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**AN INDUSTRIAL CONTROL SYSTEM FOR THE SUPERVISION OF THE CERN  
ELECTRICAL DISTRIBUTION NETWORK**

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**Abstract**

CERN operates a large distribution network for the supply of electricity to the particle accelerators, experiments and the associated infrastructure. The distribution network operates on voltage levels from 400 V to 400 kV with a total yearly consumption of near to 1000 GWh. In the past, the laboratory has developed an in-house control system for this network, using the technologies applied to the accelerator control system. However, CERN is now working on a project to purchase, configure and install an industrial Electrical Network Supervisor (ENS). This is a state-of-the-art industrial control system completely developed and supported by an external contractor. The system — based on a scalable and distributed architecture — will allow the installation to be performed gradually, and will be tested while the existing system is fully operational. Ultimately, the complete electrical distribution network will be supervised with this new system, the maintenance and further development of which will be the complete responsibility of the contractor.

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## 1 INTRODUCTION

CERN is supplied with electrical energy from Electricité de France (EDF) and Energie Ouest Suisse (EOS). CERN distributes this energy to all electricity clients on the sites via the distribution network, which consists of about 100 substations and an installed capacity of 400 MVA. Most electrical equipment is supplied by industry and is typical industrial equipment, not specific to CERN. The electrical equipment includes more than 300 devices with communication capabilities. Also, CERN installed 180 local electricity control systems (the CERN MICENE) during LEP construction, when electrical equipment was not equipped with remote supervision facilities. In total, the equipment represents more than 100 000 analog and digital data entities (or data points).

## 2 BACKGROUND

### 2.1 The existing system

CERN has in the past implemented an in-house supervisory system, based on technologies and facilities developed during the construction of the LEP accelerator. This existing system is organized as a collection of computers, services and applications, which are not developed, operated or maintained as an integrated and homogenous system. In the future, it is not viable to maintain or further develop this system, mainly because of the limited resources available at CERN.

Furthermore, the data acquisition of the existing system is based on a request–reply paradigm, which used to be common to a number of CERN systems in different domains. This model has become obsolete in the context of new developments such as the publish–subscribe paradigm, which are more appropriate for this type of control system.

### 2.2 Objectives and constraints

The ENS will provide a coherent control system, which will cover all the needs of the operation of the electrical network, while also providing the flexibility to suit future requirements via resource-effective evolutionary maintenance. By basing the ENS on an industrial control system, CERN can concentrate its human resources on the overall system engineering while reusing implemented and proven industrial solutions.

The ENS will ultimately cover all layers of the supervision infrastructure using industrial control technologies, from the lowest level of field communication with the electrical equipment, to the highest level of user interfaces in the control rooms.

Owing to the size of the electrical network, the ENS installation will be performed gradually, and has to be done in parallel with the operation of the existing system. The project has two phases: In the first phase the ENS will reuse and integrate the existing CERN Front End (CFE) computers used for data acquisition, and in the second phase it will replace the CFEs with industrial front ends, thus providing a complete industrial control system.

### 2.3 Selection criteria

The ENS will be based on an industrial control system, satisfying a number of criteria to fulfil the specific requirements for a system to be implemented in an experimental physics environment. Specifically, there are important requirements for a *scalable* and *distributed* architecture with a high degree of *openness* for integration.

#### 2.3.1 Scalability

The scalability of the system is essential to the constantly evolving CERN context. CERN plans to expand the distribution network in the future for the construction of the LHC, and the electrical equipment is evolving, therefore demanding more supervision capabilities. The ENS is expandable, so that it can manage bigger data quantities resulting from the evolution of the electrical network.

#### 2.3.2 Distribution

The equipment communicates via distributed local-area field-bus networks — each covering a limited geographical area such as an electrical substation —

and an important feature of the ENS will be a distributed data-acquisition module to interface these networks. This module will be integrated into the existing site-wide CERN communication networks. The operator posts of the ENS must also be distributed and available from dispersed locations, such as major substations and offices.

### 2.3.3 *Openness*

The openness of the ENS is vital for integration into the CERN systems. The electrical equipment to be supervised does not provide a homogenous communication interface. Only the lowest communication layers are governed by international standards, and the ENS must adapt to the specificity of every type of equipment. Thus, the ENS process interface must provide programming and configuration tools to support existing and future communication interfaces and protocols of the electrical equipment.

Similarly, openness is required at the general supervision level. CERN's policy is to integrate specialized and domain-specific SCADA systems, such as the ENS, into a general supervision infrastructure for technical services. For this supervision, the Technical Data Server (TDS) has been installed. The TDS is a middleware data server which is provided with data from specialized SCADA systems and makes this data available to external applications and systems such as the CERN Alarm System (CAS), MMI clients, data logging systems, etc.

Open communication facilities are important selection criteria for ENS. These will enable it to interface with the TDS system and possibly other external clients needing data from the electrical process.

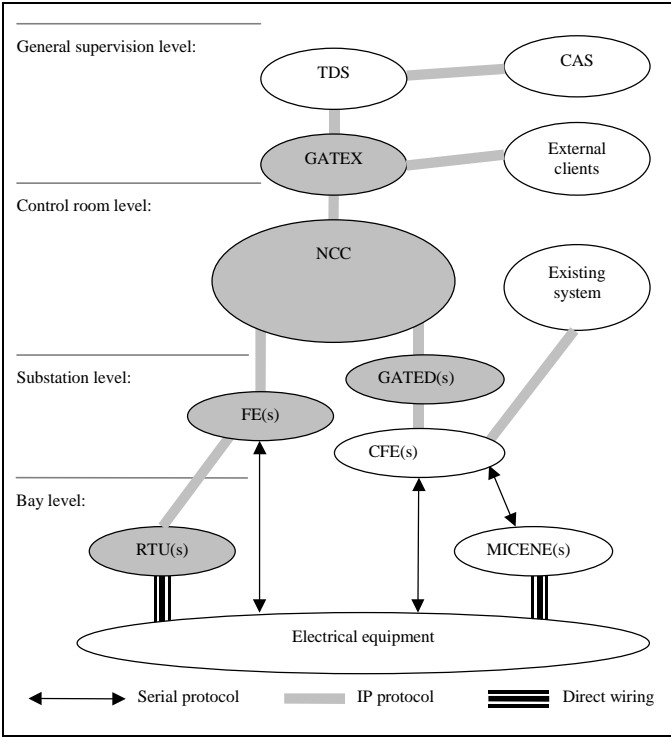
## **3 ARCHITECTURE**

The ENS will be based on a standard industrial system, which implements all modules of a control system from data acquisition to user interfaces. In addition to the standard modules of the control system, some particular ones will be developed for the integration of the ENS into the CERN environment.

The following will be the main modules of the ENS.

- Network Control Centre (NCC). The NCC is the standard central control-room facility, which provides all operational and management facilities of the system. The NCC consists of application and database servers, which are made available for access via X terminals throughout the site. The NCC is implemented on UNIX servers, and high availability of critical system components will be assured via back-up servers controlled by watchdog computers.
- Front End (FE). The FE is the distributed data-acquisition interface, which will interface to the electrical devices in the field. The FE will assume communication functions with these devices and perform some distributed data processing such as time stamping of incoming data. The FE is implemented on Windows NT PCs using special hardware, taking into account the environmental hazards present in electrical substations. Based on a standard platform, the FE is adapted to the specific electrical equipment at CERN.
- Gateway to electrical data acquisition (GATED). The GATED module is the software module specifically implemented for the first phase of the project. It will integrate the existing CFE-based data-acquisition module and the devices connected to this module, such as the MICENE computers. The GATED will be installed in each existing CFE computer without changing the functionality of the existing processes.
- Gateway to external systems (GATEX). The GATEX is the central module, which provides an interface between the NCC and external clients such as the TDS. In the case of the TDS, the GATEX makes data available via a TDS-specific TCP/IP protocol.
- Remote Terminal Unit (RTU). The RTU is the interface to equipment which does not have communication capabilities. The RTU also provides local supervision facilities independently of the NCC.

The overall system architecture and data flow of the ENS is illustrated in Fig. 1. The modules developed under the ENS project are depicted on a grey background.



**Figure1:** System architecture and data flow of the ENS.

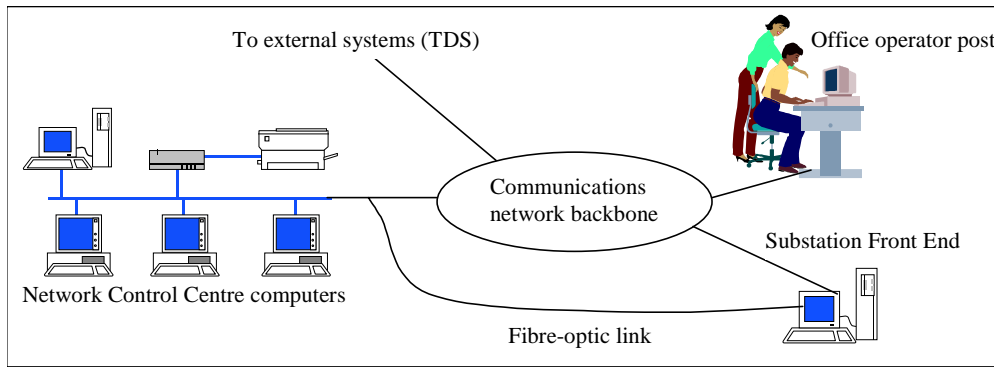
**4 COMMUNICATION**

**4.1 Infrastructure**

The ENS will be integrated into the CERN data communication infrastructure, which is based on industrial standards and available for the interconnection of industrial control systems [1]. All modules of the ENS adhere to these standards (e.g. IP) and have been tested for cohabitation with other systems relying on the communication network.

To ensure the communication with a few very important electrical substations, special communication lines will be installed to guarantee a very high availability. These point-to-point links will use the existing optical-fibre infrastructure available at CERN.

The NCC will comprise a number of servers and auxiliary systems, which have special communication requirements regarding availability and bandwidth. The communication between these machines will be implemented via an isolated segment, which only communicates with 'authorized' systems on other networks, such as the FE and GATED modules. A simplified view of the ENS communication infrastructure is illustrated in Fig. 2.



**Figure 2:** Communication infrastructure.

## 4.2 Integration

The ENS will be integrated in the CERN infrastructure at the substation level and at the general-supervision level. At the substation level this is done via the FE and GATED module, in some cases using the RTU as process interface. At the general-supervision level it is done via the GATEX module.

At the substation level, the FE will interface to electrical devices via multiple protocols and communication interfaces. These include INSUM, JBUS, MODBUS, SPABUS and proprietary protocols over RS-485 multi-drop serial buses, implemented for device-specific applications unique to each equipment type.

The GATED will provide a single IP-based communication interface to all equipment, which is already interfaced via the CFE. This communication interface will be based on the communication standard IEC 60870-5-101, which is an international standard for data transmission related to electrical process control.

At the general supervision level the Collaborative Component Bus (CCBus) [2] will provide an off-the-shelf communication interface facilitating integration with any external supervision system. The data exchange of the CCBus is based on a publish-subscribe paradigm and implemented via a CORBA-compliant event bus.

## 5 ORGANIZATION

The complete ENS system will be delivered under a supply contract with an external manufacturer. This manufacturer has developed and installed similar systems for other clients operating electrical distribution networks.

The full development and configuration of the system is the responsibility of the manufacturer, who will also perform commissioning and all tests on and off the CERN site.

CERN plays an important role in the engineering of the general system and in particular in the database design used for the system configuration. The equipment specialists, who will ultimately use the ENS for operation of the electrical network, have an important role in the definition of data points and human interfaces.

## 6 CONCLUSION

The ENS will be installed in two phases. The first phase, which includes the main developments such as the GATED module, will be installed by the end of the 1999–2000 shutdown. The second phase, which will provide a complete industrial control system including the FE and RTU module, will be implemented during 2000.

Future plans for extensions include implementation of Distribution Management System (DMS) functions, such as contingency analysis and power-flow calculations.

## REFERENCES

- [1] R. Lauckner, P. Liénard, R. Rausch, Data communication infrastructure available at CERN for interconnection of industrial control systems, 1997.
- [2] P.S. Viegas, CCBus interface to external clients, EFACEC Sistemas de Electronica, Ref. 4ET997001.