10 Linux servers for infrastructure monitoring, database servers and software repository.

The new client-server architecture, replacing Wizcon, will be deployed over the coming years, based on PCVue SCADA systems for supervision and OPC servers for alarms transmission. This is already implemented or being implemented for the LHC Hardware Commissioning, LHC Detector Cooling, PS Cooling and LHC Tunnel Ventilation systems.

3 PHYSICAL AND VIRTUAL INFRASTRUCTURE

3.1 Hardware installation

TS-CV originally installed all machines on physical computers, based on standard off-the-shelf office PCs. These computers were installed in more than 50 locations throughout the site (surface and underground). The PCs used different hardware platforms, not easily repairable, due to the installation of legacy OS versions (Windows NT and Windows 2000). Some machines were not powered by uninterruptible power supplies and were regularly subject to electrical disturbances. There were only limited facilities for remote connections, and no logical access controls. Hardware failures were frequent and repair times in the order of weeks. Data was not backed up and expensive Wizcon license dongles were stolen. Importantly, there was no separate development and test environment; all changes and updates were done directly on the operational environment, occasionally disturbing the process operation and the alarms transmission.

A number of both general and specific objectives were considered for the design and installation of a new and improved TS-CV computing infrastructure, including:

- Availability: The TS-CV processes operate continuously with only short stops for maintenance and these processes are vital to the functioning of the accelerators and the detectors. For the operation of the TS-CV installations, continuous remote supervision and alarms transmission is essential;
- Maintainability: It is important that corrective actions can be taken quickly and in many cases remotely, due to the geography of the site. Also, it must be possible to maintain the supervision systems transparently to users and other services, both for planned (preventive) and non-planned (corrective) interventions;
- Integrity: To protect the operational system from unintentional and untested changes, a dedicated architecture is needed for development and testing, and access control is mandatory.

In parallel with the TIM migration in 2005, TS-CV made a re-installation of all supervision systems as a virtual infrastructure, evaluated to be the most efficient implementation with the available man-power and budgets. Thin Clients were installed for remote access to the infrastructure. At the heart of the new infrastructure is the standard computing hardware selected by AB-CO for the CCC operation, and the installation consolidates the TS-CV supervision machines on hosts installed in the CCR racks. The CCR benefits from environmental controls as well as physical access restrictions. The electrical distribution and network infrastructure is adapted for a high-availability computing environment, and personnel are available in the vicinity of the hardware for manual supervision and corrective interventions. All applications and operating systems work without changes, and the CERN computer management tools (e.g. CMF) are fully compatible with the new machine installations.

In terms of cost, the original investment was mainly in material, but as we now use fewer physical hosts (of a better quality) than originally, we save both on purchase and recurrent maintenance expenses. An initial investment in time was necessary to learn the new technology and make the necessary adaptations to the CERN environment, and there is certain level of continuous
technological follow-up and updating. The time spent is easily recuperated due to the improvements in efficiency of operating the new installation: the regular activities (about half a day per week, performed from a remote location) are almost exclusively of a “preventive” nature, whereas in the past we spent all resources on “corrective” actions. Preventive work is a both cheaper and more satisfying. This is especially important as we do not benefit from an official 24/7 first-line intervention service.

3.2 Virtualisation principles

The TS-CV computing infrastructure installation in the CCR is made possible through the use of an emerging computing technology: virtualisation. With virtualisation technology it is possible to install and run several Virtual Machines (VMs), with different Operating System installations, executing different applications, on a single computer hardware platform. This is shown in Figure 2.

![Virtual Machines](image)

**Figure 2 - Virtual machines**

This figure shows how several VMs are installed on a single (shared) Physical Server. Each installation consists of an App (application software), and an OS (Operating System instance). The VMM (Virtual Machine Monitor) manages the shared access to the hardware resources of the Physical Server. Each VM is configured with a set of virtual hardware devices (e.g. CPU, memory, network, disks and console) which it presents to the OS. Typical virtualisation use-cases include:

- You want to run Windows XP and Windows NT simultaneously on your PC to preserve legacy NT application software, while benefiting from new XP software;
- You want to test a client-server architecture of several machines on a single hardware platform to save time, money and space;
- You want to save rack space, lower electricity usage and minimize ventilation requirements, by consolidating several under-utilized machines on a single physical server.

Compared to traditional computers, VMs have a number of unique characteristics:

- Hardware Independence: We can run the VMs on any hardware platform instance and easily migrate to newer hardware architectures to benefit from technological advances. We have regularly improved the performance of applications by updating the hardware, with only minutes of application downtime and without modifying the OS or the applications;
- Consolidation and Isolation: Several VMs run on a single physical server without intra-VM interference, as each VM is assigned to dedicated disk and memory resources. In particular, on our servers we now have dedicated and isolated VMs for network monitoring, at no cost, which assists in solving networking problems of SCADA and PLC architectures. This does not risk interfering with the operational VMs and is fully transparent to the users;
- Compatibility: Legacy Operating Systems (e.g. Windows NT) can now run on the latest hardware. As an example, we are prolonging the operational “life” of SCADA applications for the SPS, that before were running on un-maintainable hardware, and saved the money otherwise needed to port the applications to a new hardware and OS platform;
Encapsulation: Each machine is completely contained in a set of files, which can be backed up (for disaster recovery), copied (to create an identical “cloned” machine), or transferred (to test a CERN machine configuration outside CERN). We have installed an automated backup facility which regularly takes complete image level snapshots of our installations;

Performance monitoring: Via the VMM and standard tools it is possible to monitor all performance parameters of a VM or a Physical Server. We can detect and correct bottlenecks or other problems before they affect operation, and continuously adapt capacity and perform load balancing between our machines.

Using consolidated virtual machines on centralised hosts, instead of distributed physical machines, provides numerous advantages. We have very few hardware problems, almost always transparent to operation. Within the CCR, we can quickly deploy new machines remotely, and we can restore machines from backup. These operations typically take a few minutes, whereas a standard (re-)installation often takes hours. Specifically, this has allowed us to deploy comprehensive environments for development and testing. In a few hours, we can install a new client-server PCVue development platform, covering six machines; the deployment time is mostly needed for application installation.

3.3 TS-CV implementation

The virtual infrastructure is implemented by a combination of hardware and software components, certified and supported by different suppliers. TS-CV has chosen a particular implementation which:

- Supports standard Windows XP/NT and Linux machines. Thus, no changes to any SCADA applications are required, and we can use standard CERN computer management tools;
- Supports all recent generations of HP servers, which allows us to use the standard AB-CO server architectures since 2005, which lets us extend the life-time of our servers significantly (many software implementations lack this support);
- Supports scripted installations via the AB-CO automated server installation infrastructure. A new physical server is installed in approximately 10 minutes, excluding cabling works;
- Works with legacy hardware license dongles connected on parallel ports. Thus, it is possible to virtualise Wizcon machines, that depend on parallel port dongles.

All leading software vendors today offer a variety of products for virtualisation targeted for a wide range of usage scenarios. Increasingly, the software is bundled and integrated with hardware, which guarantees compatibility, reliability and support.

In the new installation, TS-CV is operating hardware for the virtual infrastructure, which covers all the machines and application enumerated previously, as well as the Thin Client PCs and the process PLCs. This infrastructure of hosts and networks is schematised Figure 3.
The diagram shows the essential elements of the hardware and network infrastructure:

- A Centralized Management Station (with remote access) for infrastructure administration;
- 20 Virtual Machine Hosts (Physical Servers) primarily for Wizcon, PCVue and OPC systems, including hosts dedicated to development and testing;
- 50 Thin Clients accessing Wizcon and PCVue via the Remote Desktop Client (or VNC);
- A Machine Image Backup server for data protection, cloning and disaster recovery.

3.4 Key success factors

The system installed in 2005 has evolved continuously to adapt to new application software and architectures, advances in hardware technology and increasingly demanding requirements for high levels of availability and maintainability. Some of the main factors to this success are:

- We are able to consolidate many distributed systems on a few servers, which fit into the limited available space in the CCR. The CCR is particularly suited for server installations and operation due to guaranteed environmental conditions as well as physical access controls. Also, the CCR is close to both end-users and AB-CO system administrators;
- We save on hardware purchases – without virtualisation we would need to purchase five times as many servers as we use today – and we save resources for electricity and ventilation;
- We can today operate systems and applications – many of which were developed and delivered prior to 2005 – on a homogeneous, reliable and maintainable hardware infrastructure. This offers a high availability compared to the original installations on distributed PCs;
- We use very little resources on system administration; we save both on hardware maintenance and regular operating system related tasks (e.g. deploying new systems). We estimate that without virtualisation we would need five to ten times the current resources for PC administration.
CONCLUSION

The virtual computing infrastructure for TS-CV SCADA systems is now operational and fulfills our requirements for a complex and mission-critical SCADA infrastructure. It offers many advantages over a traditional infrastructure, mainly in terms of the availability achieved combined with the low operation and maintenance cost. We foresee to leverage this even more in the future, as we embark on the migration of our SCADA systems to complete client-server architectures, based on PCVue; we can adapt and plan the new software architecture together with our virtual infrastructure, and easily install and manage many machines in a networked and redundant system within a performing and reliable hardware environment. We observe that other companies and industries are implementing similar systems, and the main provider of SCADA software to TS-CV is applying this architecture to future installations. We will continue to develop and apply it to current and future SCADA projects, and we expect that this technology will play an important role in tomorrow’s control systems.