eXPert Run-Time Environment

Product description

Document Revision List

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1. Introduction

1.1 Purpose and scope of the document

This document describes the functions of the **eXPert** system's real time environment software.

The **eXPert Run-Time Environment** product is composed of a series of software components that can be distributed on local/geographical networks and configured according to specific plant requirements. Therefore, a detailed description is also provided of the architecture and features of the supervision, control and/or telecontrol systems for which they can be used.

For a description of the configuration tools that come with the **eXPert** system, please refer to the document *eXPert integrated development tools – product description.*

The hardware devices for acquisition and control produced by s.d.i. automazione industriale and integrated into the **eXPert** system are described in the document *eXPert field data acquisition and control – product description.*

1.2 The eXPert system

eXPert is the integrated environment created by s.d.i. automazione industriale (Sdi) for producing automation, control and telecontrol systems.

In its entirety, **eXPert** is a set of software and hardware products designed and manufactured solely by Sdi with the aim of providing integrators and OEMs with a complete and scalable solution capable of meeting all possible requirements in the field of automation.

eXPert includes the hardware apparatus (DCS, PLC, RTU) directly connected to the field, used for managing acquisition, regulation and control, and also the software for processing, storing and viewing the data acquired, which is designed for Windows 7 64bit, Windows Vista, Windows XP, Windows Server 2008 64bit, Windows Server 2003 32 bit, Linux Suse and Linux Red Hat.

The hardware equipments are grouped in the **eXPert STAR** products family (acronym that indicates STation for data Acquisition and Regulation). To this family belong the following products classes:

- **STAR DualBus** device class***:*** composed by CPU, I/O, regulation and communication rack mounted boards, for setting up modular DCS systems
- RTU devices for telecontrol system application and remote I/O acquisition (remote terminal blocks)
- Single board **microSTAR** and **nanoSTAR** equipment created especially for telecontrol applications

eXPert Run-Time Environment, on the other hand, is the package of software components used for setting up automation and control systems. It includes SCADA and HMI systems, data storage stations (Historian), I/O Servers for establishing connections with the field and managing (any) communication lines, and Soft PLC functions. The package includes a series of components dedicated to connectivity, used in telecontrol applications or, more generally, in control applications distributed over a geographical area. The tools for connection (hierarchical or relational) include SCADA stations, a Remote Alarming package for managing alarm notification (through telephone calls, SMS or e-mail) and a package for displaying plant synoptics via WEB (WEB HMI).

eXPert Engineering Station is a multi-user station that allows the whole system configuration. It includes a series of editors that allow configuration of all the components, both software and hardware, of the automation and telecontrol system. The main tools are the HMI graphic page editor, SCADA database editor (Point Editor), automation/regulation logics editor (Soft Logic Editor), the system architecture definition editor (Net Editor), the administration utilities of the data storage server (Historian) and I/O Server (I/O Server Admin).

eXPert can be provided as an integrated and proprietary system (if **eXPert** hardware equipment and software tools are used) or as a set of interconnecting components with equipment and systems produced by third parties.

When **eXPert** is used in integrated systems, the system's configuration and maintenance tools, contained within **eXPert Engineering Station**, are put to full use. This allows logic programming of **STAR** peripherals or Soft PLC stations and also configuration of the display, data storage and processing services provided by the SCADA/HMI systems, all from a single configuration station. The strong integration of these tools allows constant monitoring of the congruence of the configuration data inserted, particularly the accuracy of the I/O signals in relation to the hardware, and the congruence of the data present in the SCADA databases, video pages and archives.

In *mixed* systems, where hardware equipment produced by third parties are used or where integration with pre-existing SCADA and/or DCS systems is required, **eXPert** offers a range of solutions capable of meeting all possible requirements.

In order to interface with hardware produced by third parties, I/O servers are used, which allow interfacing with most PLCs or with telecontrol equipment that uses standard protocols such as IEC 60870-5-101(104), MODBUS, OPC and TCP/IP. The modular structure of I/O servers also permits rapid development, if necessary, of specific protocols that are not yet supported.

For integration with other SCADA/DCS systems, there are two options: APIs for direct interfacing with SCADA and with **eXPert**'s Historian, or OPC (Client and Server) and IEC 60870-5-101/104 interfaces.

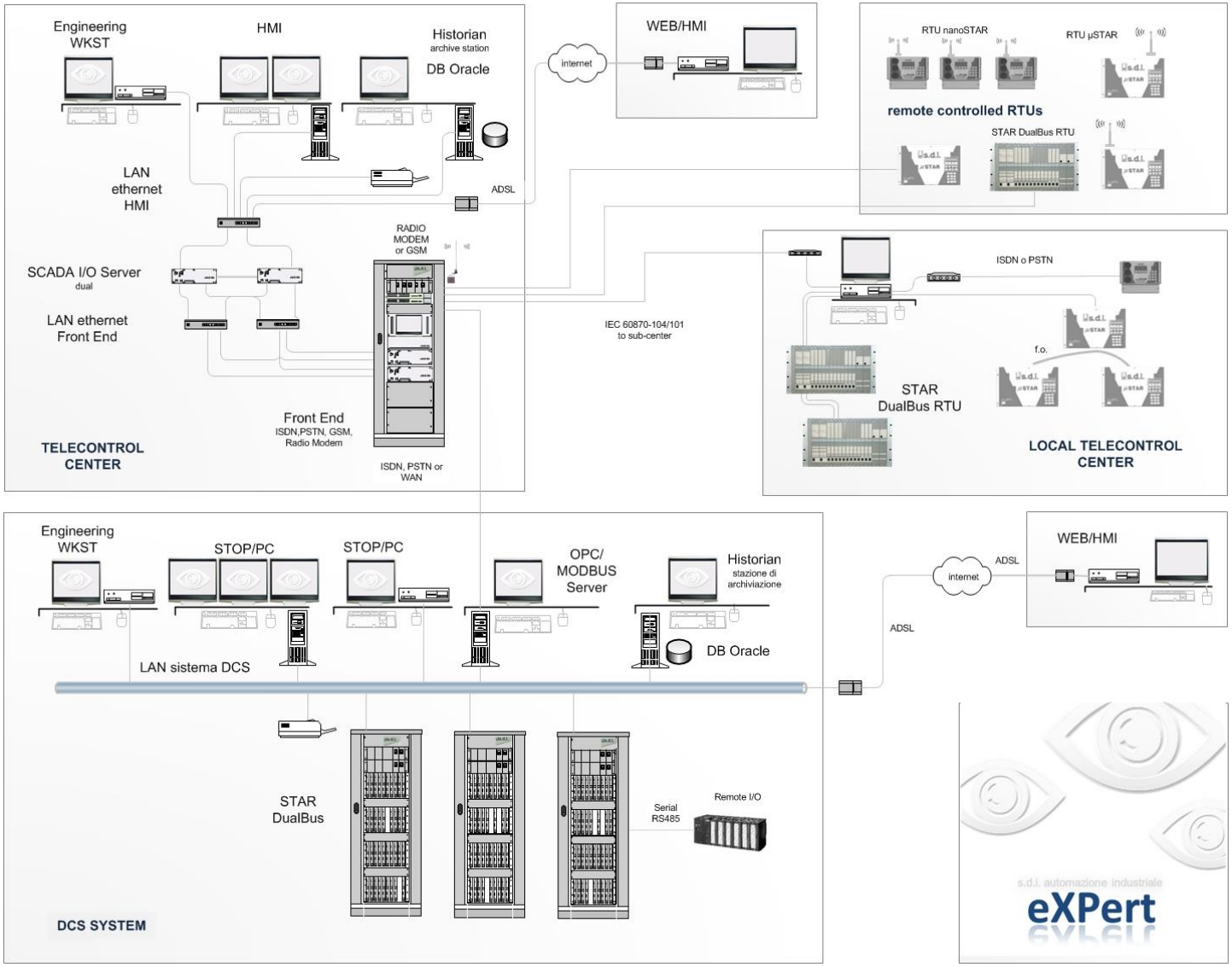

Figure 1-1: General architecture layout of eXPert system

The following tables briefly describe the components of the **eXPert** system.

eXPert Run-Time Environment	
SCADA Server	Main functions: dynamic plant database, alarm management, calculation and application management, and access servers for HMI functions or other external connections.
HMI Client	Performs human-machine interfacing (Human Machine Interface).
WEB HMI Client	Performs human-machine interfacing for WEB connections using standard WEB Browsers.
WEB HMI Server	Manages connections from remote HMIs connected via WEB to SCADA/Historian.
I/O Server	I/O server for managing the communication lines and/or field network. The package communicates with SCADA as a uniform interface regardless of the number and type of protocols managed.
Historian Server	Server for storing the plant's historical data.
SoftPLC	Functions for setting up automation and control logics on PCs. In this case, the PC interfaces directly with the field bus, which is connected to the acquisition equipment.
Reporting	Periodic and event triggered reports editing tools. The reports are based both on real time plant data and on historical data.
Connectivity	System connectivity components (API, OPC, OLE and DDE), connection between SCADA (SCADA data-link), HMI services via WEB (WEB HMI).
Remote Alarming	Telephone calls, text message (SMS) and e-mail services for contacting available personnel.
Disaster Recovery	Disaster recovery telecontrol centers management functions.

eXPert Engineering Station	
Engineering Station	Station supporting all configuration tools. It manages collaborative multi-user development of all system configuration aspects.
Development Tools	
Net Editor	System architecture graphical configuration
Point Editor	Configuration of the SCADA Run Time database and the I/O peripherals; definition of historical data archives.
Page Editor	Configuration of synoptic video pages.
Soft Logic Editor (GAPS and APS)	Logic and control functions editor according to IEC 1131.3 standard, using both graphical and textual languages.
Plant Editor	Object oriented configuration of the SCADA plant database.
Distributed Plant Loader	Distributed SCADA database configuration in system architectures composed by a central SCADA and multiple peripheral data concentrators (FEP).

eXPert STAR DualBus and telecontrol peripherals	
STAR DualBus DCS	Field controllers with modular architecture, which can be used in DCS systems. Connectivity via Ethernet TCP/IP.
STAR DualBus RTU	Field controllers with modular architecture, connected in series for automation, control and telecontrol applications.
microSTAR e nanoSTAR	Single-board field controllers with on board I/O, for telecontrol applications. Connectivity via PSTN or GSM telephone or integrated radio link.

1.3 eXPert's history and positioning

The **eXPert** product originated from PSCS systems created and installed by since 1979.

PSCSs (Plant Supervisory and Control Systems) are SCADA systems used for numerous applications of considerable size and complexity (supervision of thermoelectric power plants, supervision and telecontrol of natural gas production, storage and distribution, and training simulators). The factors that led to the creation of the **eXPert** system were Sdi's experience with these systems, diversification following the applications created in contexts such as telecontrol of gas, water and electricity distribution networks, and the need to make the system flexible for smaller-scale applications.

The move took place through the WIN/PSCS product versions and the STOP operator station which, in the 1990s, made it possible to create distributed PC-based systems using Microsoft Windows and/or UNIX operating systems, and to develop acquisition and regulation systems (**STAR** stations) for the creation of DCS (Distributed Control System) system architectures.

eXPert's main features are the freedom to build system architectures of varying complexity with the option of duplicating especially critical functions to achieve redundancy by breaking down the various functions into different network nodes, and the option of sharing (remotely via the Web or by connecting to relational databases) information acquired and/or processed by the plant. The spread of telecontrol systems has also led to the development of management of different kinds of telephone lines, management of call systems for notifying operators on duty of alarms, and the possibility for HMI clients to connect remotely via WEB or telephone line.

The simultaneous enhancement of **STAR** stations has made it possible, using **eXPert**, to construct complete DCS systems and telecontrol systems for equipment in problematic or critical areas, and to create control systems based on PCs and SoftPLC technology.

2. Architectures and Functions

2.1 Functions of the supervision and control system

Complete supervision and control systems can be created by distributing **eXPert Run-Time Environment**'s components between various PCs in network configurations that suit the application.

One of **eXPert**'s main features is the freedom to set the architecture of the entire system depending on the characteristics of the process being controlled and the specific requirements of the end user.

The heart of the system is composed of SCADA (Supervisory Control And Data Acquisition) Server and HMI (Human Machine Interface) components.

SCADA Server manages the dynamic process database, calculations, system logics and alarm database. HMI acts as a client in relation to SCADA, requiring only the data necessary to display the video pages displayed at that moment by the operator.

The alarms are managed through queries by the client (HMI) regarding the current alarm situation, which is controlled and kept up-to-date by SCADA.

Field data acquisition and protocol management are performed by the I/O Server component. When used in telecontrol applications, **eXPert** also provides functions for management of communication lines and protocols for peripheral acquisition and control equipment (I/O Server functions).

Historical data storage functions are provided by Historian Server, which allows various types of database to be used for storing historical data (from binary to SQL relational databases).

Below is a brief description of the functions performed by each component. For detailed descriptions of the individual SW packages, please refer to Chapter 5. and subsequent.

SCADA functions:

- Data acquisition or transmission from acquisition stations (**STAR** stations, PLCs, programmable controllers, regulators, etc.) via the field network;
- Creation of a dynamic system database (DBS) containing an image, updated in real time, of the data acquired from the plant or calculated by SCADA itself;
- Management of ordered and controlled access to the system's dynamic databases;
- Server functions in relation to additional HMIs and any other stations (PCs, Workstations, etc.);
- Standard calculations;
- Alarm detection;
- Alarm data storage;
- Alarm printing;
- Telephone calls or SMS/email to external operators in the event of an alarm;
- Management of plant devices;
- Command management;

- Daily Report printing;
- Production of printouts;
- Functions supporting application programs;
- Query interface for the access to dynamic system database from external systems via the network;

I/O Server Functions:

- Data acquisition or transmission from/to acquisition and regulation stations in continual connection (**STAR**s, PLCs, RTUs, programmable controllers, regulators, etc);
- Data acquisition or transmission from/to remote RTUs (e.g. **microSTAR** and **nanoSTAR** controllers) via the telecontrol network;
- Management of modems and associated communication lines;
- Management of round cycles and/or historical data acquisition on remote stations with non-continual connections;
- Acquisition of spontaneous data transmitted from remote telecontrol stations;
- Display of data acquired from local/remote SCADA stations, with interfacing that is independent of the type of protocols and lines being managed;
- Management of connection, line and peripheral device diagnostic
- Standardization and conversion of data originating from different types of equipment;

Historian Functions:

- Management of data storage in binary and/or relational files (through ODBC, ADO and OCI for Oracle DB);
- Server functions regarding requests for display and retrieval of historical data;

HMI Functions:

- Management of the HMI synoptics interface, on single or multiple monitors, with extensive use of colored graphics, Microsoft Windows-style windows, and numerous methods of accessing and presenting data;
- Video-wall management;
- Management of the graphic/interactive display of historical data stored by the station;
- Management of color hard copies, with the option of centralizing the printer;

SoftPLC Functions:

- Direct connection with the field Bus;
- Execution of automation logics;

Disaster Recovery Functions

- Process database alignment between primary and recovery centers;
- Configuration alignment of the two centers;

- Command management and taking over from recovery center.

2.2 Scalability of the system

eXPert Run-Time Environment makes it possible to create systems that differ in three areas:

- Functional distribution;
- Redundancy;
- LAN/WAN structure.

The most suitable choice of architecture will depend on performance considerations, reliability and the operational requirements of the controlled plant.

Any system upgrades or enhancements - from simple stand-alone configurations to distributed network or duplicated architectures – may be performed without modifying the system's applications (video pages, local databases, I/O peripheral settings, archives, etc.).

2.2.1 Functional distribution

The system consists of a set of nodes (PCs) connected to one another via TCP/IP LAN. The various functions of the supervision and control system (SCADA, HMI, I/O Server, etc.) can be activated on a PC dedicated to that specific function. Compact systems can also be created in which all the necessary functions coexist on a single PC.

This is the case with the *basic* configuration of the system, in which the SCADA, HMI, I/O Server and Historian functions are housed on a single PC.

The configuration functions (**eXPert Development Tools**) can also be activated on the same station.

2.2.1.1 HMI functions

The first level of functional distribution is normally performed by introducing network nodes dedicated to HMI functions, in order to make multiple operator stations available. In this case, the system must be enabled to HMI connections made using a company intranet or the internet.

Thanks to the client/server structure on which the connection between HMI and SCADA is based, it is possible to extend the system by connecting a maximum of 32 operator stations with HMI functions.

For telecontrol centers HMI function are also provided by the use of multiple matrix arranged screens. Appropriate functions allow sharing of plant synoptic main page and operating pages of interest among the operators.

The HMI stations can very easily be made remote using even relatively low speed telephone lines. This can be achieved by using the following architectures:

- The connection on the Ethernet network uses standard TCP/IP protocol and is therefore fully compatible with all the remote connection devices available in the context of Ethernet-TCP/IP (routers, repeaters, connectors, remote connections via modems, the internet, etc.);
- Only plant data necessary to animate the pages displayed at that moment is exchanged between the SCADA units and the HMI station. This data are transmitted in compressed binary format only when changed. Therefore, only

an extremely limited flow of data is necessary to refresh the video pages on the HMI station.

It is also possible to make HMI internet services remote by using WEB HMI Client.

This product allows plant data access, to remote located personnel, using a standard web browser. User identification (login) assign an account grant level (View Only, Operator Level, System manager, etc.) that automatically defines which type of operation is allowed

Each connected user can activate their own WEB HMI Client session without having to install special software on their own station or upload the latest changes to the operator interface configuration.

SCADA Server is capable of managing the various users and ensuring access to data in the dynamic database and the alarm database.

Alarms management allows concurrent user operations; user or plant area specific alarms databases can be defined, a locking/unlocking mechanism for simultaneously used alarms page is provided.

All access to the supervision and control system, are managed centrally on a server (WEB HMI Server station) where are also performed maintenance tasks on synoptic pages... This station may be the same dedicated to SCADA functions or it may be a special station connected to SCADA through the local network. The choice depends on performance considerations relating to the size of the supervision and control system and the number of planned user connections.

A single station, normally referred to as Engineering Workstation, performs configuration and development tasks (**eXPert Development Tools**). It updates all relevant PCs with the changes made (take, for example, the changes to video pages used by various HMI users).

Access to the Engineering Workstation is allowed also in Client/Server mode allowing multiple users simultaneous access to the configuration functions.

Generally, if only single-user mode is needed, the function of configuration station can also be performed by any of the HMI units or a SCADA/HMI station.

2.2.1.2 I/O Server functions

I/O Server is normally used from the same PC that hosts SCADA functions. The I/O Server functions are implemented from dedicated PCs in cases where the system is strongly oriented towards management of a large number of communication lines to automation and regulation peripherals or where several types of network and/or protocol coexist and the system is required to be structured according to modular criteria.

I/O Server interfaces with the automation and control peripherals. It carries out specific communication protocols and also functions as manager of the communication lines, optimizing allocation of the available lines (line pool management) and performing regular diagnostics on the functioning of these lines.

All diagnostic information, related to communication lines and data acquisition quality are communicated by I/O Server to SCADA.

Several PCs may be used, each dedicated to communication with specific field devices or else specializing in connection to the different specific types of protocol or communication method used.

It is possible to use up to a maximum of 12 I/O Server stations (single or dual) in a system, all connected to the same SCADA node.

2.2.1.3 Historian functions

Often, historical data storage functions are restricted to dedicated stations (PCs). With **eXPert**, however, it is possible to structure the data storage system in a very flexible way.

Up to 4 data storage stations can exist simultaneously, and 4 archive managers of different types can be activated on each of them.

In this way it is possible to create *mixed* data storage systems in which, depending on requirements, *file-based* archives, as opposed to relational databases, can be used.

Where relational databases are used, a PC with specific database server features (RAID disks, multiprocessor architectures, cluster configuration, etc.) is often used.

2.2.1.4 Soft PLC functions

If the system's automation functions are created as Soft Logic executed on PCs, there is a general tendency to dedicate a PC to these functions, so that the necessary performances for execution of the logics themselves may be guaranteed.

Nodes with soft PLC functions are connected to the SCADA station through special I/O Server software. These nodes are seen as parallel to an automation and regulation station.

2.2.2 Redundancy

Redundancy is implemented to increase the reliability of the system and to allow maintainability with no functional interruptions.

In this type of configuration, all the individual units whose failure could result in loss of fundamental system functions are duplicated.

eXPert software is designed especially to manage such duplicated (dual) architectures, so that both twin units function in parallel and the loss of one of the units does not cause even the slightest disturbance to the running of the system. This functional method is commonly known as *Master/Slave dual, with hot back-up units*.

The duplicated functional units should be:

- SCADA;
- I/O Server;
- Historian;
- SoftPLC;
- Remote Alarming;
- Reporting.

Management of redundancy is the same for all functional units; it can be achieved using a watch dog function managed by the two SCADA using the network connection, or using an external master/slave arbitration unit.

In this last case, a special external unit, called iEWDS (Intelligent External Watch Dog and Switch), connected to the PCs via a serial line, monitors the correct running (in terms of both software and hardware) of the two units and automatically selects one to assume the role of Master.

This same external unit is capable of switching the individual peripherals (normally printers, serial communication lines and USBs) to the Master unit. The switch is fully automatic and occurs in a way that is completely transparent to the operator and causes absolutely no loss of plant control.

The Slave unit is kept constantly up-to-date through a special 100 Mbit network connection between the two PCs[1].

Some units may have more than one of the functions listed above (a typical example is a unit with both SCADA and I/O Server functions). In this case, redundancy is configured and the correct performance of all the functions (e.g. diagnostics on the functioning of SCADA and I/O Server) is monitored using the same master/slave arbitration mechanism.

The use of redundancy can also be extended to the acquisition peripherals, if they allow it. In this case, **eXPert** manages the field LAN connection of the dual peripherals (e.g. duplicated PLCs or **STAR** stations in dual redundant configuration).

2.2.3 Redundancy for systems with Disaster Tolerance features

A particular method of managing dual SCADA and I/O Server systems is provided for systems whose architecture requires that units with SCADA (and/or I/O Server) functions are localized in different sites in order to ensure functional continuity in the event of disasters.

In this case, a main center (primary) and a recovery center (secondary). are defined.

The SCADAs of the two centers (which are generally both in redundant configuration), to continuously update and align process data and configuration, use additional messages exchanging functions through a single or dual Ethernet connection that links the two remote sites

The alignment covers the following functional areas:

- Configuration alignment;
- Dynamic database alignment;
- Historical database alignment (ORACLE database).

The ordinary operation of the recovery system provides for the alignment of all three functional areas defined above.

The control of the plant is generally made from HMI stations connected to the primary center, but can also be implemented customized applications that use a policy that provides dynamic transfer of competences between secondary and primary center connected HMI stations.

[1] In less critical cases, the system network or field network can be used directly for the connection between Master and Slave.

2.2.4 LAN/WAN structure

The system may be structured according to different architectures with regard to the local network connections of the nodes constituting the automation system.

In general, the system can be schematized according to a three-tier structure (Figure 2-1): one LAN is used to connect the SCADA system, HMI and Historian stations (system LAN), a second LAN is used for the connection between SCADA and stations dedicated to I/O Server, and the third is the field network, used for input/output signal traffic relating to the I/O Server. The latter can be composed of a field LAN and/or telephone connections to the telecontrol equipment (Communication Subsystems).

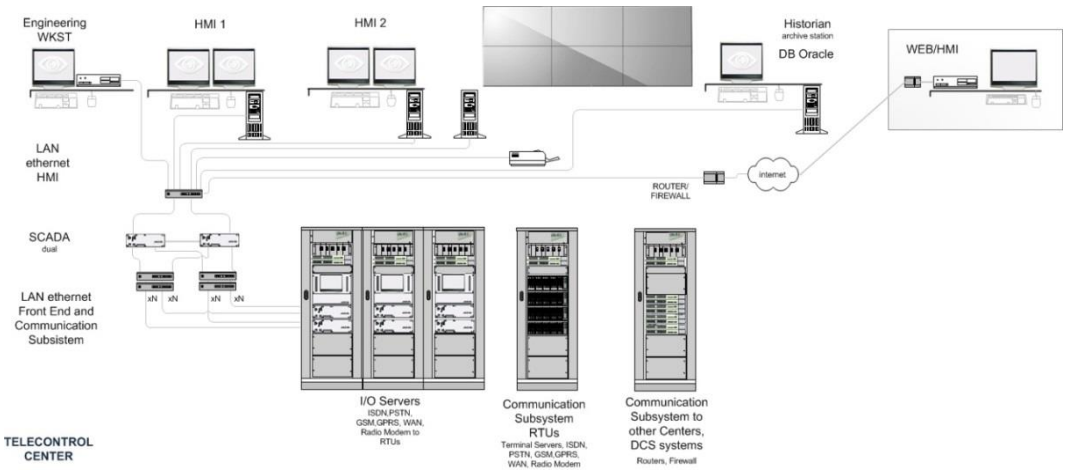

Figure 2-1: Use of a three tier network structure

With **eXPert**, double networks can always be used. For functional units in dual configuration, each PC can be equipped with a double controller for connection with other functional nodes.

In all cases, the use of double networks is completely managed by the system, with no need to modify the application information (point databases, pages, etc.).

The standard 10/100 Mbit/s Ethernet or Gigabit Ethernet (1 Gbit/s) is used for the system LAN, and a TCP/IP *transport* level protocol is used.

The system LAN, seen purely at TCP/IP level, is also the point of connection with external users (PCs, Workstations, Mainframes, etc.) which need to access the plant database in the SCADA units.

Being, for all intents and purposes, an Ethernet TCP/IP local network, any type of device designed for these network architectures (Bridge, Router, Hub, standard converters, etc.) can be implemented by creating distributed configurations via the WAN.

2.2.5 Examples of architectures

The diagram in Figure 1-1 is a compendium of the different types of architectures that can be constructed using the **eXPert** system.

A system in *basic* configuration is shown in the central right section (local telecontrol center). It is a single SCADA - I/O Server - HMI station that acquires from peripheral equipment (in this case, **STAR NTA** stations connected to a serial line in multidrop mode). The same station acquires signals from telecontrol equipment connected remotely via modems and switched telephone and local lines (serial line).

The system that occupies the rest of the diagram consists of a pair of PCs in dual configuration, which host the SCADA and I/O Server functions. The system acquires (through I/O Server functions) from a series of **STAR OHP** cabinets.

Also, for acquisition from telecontrol equipment (**microSTAR** and **nanoSTAR**), there is a cabinet containing two PCs in dual configuration and a modem battery which, together, perform the function of I/O Server dedicated to the telecontrol part of the system.

The system includes the HMI stations connected to the system network and a WEB HMI connection via the internet.

Note the use of duplicated networks, both for the system network and the field network which connects the **STAR OHP** equipment.

From this diagram, simpler LAN-based architectures can be deduced in single configuration, or the dual components (SCADA and I/O Server) can be made single.

2.3 Management of printing devices

The **eXPert** system ensures extremely accurate management of the printing devices for the documentation functions involved in the running of the plant (*Daily Report*) and in reporting.

The printing devices (if there are more than one) can be configured in such a way as to automatically compensate for the failure of one of them ("fail over" strategy). All the prints jobs sent to the non-functioning devices are automatically redirected by the system to one or more alternative tools until the faulty tool is back online.

Up to 8 printers with Daily Report and/or Printout functions can be connected. The printers can be connected to any of the SCADA units or any other unit connected to the system LAN. The printers can therefore be connected:

- To the system LAN through printer servers;
- Centrally to the SCADA units;
- Locally to the HMI units or to any networked PC;

Serial printers (RS232 or USB) connected to the SCADA unit in dual configuration are automatically switched to the Master unit through the iEWDS unit or using Terminal Server devices.

The printers can act as local or networked hard copies (shared by several HMIs).

2.4 Archiving based on relational database

The recording functions related to on alarms, events and plant data make use of a relational database (the default is Oracle)

The database in particular contains:

- Events;
- SOE (also called RCE);
- Measures and signals archives.

In addition the configuration of plant's reports, allows the creation of periodical or event-triggered reports files which are saved on disk.

All these functions are carried out typically using, for safety reasons, doubled storage media (RAID Disks).

2.5 Connection with field devices

The exchange of data between SCADA and the field devices, as previously illustrated, is managed by the I/O Server component. I/O Server implements all the particulars of the protocols, presenting SCADA with an interface that is uniform and completely independent of the specifics of the protocol itself. Also, in the case of connection to switched telephone lines, I/O Server manages the telephone calls and the optimizes allocation of the available communication lines (a configuration common to telecontrol applications).

The connections between I/O Server and the field can be duplicated. In this case, two parallel networks are used, controlled by the system's components including those not in dual configuration. If a component is in dual configuration, each of its sections can control either one or both the dual networks, creating, in the latter case, an extremely reliable structure.

More than one I/O Server can be used simultaneously (even on the same PC), creating connections with field devices through different types of transmission media and protocols.

The modular structure of the I/O Server component allows fast implementation of particular protocols that are not yet available.

The main protocols for which I/O servers are available are:

- IEC 60870-5-101, IEC 60870-5-104;
- IEC 61850
- MMS UCA 2;
- OPC Client/Server;
- MODBUS RTU/ASCII/TCP;
- SELTA SASP/SAMP,SELTA TIC1000;
- SIEMENS S5 AS511;
- SIEMENS S7 Ethernet TCP/IP (Send/Receive);
- FIP;
- SDI INET,AA55; 870-5;
- SNMP;
- SQL.

2.6 Telecontrol applications

Telecontrol applications normally use a system architecture in which more than one I/O Server and multiple types of transmission media/protocols are used.

This architecture is commonly used for connecting RTU (Remote Terminal Unit) telecontrol equipment. Where Sdi equipment is used, this architecture is typically used for connecting to remote **microSTAR**, **nanoSTAR** or **STAR NTA** stations

The suggested default protocol for connecting to dedicated lines is IEC870-5-101, in the case of WAN TCP/IP it is IEC 60870-5-104. The same protocol, with special variations, is used for switched (PSTN, GSM, ISDN) or radio modem lines.

In applications of this type, there are normally RTUs which connect to the control system by telephone, thus creating a discontinuous connection. The system allows optimal management of connections of this type. Firstly, the query rounds of groups of peripherals can be set for specific times and dates. Secondly, it is possible to set which

conditions of the status of the acquired variables should cause the peripheral to spontaneously call the telecontrol centre.

It is possible to configure telecontrol networks using:

- Switched PSTN, GSM or ISDN telephone lines or lines which use radiomodems;
- Dedicated telephone lines;
- Dedicated radio-linked lines;
- GPRS/UMTS connections;
- WAN TCP/IP connections.

Depending on the number of lines configured, it is possible to configure one or more units (PCs) dedicated to the communication lines and protocols. The I/O Server component is installed in each unit and manages a particular type of line and protocol. These units are connected to the Ethernet TCP/IP network and can be supplied in single or dual configurations. In less complex cases, it is possible to equip the same unit that hosts the SCADA component with I/O Server functions.

The **microSTAR** stations can be connected to one another in fiber optic networks. In this case, one of the devices, named Master Terminal Unit, (MTU) assumes the role of data concentrator and deals with communications with the telecontrol centre and execution of the local network control/command logics. The other **microSTAR**s (RTUs) function as remote terminal blocks.

Remote stations produced by third parties can be connected using the appropriate version of I/O Server depending on the protocol used by the equipment.

2.7 Integration with other systems

Integration with other SCADA/DCS systems or with external applications is possible using the **eXPert** connectivity components supplied with the **eXPert** system (named **eXPert Connectivity**).

Connection methods can be chosen from the following, depending on the features/requirements of the system to be integrated:

- Use of the APIs supplied by the **eXPert** system which, through the TCP/IP protocol, provide secure and controlled access to the entire SCADA database;
- Use of standardized Web Services based services, that provide access, in a secure and controlled way, to the whole SCADA system database, using a TCP/IP connection.
- Use of OPC interfaces (Client and/or Server) for connecting OPC compatible systems;
- Use of IEC 60870 and/or MODBUS protocols for the connection with telecontrol centers and with other automation and control systems:
- Use of relational databases used by Historian as an area for sharing data with other (mainly management) applications;
- Use of the toolkit for managing interconnected SCADA networks (SCADA data links). The toolkit makes it possible to configure and manage connections between interconnected SCADAs in generic or hierarchical network architectures.
- Proprietary protocols that can be developed for specific applications.

3. System hardware requirements

3.1 General information

eXPert is based on Microsoft Windows (supported versions are Windows 7, Windows Vista, Windows XP, Windows2008 Server and Windows2003 Server) and Linux operating systems for the SCADA and I/O Server components. The HMI and **eXPert Development Tools** components are available for Microsoft Windows operating systems only.

The things to consider as far as the type of hardware and supported peripherals, are issues of compatibility with the operating system itself (performances aside).

The latest generation of compatible PC processors and Windows accelerating graphic cards, with increasingly high performances and resolutions, are immediately usable in the hardware platforms for the units comprising the **eXPert** system.

The system's local network communications, provided in **eXPert** distributed systems, comply with the LAN standard currently most widespread on the market: Ethernet IEEE 802.3 or 802.3u, with TCP/IP protocol.

Since the processing units are based on hardware configurations compatible with standard PCs, **eXPert**-based systems can be supplied using the entire range of hardware solutions currently available on the market, such as:

- Commercial PCs;
- Industrial PCs;
- Server class PC;
- Industrial Bus-based PCs (VME,VXI. etc.);
- Compact PCs based on industrial standards (CompactPCI or PC/104);
- Single board computer (SBC) PCs;
- Box PC.

From a physical point of view, an **eXPert** supervision and control system can be broken down into the following subsets:

- Processing units (one or more compatible microcalculator PCs);
- Historical data storage devices (often integrated in elaboration units using RAID disk array).
- (if required) Devices for managing duality (iEWDS): i.e. devices with hardware logic that perform the functions of watch dog, Master/Slave unit selection and peripheral switching (in dual systems only);
- Network devices such as hubs, switches, firewalls and routers;
- Devices for managing the communication lines (modems, radio-modems, ...).

For HMI units, each PC is equipped with (multi)video, keyboard and pointing device (mouse or trackball), chosen according to the type of use and the environmental features of the installation site (e.g. degree of IP65 protection required).

For all other units, in the case of rack installation of dual systems, use of a single video + keyboard, connectable through a KVM switch to the various PCs comprising the SCADA, I/O Server and Historian Server group, is generally preferred.

The system can also include:

- Videowall for plant synoptic representation
- Black and white printers for Daily Reports and/or printouts;
- Graphic color printers with local or centralized video operator hard copy functions.

3.2 Processing units

The processing units are based on compatible Personal Computer microprocessor systems.

The features of the units can vary according to the functions they have to perform.

Below we give some indicative guidelines.

3.2.1 Units with SCADA functions only, with I/O Server functions only or with integrated SCADA and I/O Server functions

The units that have to perform the above-mentioned functions must have the following **minimum features**:

- CPU Intel I-5 2,70 GHz;
- RAM memory 4 Gbytes;
- Hard disk 160 Gbytes;
- SVGA video controller or higher (XVGA, UVGA, etc.).

Integrated cards and devices:

- Single or dual network controller for field LAN (Ethernet 100/1000 Mbps, copper or optical fiber);
- Single or dual network controller for the system network (Ethernet 100/1000 Mbps, copper or optical fiber);
- 100/1000 Ethernet controller in dual versions for Master/Slave connection (optional);
- 1 serial available to pilot the iEWDS unit (for dual versions with external watch-dog only);
- One or more multi-serial cards for I/O Server with serial line management (for telecontrol via modem and I/O Server functions only).

Operating systems: Windows 7, Vista, Windows XP, Windows 2008 Server, Windows 2003 Server, Linux Suse, Linux Red Hat.

3.2.2 Units with SCADA SERVER functions

We indicate with the name SCADA SERVER, the stations that are used for large applications (eg. remote controlled power distribnution and transmission grids) or that have to provide however, for specific reasons, a server-class hardware and operating system. The units that have to perform the above-mentioned functions must have the following **minimum features**:

- Intel Xeon 2,4 GHz;
- RAM memory 4 Gbytes;

- Hard disk 300 Gbytes (RAID arrays are suggested if local data archiving functions are provided)
- SVGA video controller or higher (XVGA, UVGA, etc.).

Integrated cards and devices:

- Single or dual network controller for field LAN (Ethernet 100/1000 Mbps, copper or optical fiber);
- Single or dual network controller for the system network (Ethernet 100/1000 Mbps, copper or optical fiber);
- 100/1000 Ethernet controller in dual versions for Master/Slave connection (optional);
- 1 serial available to pilot the iEWDS unit (for dual versions with external watch-dog only);
- One or more multi-serial cards for I/O Server with serial line management (for telecontrol via modem and I/O Server functions only).

Operating systems: Windows 2008 Server, Windows 2003 Server, Linux Suse, Linux Red Hat.

3.2.3 Units with SCADA and HMI functions

If the unit has HMI functions as well as SCADA functions, it is advisable to equip the central units with the following **minimum features**:

- CPU Intel I-5 2,70 GHz;
- RAM Memory 4 Gbytes
- 160 Gbytes Hard disk;
- SGVA video controller or higher (XVGA, UVGA, etc.) with minimum recommended resolution of 1024x768 with 256 colors.

Integrated cards and devices:

- Single or dual network controller for field LAN (Ethernet 100/1000 Mbps, copper or optical fiber);
- Single or dual network controller for the system network (Ethernet 100/1000 Mbps, copper or optical fiber);
- 17” color monitor (or larger), compatible with the video controller;
- Standard PC keyboard in types for industrial use if required (IP65 protection with integrated pointing device if desired);
- 10/100/1000 Fast Ethernet controller in dual versions;
- 1 serial available to pilot the iEWDS unit (for dual versions with external watch-dog only).

Operating system: Windows 7, Windows XP, Windows Vista, Windows 2008 Server, Windows 2003 Server.

3.2.4 Units with HMI function only

Units with only HMI function require the following **minimum features**:

- CPU Intel I-5 2,70 GHz;
- RAM Memory 4 Gbytes;
- 160 Gbytes Hard disk;
- SGVA video controller or higher (XVGA, UVGA, etc.) with minimum recommended resolution of 1024x768 with 256 colors.

Integrated cards and devices:

- Single or dual network controller for the system network (Ethernet 10/100/1000 Mbps, copper or optical fiber);
- 17” color monitor (or larger), compatible with the video controller;
- Standard PC keyboard suitable for industrial use if required (IP65 protection with integrated pointing device if desired).

Operating system: Windows 7, Windows Vista, Windows XP.

3.2.5 Units with Developoment or HMI/Development function

Units with Development or HMI/Development function require the following **minimum features**:

- CPU CPU Intel I-5 2,70 GHz;
- RAM Memory 4 Gbytes;
- 160 Gbytes Hard disk;
- VGA video controller or higher (SVGA, XVGA, etc.) with minimum recommended resolution of 1025x768 with 256 colours.

Integrated cards and devices:

- Single or dual Ethernet 10/100 o 10/100/1000 controller for the system network;
- 17” colour monitor or larger, compatible with the video controller;
- Standard PC keyboard with pointing device (mouse, trackball, etc.).

Operating system: Windows 7, Windows Vista, Windows XP.

Table 3-1 summarizes the minimum features required of processing units:

Station type	CPU (Minimum)	RAM (GB)		HD (GB)		Operating System
		Minimum	Suggested	Minimum	Suggested	
SCADA WINDOWS	Intel I-5 2,70 GHz	4	4	160	160	Windows 7 Vista, Windows XP
SCADA WINDOWS SERVER	Intel Xeon 2,4 GHz	4	4	300	300	Windows 2008 Windows 2003 Server
SCADA LINUX SERVER	Intel Xeon 2,4 GHz	2	4	300	300	Suse Linux Enterprise Server
SCADA/HMI	Intel I-5 2,70 GHz	4	4	40	160	Windows 7, Vista, Windows XP
HMI	Intel I-5 2,70 GHz	2	4	40	20	Windows 7, Vista, Windows XP
Development	Intel I-5 2,70 GHz	4	4	160	300	Windows 7, Vista, Windows XP

Table 3-1: Minimum features required of processing units

3.3 Monitor

Color monitors of any type, technology and size (from 17”), with the following features, can be used:

- compatible with VGA, XGA standard or higher, and compatible with the operating system in use;
- maximum distance of approx. 4 m. from the HMI unit, or up to 40 – 60 m. using suitable adaptors;
- resolution that can be set depending on the graphic controller/monitor combination.

By using special multi-monitor graphic controllers (or more than one graphic controller installed on the same unit), it is possible to equip each individual HMI station with 2 or more monitors that can be used separately or as one single monitor (sum of the individual ones) on which video pages of appropriate sizes can be displayed.

3.4 Videowall

An HMI station can be used to drive a video wall for the realization of a large synoptic.

A typical configuration consists of an array of 4 or more monitor with a single monitor resolution of 1600x1200 (ratio 4:3) or 1920x1080(16:9).

The following types of monitor are supported:

- LCD or LED-backlit LCD with thin edges used side by side (recommended for applications such as traditional synoptic);
- Borderless rear projection modules (recommended for applications such as control rooms for videowall H24);
- Video projectors (available in LCD or DLP).

HMI allows to use the entire area of the video wall or to subdivide it into different areas used for displaying different kinds of information; also is possible to reserve some areas for displaying images from a video camera.

3.5 Keyboards and pointing devices

For HMI stations, any keyboard of standard size and any pointing device available on the market can be used, provided that they are compatible with the operating system in use.

Depending on requirements, it is possible to use either ordinary mice/keyboards or industrial devices with a high degree of protection (IP65), membrane or traditional keys, trackball or built-in mini-joystick, etc.

3.6 System printers

The **eXPert SCADA** system manages up to a maximum of 8 system printers. The exact maximum number depends on the configuration of the station and the hardware installed on each unit.

In general, the printers can be connected, as desired, to:

a) The system Ethernet network, if equipped with internal network interface or printer server;

b) Using a dedicated unit equipped with a single or double Ethernet controller for connection to the single or double system network.

c) The units with HMI functions.

Method b) ensures printer function in dual architecture systems with double system network.

Method c) requires correct functioning of the HMI unit to which the printer is connected.

The system printers are dedicated to specific functions such as:

- Alarm/event log printing;
- Producing Printouts.

Often, line printers are supplied on continuous module with impact ink-jet technology. In particular, the “alarm/event log” function must have a “line” type as opposed to a “page” type printer so that the printing of an individual line of the alarm/event log is immediately visible without having to wait for the previous page to be filled before printing takes place.

It is possible, however, to use any type of printer, including a page type one, provided that it is supported by the Operating System. In this case, of course, the alarm/event log is only printed out when a whole page has been filled.

3.7 Hard Copy printers

The station can be equipped with one or more color or black and white printers with hard copy functions of synoptic video pages displayed on the monitors of units with HMI functions.

The printers can be connected to any unit provided that it is equipped with a suitable interface, normally an USB port.

Each printer can have the following hard copy functions:

- *Local:* dedicated to the video of the HMI station to which it is connected;
- *Centralized:* with the hard copies of several HMI stations sent to it.

It is possible to request printouts of hard copies of the entire video screen, of parts of it or with inverted colors (useful for pages with a black background). Networked hard copy printers can share the function of producing printouts.

4. Software Components of the System

4.1 eXPert Run-Time Environment software packages

eXPert Run-Time Environment comprises the following packages:

- SCADA Server;
- I/O Server;
- Historian;
- HMI Client;
- WEB HMI (Client and Server);
- Report;
- Remote Alarming;
- Connectivity;
- Soft PLC.

The **SCADA** server package constitutes the basis of **eXPert Run-Time Environment** and performs the normal Supervision and Control functions. It is responsible for management and updating in real time of the plant's live databases.

I/O Server is the package dedicated to acquisition functions and, when used in telecontrol applications, management of communication lines. The package is available in different versions depending on the hardware to be interfaced with and the protocols/communication methods used.

Historian is the data storage server that permits storage of historical data in multiple archives of different types, from storage in binary archives to recording in relational databases.

The **HMI** and **WEB HMI** packages are responsible for the sole function of managing human-machine interaction (for WEB HMI, the system is displayed by access from remote stations via the internet or intranet).

Reporting manages the production of printouts on local or networked printers or via e-mail. Printouts, or "reports", can be produced cyclically, on event or at the operator's request.

Remote Alarming is the package that manages alarm calls and assigns them to contactable personnel. Various types of notification are managed: telephone calls, text messages (SMS) and e-mails.

Connectivity consists of a suite of software components used for connecting and/or integrating the **eXPert** system with other systems. It includes Web Services, OPC Client and Server, API and support functions for the creation of interconnected SCADA networks, IEC 60870-5-104 Server, SNMP Server for diagnostic functions.

Soft PLC is the software that performs PLC functions on a PC that interfaces directly with devices connected to field buses (remote terminal blocks).

Historian Viewer & Backup is the web-based application for consulting, extracting in exchange formats, and reporting on archived data, SOE sequences and recordings in the alarm/event log. Together with the backup module allows you to make periodic copies of the system data and alarm list/events so you can store off-line information of DB and prevent loss of data due to recirculation overwriting; also allows you to re-import information to be displayed in the Historian Viewer module.

4.2 Configurability of the eXPert system

For system configuration functions, special tools available on the **eXPert Engineering Station** are used. The tools constitutes the **eXPert Development Tools**[2] product suite.

The **eXPert** system is fully configurable by the user in order to meet all possible requirements for the running, supervision and control of the plant and general human/machine interaction.

The development tools allow coordinated and integrated configuration of all the **eXPert** system's functions, independently of the hardware structure chosen for the system. This means that congruence tests are always carried out on the shared resources used by the various components (for example on the use of database variables, the congruence of the I/O variables with the acquisition hardware configured, etc.). In addition, the procedure for updating the new configuration of affected system components is fully automated, for components used in both single and duplicate configuration.

Most of the configuration functions take place while the system is running ("on-line" configuration function) and the activation of the modifications implemented does not cause any loss of system function or reduction in performance.

All **eXPert Engineering Station** functions can be installed directly on the SCADA station, on one of the PCs with HMI functions or on a dedicated station (development station).

The configurable elements of the system are:

- The overall system structure and deployment of the different **eXPert** functions on the various nodes constituting the system
- Type and quantity of acquisition/control equipment;
- Signals acquired from and to the field (digital and analog signals, counters, commands, set points, etc.);
- Handling of acquired signals (alarms, thresholds, validity, etc.);
- Functions relating to rounds and methods of use of communication lines for telecontrol peripherals;
- Analog and digital calculations on acquired signals and/or on the calculations themselves (averages of various types, derivative, integral, logic functions, etc.);
- Video pages (plant synoptics, pages with preset structures);
- Access to the station's functions via video and keyboard;
- Alarm/events log;
- Reports;

[2] For a description of the configuration tools, please see the document *eXPert development tools – product description*. This chapter describes the general considerations regarding the supplied functions and their impact on the automation and control system.

- Historical data storage (continuous, on event, by two different sampling rates, etc.) in binary and/or relational databases;
- Alarm management by telephone calls, text messages (SMS) or e-mails to contactable personnel;
- Logics and regulations applied to the acquisition stations, Soft PLC nodes or the SCADA system;
- Flow of data between SCADA systems interconnected through flat or centre/sub-centre architectures;
- General connectivity services with external systems.

The configuration functions can be used even while the system is running, also from client stations remotely connected to the Engineering Station, with complete support of concurrent use of development tools.

The development station therefore operates as a fully online engineering station. It is possible to add, modify or cancel functions, from a HMI/Development station, which assumes the role of configuration station or station dedicated exclusively to development tools.

Its capacity to update the system while the functions remain active is used in a specific way to facilitate development and updating over time. It is of paramount importance, in the interest of correct and effective management of the plant, to begin with a system with a simple and reliable operator/plant interface that can be progressively modified, enlarged and made more sophisticated (both in terms of hardware configuration and, above all, in terms of configuration of the functions of processing, organization of the plant's layout and methods of human-machine interaction). These modifications normally have the purpose of adapting the system to new plant requirements and/or enabling it to efficiently provide an increasing quantity of information.

5. SCADA

5.1 General information

The term SCADA (acronym of Supervisory Control And Data Acquisition) is used in this context to describe software that, in an **eXPert** system, performs the basic functions of plant supervision and control, with the exclusion of pure human/plant graphic interface operations (HMI – Human Machine Interface).

SCADA functions relate to a dynamic database that contains all the plant data, updated in real time. This applies both to data acquired from the acquisition/control stations (programmable controllers, PLCs, etc.), and data calculated internally by the SCADA functions or supplied by any external systems connected to the network.

The main functions of SCADA software are:

- Creation of a dynamic system database (DBS), containing the image, updated in real time, of data acquired from the plant and calculated by SCADA;
- Creation of up to 6 dynamic alarm databases[3] (DBAs), containing the image, updated in real time, of the following alarm types:
  - Plant alarms;
  - Alarms calculated by SCADA;
  - Alarms generated by external applications;
  - Internal system alarms (online diagnostics);
- Access to the dynamic system databases by HMI software;
- Access to the dynamic system databases by application programs;
- Access to the dynamic system databases by general programs activated within SCADA;
- Access to the dynamic system databases by external applications via the network;
- Data acquisition and transmission of commands, in real time, from/to the acquisition/control equipment connected to the field network;
- Data acquisition and management by SOE equipment;
- Data acquisition and transmission of commands from/to the telecontrol equipment according to the configured methods;
- Data acquisition and transmission of commands, in real time, from/to equipment produced by third parties (PLCs, controllers, etc.);
- Standard calculations;
- Alarm notification;
- Alarm data storage;
- Alarm printing and storage;
- Alarm management through display, acknowledgement, acoustic signal emission, etc.;

[3] The number of DBS can be increased upon specific customer request for particular applications

- Alarm management through telephone calls, text messages (SMS), e-mails and vocal alarm notification and acknowledgement by DTMF keyboard;
- Management of system components;
- Command management;
- Daily report printing;
- Production of printouts;
- Production of SOE printouts;
- Management of historical data archives, SOE archives, etc.;
- Support functions for user application programs;
- Server interface for accessing, reading and writing to the DBS and archived data.

SCADA software uses the operating system's *multithreading* functions to guarantee correct performances and scheduling, whatever the plant's configuration and situation. Particularly beneficial is the ability to assign strict priorities to the different operations depending on their importance in the running of the plant.

5.2 Dynamic database (DBS)

In the dynamic database, called DBS, the values and current statuses of the plant variables (called points) acquired from equipment connected to the field network (acquisition/control stations, PLCs and RTUs) are saved and updated in real time.

The values and statuses of the variables that the SCADA station sends to the field equipment are maintained in the same way.

DBS points can be subdivided into the following general categories:

- Points acquired from the field (digital measurements and signals);
- Points sent to the field (digital measurements and commands);
- Points calculated within the station, depending on other points in the DBS (measurements, digital statuses, complex digital statuses and alphanumeric strings);
- Points calculated by external applications (measurements, digital statuses, complex digital statuses and alphanumeric strings);
- Diagnostic points of the equipment that comprises the station (measurements, digital statuses, complex digital statuses and alphanumeric strings).

Addressing the objects of the System Database is made with 32-bit pointers.

Theoretically it is possible to address up to 2^{32} items for each point type (4 billion points each), in practice, the DBS is limited only by available RAM and software limitations imposed by Sdi and removable with respect to particular customer needs.

As an example, the whole SCADA occupies:

- 1.220 Mbytes of RAM for a 4.000.000 points configuration, of which 1.900.000 I/O;
- 650 Mbytes di RAM for a 2.100.000 points configuration, of which 1.000.000 I/O;
- 312 Mbytes of RAM for a 1.000.000 points configuration, of which 400.000 I/O.

All the software modules, whichever part of the system they are located in, can access a DBS. This includes modules that perform application functions set by the user.

Special functions provide a Server interface for external Client and third party applications.

Each DBS point is identified using a unique code, assigned during configuration, in the form of a string of 20[4] alphanumeric characters.

Additional descriptive information (descriptions, units of measure, unencrypted statuses, wiring terminals, equipment type, etc.) and functional data (handling and processing of the points, etc.) are also kept in the system.

The type and quantity of information that the system holds for each point normally depends on the type of point in question (analog, digital, acquired, calculated, etc.).

The DBS points use all the services (alarms, displays, printing, data storage, etc.) provided by the system.

Any DBS point can be linked to an area of the plant and arranged in a “hierarchy” of 6 levels maximum. Some standard processes (alarms, printing, printouts, etc.) use this point subdivision to process the points of the plant in different ways and/or to send their signals to different storage or output devices.

In this way, functions relating to physically disjointed parts of the plant can be clearly separated (e.g. simultaneous supervision of two different thermoelectric groups or of different areas of one factory, etc.). Additional static or on-demand filters can be applied on alarm and events list views.

With regard to their informative content, the points are subdivided into the following types:

- Analog;
- Digital;
- Device (digital multiple point);
- Alphanumeric string.

From the point of view of their origin, they are divided into:

- Acquired points (“hard” points);
- Points acquired from another **eXPert** SCADA system;
- Points calculated within the system (standard calculations);
- Points calculated by external applications (non standard calculations);
- Diagnostics.

The **eXPert** SCADA system is provided with a plant tag access dictionary, that allows the read/write of database contents in an optimized high performance way.

5.2.1 Events management and SOE lists (Sequence of Events)

The suite **eXPert** integrates natively with the Oracle database (or SQLite for smaller systems) for storing event data (journal) and sequence of events (SOE Lists) which allow storing of event acquired from external devices with millisecond resolution.

The storage of events is implemented using data management mechanisms suitable for large amounts of data in SCADA real-time applications; adopting the technique of partitioning, that splits the individual tables in sub-tables, an efficient storage/retrieving mechanism for large amounts of time-stamped data is provided.

[4] Number of characters adopted to define system tags can be increased on customer specification for specific purposes.

Event handling is done on circular lists; when the maximum number of events is reached (typically 100,000 events, a quantity defined by the customer) the system will delete the older events in excess.

5.2.2 Analog points

Analog points are stored in the DBS in a record containing:

- The value of the measurement in engineering units, stored as a “floating point” value on 32 or 64 bits (if managed by the data acquisition protocol used);
- Up to 16 logic indicators of the measurement’s quality and status;
- Up to 8 quality indicators of the physical acquisition channel of the field measurements.

5.2.2.1 Acquired analog points

Acquired analog points are either acquired from the processing interfaces (physical input) or logically generated by an external subsystem (e.g. PLC, intelligent controller, **eXPert STAR** station, etc.)

Examples of analog points are measurements of temperature, pressure, level, etc.

5.2.2.2 Calculated analog points

Analog points can also be calculated based on other points in the DBS by SCADA package library functions (standard analog calculations), or they can be calculated by application programs installed in the system by the user (non standard analog calculations).

5.2.2.3 Status value and flag

Analog points have a value in engineering units (current value of the point) and 16 logic indicators, called status flags, which indicate their validity, quality, alarm status, etc.

5.2.3 Digital points

Digital points have a logical value (0 = inactive, 1 = active) and up to a maximum of 7 logic indicators called status flags. Examples of digital points are: pressure switch alarms, safety device triggers, end of round statuses, etc.

Digital points are normally system status signals and alarms, and may be acquired externally (digital acquisitions), calculated based on system library functions based on other points in the DBS (standard digital calculations) or calculated by application programs installed by the user (non standard digital calculations). Each digital point is described in the DBS using a logical status (0 = resting, 1 = active) and a maximum of 7 “status indicators” (flags) which describe its current plant conditions.

Similarly to the DBS of analog points, the DBS of digital points is subdivided into three sections depending on the subtype of the digital point in question: acquired, calculated by standard calculation or calculated by non standard calculation.

5.2.4 Device points

A device point is a software structure at a higher level than a digital point. It facilitates management of the physical devices of the plant, whose status is determined by the status of a certain number of digital points.

Generally, device points are used to manage pumps, valves, switches to various positions, furnaces, heaters, silos, conveyor belts, etc.

More specifically, the device is defined as the ordered set of one or more digital points relating to a specific device.

Digital points that define the status of a device are known as contributing signals.

The status of a device at any given moment depends entirely on the status of the contributing signals at that same moment.

The function of transfer from the status of the digital signal to the status of the device is an complete function and depends exclusively on the type of device.

One specific type of device is “without contributors" and is used in all cases where status is calculated by functions written especially using the functions of internal programming (PASs) or external applications (PAGs). One example of a device "without contributors" is where the value of the device is read by another SCADA station.

Each device point is described in the DBS by the current status, the most recent stable status reached, a timer (used during status transitions) and a maximum of 8 status indicators (flags).

5.2.5 Alphanumeric string points

These are points that store an alphanumeric string of up 255 characters.

They are used as “*passwords*”, product codes, prescription codes, “*product tracking*” functions, manual signals or operator notes and messages, etc.

String points, too, have status indicators that can be used in various ways: for example, to validate the string, block alterations, etc.

5.2.6 Updating the database

Updating of the DBS takes place in various ways depending on the type of signal and the type of equipment of origin and destination. Interfacing with field signals is performed by acquisition/control equipment (controllers, regulators, PLCs, **eXPert STAR** equipment, etc.) connected to the SCADA system through a suitable I/O Server.

The SCADA system can receive and transmit, completely asynchronously, the value and/or status of the signals acquired or commanded (transmission takes place on spontaneous initiative by the equipment responsible for the physical acquisition). This optimizes the flow of data from and to the acquisition/control equipment.

The following general rules are obeyed:

- Acquired analog points: periodically, with variable periods, configurable to SCADA station level in one of the following classes: 0.5”, 1”, 5”, 15”, 30" and 60”;
- Acquired digital points: on variation, with typical updating times ranging from 1 to 100 ms;
- Output analog points: on variation, with typical updating times of approximately 100 ms;
- Output digital points: on variation, with typical updating times from 5 to 50 ms;

- Calculated analog points: periodically, with variable periods, configurable to SCADA station level in one of the following classes: 0.5”, 1”, 5”, 15”, 30" and 60”;
- Calculated digital points: on variation of the contributor to the calculation;
- Device points: on variation of the contributor to the calculation;
- Alphanumeric string points: on variation.

5.3 Data acquisition from field network equipment

Acquisition of data from acquisition and control equipment takes place with complete transparency to the SCADA and HMI functions hosted by the station. Generally, acquisition of measurements is cyclical while acquisition of digital signals is on event and takes priority over that of measurements.

Management of communication to field equipment is performed by the I/O Server, which transfers the data to SCADA in a uniform format that is independent of the protocols used.

The process of acquisition from the field devices is in direct relation to the type and characteristics of the acquisition and control equipment used.

Indeed, the SCADA station is *logically passive* with regard to the methods of acquiring data from the field, and can accept data from the I/O Server functions at any moment. The I/O Server functions, which depend on the characteristics of the connection and implemented protocol, set the details of the acquisition methods used.

5.4 Data acquisition from SOE equipment

SCADA supports the transmission of data from SOE (Sequence Of Events) equipment. Using this information and the time locally associated with each event (timestamp), it manages the temporal reordering of events with millisecond resolution.

Both acquisition stations with SOE functions and normal stations can be connected to the same field network.

SOE stations are data acquisition stations that are able to associate with each variation of the acquired data the instant in time at which the change is made, with an accuracy of less than 1 millisecond. Any acquisition station connected with a protocol that carries the "timestamp" associated with the acquired signal can provide SOE points.

eXPert STAR acquisition stations can realize the SOE function on digital signals.

5.5 Time synchronization

Generally, the SCADA system is synchronized with respect to an absolute time reference so that you can keep the alarms and events generated by SCADA perfectly comparable in time with the events recorded by peripheral devices.

Time synchronization is carried out using the hourly signal originating from a satellite synchronization clock (GPS). Alternatively, it is possible to use a clock with DCF 77 channel synchronization.

The clock can be connected directly to the SCADA station (for resolutions of up to 10 ms) or directly to each acquisition station. In this case, the SCADA system clock is updated based on the one acquired from the GPS-synchronized acquisition stations.

Another solution is to connect to the LAN a GPS synchronized time server device (it can be a dedicated time server or a peripheral device with time server functionalities) that transmits the synchronization signal using NTP (Network Time Protocol).

5.6 Data acquisition from telecontrol equipment

The term telecontrol equipment refers to all equipment far away from the management centre and consequently in need of connection to transmission vectors that are easily accessible and (in general) low cost. Often, such equipment is not connected permanently to the SCADA system.

In general, this type of equipment (e.g. RTU stations, **microSTAR** and **nanoSTAR** stations, etc.) is connected to low speed communication lines in dedicated and/or switched mode.

Acquisition of data from remote telecontrol equipment is carried out according to criteria typical of this type of connection: the centre (through the I/O Server functions) performs periodic query "rounds", in order to access low priority cyclical and historical data and to check the correct functioning of the entire chain of communication and acquisition.

The centre connects spontaneously or on request (by the operator or by internal and external applications) to equipment for sending commands, downloading specific historical information or continuous monitoring of the variables of one or more pieces of equipment.

The remote equipment can, in turn, be connected to the centre (by *spontaneous calls*) to transmit alarms and/or specific information (events) depending on the configuration of the equipment itself. The conditions that trigger spontaneous calls are configured, where **eXPert STAR** equipment is used, by setting the properties of the point acquired or produced by a specific computational logic, working directly from the **eXPert Engineering Station**.

The information transmitted by the telecontrol equipment is connected to the time of the event (timestamp). The centre (SCADA) uses this time for all functions requiring correct temporal placement of the acquired data (Daily Report, printouts, data storage using Historian Server, etc.)

Telecontrol equipment can normally archive a temporal sequence of acquired values in its (local data archives). On connection to SCADA through I/O Server, the buffers of the local archives are also acquired in addition to the current data. Since each acquired value is supplied by the temporal tag, SCADA can correctly reconstruct the sequence of events and send the historical data to Historian to be stored.

Generally, the protocol used for communication with telecontrol equipment complies with IEC standard 60870-5-101 or IEC 60870-5-104 (over LAN or WAN). Appropriate extensions also make it possible to use it on switched lines (PSTN) or on the ISDN or cellular GSM network.

Other types of protocol are also available, such as:

- MMS UCA.2;
- IEC 61850;
- MODBUS RTU/ASCII/TCP;
- SAMP o SASP (SELTA protocols);
- TIC 1000, TIC2 (standard ENEL protocols);
- OPC.

5.7 Standard calculations

These are processes carried out on DBS points following acquisition of data input from outside the system. They are carried out on analog and digital points, and generate analog or digital calculated points.

The calculation functions are preset and can be selected simply and instantly during configuration of the calculation. The result of these calculations is a new system point that is automatically input into the DBS and, there, updated with the usual characteristics of the preselected calculation.

5.7.1 Analog standard calculated points

All analog standard calculations are carried out at a fixed frequency (0.5, 1, 5, 15, 30 or 60 seconds) but are not necessarily in phase with the function of acquiring measurements from outside.

Measurements used as contributors to calculations may be acquired, standard calculated or non standard calculated, without distinction.

Analog points are calculated using preset functions such as:

- Average over time of a measurement on an hourly, daily or monthly basis;
- Maximum over time of a measurement on an hourly, daily or monthly basis;
- Minimum over time of a measurement on an hourly, daily or monthly basis;
- Integral in time a measurement on an hourly, daily or monthly basis;
- Accumulation over time of a measurement on an hourly, daily or monthly basis;
- Mean square deviation of a measurement on an hourly, daily or monthly basis;
- Calculation of the capacity of a gas under AGA standards;
- Calculation of the capacity of a gas under UNI standards;
- Filter of the first order of a measurement;
- Instantaneous average of a maximum of 6 measurements;
- Arithmetic operations (+, -, *, /) between two measurements or between a measurement and a constant;
- Summation of a maximum of 10 measurements;
- Functioning hours of a device, with the option of hourly, daily and monthly re-start;
- Number of transitions of a device to a preset status;
- Functioning minutes for a measurement (count of the time for which a measurement has a value over a preset threshold);
- Delay: accumulation of up to 240 samples of a measurement on input and presentation of them on output delayed by up to 240 * T seconds (where T = calculation period);
- Free calculation: described by a formula in “C-like” notation. The formula can be written freely using up to 255 characters and can operate on up to 10 contributors (analog points of the DBS) and 4 constants, that can be set according to preference. The following calculation primitives can be used when writing the formula:
  - 4 operations (+, -, *, /);
  - Raise to power;

- Sine, cosine and tangent;
- Logarithm;
- Open and closed step;
- User defined calculations based on an external routine written in high level programming language (C, C++, Visual Basic).

5.7.2 Digital standard calculated points

Digital standard calculated points are calculated when one of the digital contributors changes.

Digital points (acquired, standard and non standard calculated) are used as contributors to the calculations.

Each digital signal, of any type, can contribute to up to a maximum of 20 different calculations.

They are calculated using standard logic functions such as:

- ORs of a maximum of 30 digital signals;
- ANDs of a maximum of 30 digital signals;
- EXCLUSIVE OR of a maximum of 30 digital signals
- NOTs in digital.

Any signal that contributes to a digital calculation can be pre-emptively negated (NOT function).

5.8 Non standard calculations

The station makes it possible to configure user applications that perform additional functions to those carried out automatically by SCADA. The results of these applications are normally stored in the same station DBS so that they are available to any other standard function and undergo the usual processing of each DBS point (alarm notification, printing display, data storage, derived calculations, etc.).

It is therefore possible to set the following types of points, known as non standard calculations:

- Analog non standard calculations;
- Digital non standard calculations;
- Devices;
- Alphanumeric strings;

present in the DBS, whose value and/or status is updated by programs developed ad hoc for the application.

From the point of view of whoever reads them, these points are, for all intents and purposes, identical to those acquired from the plant or calculated using the system's standard calculation functions.

Updating of the values, statuses and quality indicators (Flags) of these points can take place through:

- Standard Application Processes (SAPs). These are applications written by users and integrated into the SCADA system and/or **eXPert STAR** stations. The applications are written using **eXPert Soft Logic Editor**, a graphic logic engineering tool compatible with IEC 61131-3 standard.

- General Application Processes (PAGs). These are applications written in Microsoft Visual (C, C++, etc.), like DLLs, which are automatically uploaded from the SCADA station to that station and carried out on system start-up.
- External Application Processes (EAPs). These are applications written in C/C++ in any language and environment, which behave like Clients of the Server interface of the DBS hosted by the SCADA system. They can be activated on any unit physically connected to the system network by TCP/IP. They use **eXPert**'s APIs to access and read from/write to the DBS and can update its non standard calculated values.
- Animation logics are linked to the video pages of the HMI stations. These logics can also be written in C language.

5.9 Alarm management

All types of DBS can be subjected to alarm management in order to automatically generate appropriate signals (video, printed, sound, etc.) to the operator when certain events occur. Information relating to the name, description and status of the point, already input during set-up of the points database, is automatically used to compose the alarm message together with the description of the type of alarm found. Messages composed in this way can be displayed, sent to personnel on duty (via e-mail, text message/SMS or voice message), printed and/or stored in the system.

Alarm management can be broken down into the following activities:

- Notification;
- Processing;
- Storage;
- Display;
- Printing;
- Silencing.

5.9.1 Types of alarm

Various types of alarms are provided. The main types are described below.

5.9.1.1 Alarms due to acquisition anomaly

These are alarms notified directly by the acquisition and control station, and depend on the device used. For devices from the **eXPert STAR** family, for example, the following signals exist:

- Outside acceptable lower (field) limit;
- Outside acceptable upper (field) limit;
- Significant change;
- Conversion channel out of service;
- Correction of cold joint not performed (for thermocouples only).

5.9.1.2 Alarms due to change in value of an analog point

The value of each measurement (acquired, calculated or diagnostic) can be compared to fixed or variable thresholds (dynamic value of other analog points). For each analog point, the SCADA DBS accepts two pairs of limits (or thresholds): high/low and extremely high/extremely low. Each point can have any combination of these four thresholds linked to it.

Each threshold can be set (individually) either as a fixed value or as the value of another analog point (acquired, standard calculated, non standard calculated or diagnostic) in the DBS. Each threshold has a dead band linked to it, which is specified individually for each point.

If one (or more) of the thresholds is exceeded, an appropriate alarm signal is emitted and the event is stored as a status indicator (status flag) in the DBS.

It is possible to dynamically disable the alarm threshold control, from the operator station or from any internal or external system application.

5.9.1.3 Alarms due to change in value of a digital point

These are alarms generated by changes in the status of digital points in the DBS. They correspond to alarm points. The alarm can be generated on one or both of the status transitions.

Digital points subject to this control can be acquired, standard calculated, non standard calculated or diagnostic.

5.9.1.4 Alarms due to a change in status of a device

These are alarms generated following the transition (or lack of transition) in the status of a device.

For this type of point, the following controls can be configured, which can, in turn, generate alarms:

- Correctness control of an operator command;
- Correctness control of an (automatic) program command;
- Safety device intervention control;
- Spontaneous device change control;
- Incongruent device statuses (including dynamic) control.

5.9.1.5 Alarms due to a change in validity status

These are alarms generated following a change in the conditions or methods of updating a point, e.g.:

- Point not scanned;
- Point not reliable;
- Point forced by operator.

5.9.1.6 Alarms due to a change in the content of an alphanumeric string point

These are alarms generated by a change in the content in an alphanumeric string in the DBS. They are used to record specific unencrypted plant conditions, operator changeover procedures, unencrypted operator signals, etc.

5.9.2 Alarm notification

The function of alarm notification consists of identifying the various conditions that place a point in a state of alarm, and of generating the corresponding alarm signal for the subsequent functions of alarm processing. These signals, along with a time, are appropriately stored and, if requested, subsequently displayed, printed and archived.

The function of alarm notification is performed “asynchronously”, when the piece of data being processed by the function changes. For this reason, the system’s “response times” with regard to the alarm notification function are practically instantaneous, and are the same as the response times of acquisition or calculation of the piece of data and, more generally with the insertion of the data into the SCADA station's DBS.

An exception to these times are alarms notified by telecontrol equipment connected to switched lines. For these, the response time depends heavily on the time necessary for the “spontaneous" telephone call made by the peripheral and on the characteristics of the medium of communication used. As already discussed, in this case the temporal reference is still correct, since the points are transferred to SCADA complete with a time tag.

Appropriate internal storage allows the system to handle even considerable alarm peaks without risk of losing signals.

Alarms can also be notified by user applications within the system (e.g. SAP Scheduling Application Processes) or by applications external to the system which interface with it and deposit data in the system’s DBS.

5.9.3 Alarm processing

The system makes it possible to set, during configuration and at individual point level, not only the alarm controls but also the subsequent actions that the system must automatically take:

- Daily Report printing;
- Display;
- Storage;
- Telephone call (or text message-SMS/e-mail) to contactable personnel[5].

In addition, a series of parameters can be set for highlighting alarms or grouping them together by, for example, alarm color, alarm level, or area of the plant with which the alarm is associated.

It is also possible to organize the alarm signals according to a “hierarchy” of a maximum of 6 levels. In this way, the alarms can be subdivided using inverted tree architecture with a maximum of 10 levels and 127 branches for each level (127^6 subgroups maximum). The hierarchical structure can therefore be used to easily create procedures for accessing the video pages containing the alarms through hierarchical channels. It can

[5] Only if the **eXPert Remote Alarming** component is installed.

also/alternatively be used for generating summary information on the alarms and on specific parts and/or components of the plant.

The following general types of alarm processing can be distinguished:

- No processing;
- Printing of the activation and deactivation of each alarm;
- Printing of the alarm activation only;
- Display of the activation/deactivation and acknowledgement of each alarm;
- Display of the activation only;
- Display and acknowledgement of the activation only.

The process of notifying the alarm to contactable personnel (which occurs if the **eXPert Remote Alarming** component is active) is activated by specifying the variable in question and the type and condition of alarm that is desired to trigger the call.

5.9.4 Storing alarms

The alarms are stored in a special database structure called an Alarm Database (DBA).

If required, a alarm management procedure that dived the alarms in sectors can be configured, with independent operating sectors, it is possible to define several ADBs each dedicated to a single operating sector. Each DBA is composed by alarms belonging to specified plant areas.

The DBA contains all the information relating to each alarm (including the activation and deactivation times) in chronological order.

Each DBA can contain up to a maximum of 32,000 alarms.

The alarms relating to one area of the plant can be stored in parallel in several DBAs, so that the same alarms are “duplicated”. In this way, configurations with operator stations can be set up to manage the alarms relating to independent parts of the plant separately, but which are also notified in parallel of alarms that relate to shared parts of the plant and/or are especially serious. In this way, the alarm information on all the different stations is complete and the alarm acknowledgement operations do not interfere with one another.

The alarms are stored in the DBA in chronological order according to the activation time, where they remain while the alarm is valid and until the operator has acknowledged its activation (alarm acknowledgement function).

Depending on the configuration at individual point level, the alarm may alternatively not be stored or not require operator acknowledgement.

If appropriately configured, the DBA can also store the event corresponding to the return of an alarm signal to "normal" (alarm deactivation).

The part of the DBA containing the alarms that have been acknowledged but are still in progress is known as the “acquired alarm archive”.

The part of the DBA containing the alarms yet to be acknowledged is known as the "rising alarm archive".

5.9.5 Displaying alarms

The alarm display function makes it possible to call up specific video pages (Alarms Page) on the operator video screens, so that the contents of the selected DBA can be viewed.

Each alarm is displayed on a separate line. The content and formatting of the displayed line can be personalized. The fields that can be used for composing the alarm line are:

- Month, day, hours, minutes and seconds of the event;
- Milliseconds of the event;
- Month, day, hours, minutes and seconds of the event printout;
- Code of the point affected by the event;
- Unencrypted description of the point;
- Condition or cause of the alarm;
- Unencrypted previous status and current status (if a digital or device point);
- Value of the threshold exceeded (if a measurement);
- Current value (if a measurement).

The alarms are presented in chronological order and continually updated on the video in real time.

The alarm page displays the list of pending alarms, as well as other summarized information such as: the number of pending alarms, the number of acknowledged alarms, etc.

In the alarm list the operation can view only rising alarms (un-acknowledged) or all acknowledged alarms (alarms archive).

The alarms archive is continually temporally ordered and updated on the video depending on the alarm activations and deactivations acknowledged by the operator.

The archive can be displayed in its entirety (all the alarms stored in that DBA) or the alarms can be filtered by area of the plant (a maximum of 32 areas) or by level of seriousness.

Special functions at HMI level make it possible to display its contents and acknowledge the alarms contained within it, in groups and/or individually.

For further details, please refer to the “HMI FUNCTIONS” chapter, which describes the alarm page and alarm archive page.

5.9.6 Printing alarms and events (Daily Report)

The system produces permanent records, in the form of printouts and/or files, of all the alarms or significant events that it acknowledges. This recording is called the “Daily Report” and, in many plants, it is used for tax purposes.

For this reason, up to a maximum of 8 recording devices (printers, disk files, videos, etc.) can be configured for storing the Daily Report. These devices, also known as “Daily Report peripherals”, are managed through “failure recovery” procedures. This means that if the physical device fails, the recording will automatically be sent to a back-up device (which may be shared with other recordings) while the faulty peripheral is repaired.

Each recording device is assigned alarms and events relating to one or more areas of the plant. The alarm signals from one area of the plant can be sent in parallel to more than one recording device.

Each alarm or event is recorded as one printed line. The Daily Report is organized into pages which are numbered progressively on a daily basis.

The heading and format of each printed page can be personalized.

The content (printed fields) and format of the printed line can be personalized. The fields that can be used for composing the printed line are:

- Month, day, hours, minutes and seconds of the event;
- Milliseconds of the event;
- Month, day, hours, minutes and seconds of the event printout;
- Code of the point affected by the event;
- Unencrypted description of the point;
- Condition or cause of the alarm;
- Unencrypted previous status and current status (if a digital or device point);
- Value of the threshold exceeded (if a measurement);
- Current value (if a measurement).

If the Daily Report is stored on disk, a file is created for each day or, alternatively, for each week, with the latest 8 files stored.

The Daily Report files can be displayed at any time and printed directly from the operator consoles.

It is possible to request storage of the Daily Report files for up to 1 year. This function means that the files can be saved as normal in a tree structure, organized on a daily or weekly basis.

Special functions also make it possible to copy these files onto back-up media and conduct selective searches based on key search parameters.

5.9.7 Recording of alarms and events in relational database

The system provides the permanent recording in the relational database of all significant events or alarms that the system recognizes. This registration takes place parallel to the management of the Daily Report described in the preceding paragraph, to which we refer to the description of the records stored.

This registration can be accessed from HMI pages or via direct SQL queries to the database.

It is possible to perform filtering operations on the list according to time limits and/or tag names.

Also export functions in Excel, txt and xml format are available.

The system is able to store and manage in a circular manner, a number of events depending on the amount of mass memory in the system, and hence without any limitation due to the software. To date, we can ensure efficient performance of systems that require the registration of millions of events (control systems have been developed that handle up to 8,000,000 events).

The storage is done on per week coverage tables, which ensures a good efficiency of the system even for large data sets.

5.9.8 Displaying the most recent alarm

It is possible to insert a field into any video page displaying the latest alarm notified by the system; the list can be sized to display the number of alarms required and can also be dedicated to a specific hierarchy, zone alarm system or specific DBA.

A typical choice is to use an area of the video always in view (for example the header or footer area of the main page) to always have a view to the last alarm issued.

5.9.9 Alarms inhibition

In the definition of a digital point you can define a point which, when in the active state, causes the inhibition of the alarm associated with the same digital.

For analog points silencing is defined by two digital points that cause inhibition, respectively, of the alarms associated to conduction thresholds and of the alarms associated to safety thresholds.

Even complex logic can be created, using application functions, that, as a result of certain plant operation conditions, should set appropriately alarm silencing points.

5.10 SOE management

The SOE (Sequence of Event) stores SOE events acquired from field intelligent devices that provides digital signal with time stamp, and groups them together in chronological order in “SOE sequences of events” (SOEs).

“SOE sequences of events” are started by the occurrence of a digital change in a point set as a "trigger event”.

The station establishes the end of a sequence when the following are exceeded:

- The maximum time from the trigger event;
- The maximum time between one event and the next;
- The maximum number of events in the sequence.

The event sequence stores all the digital signals that are set as SOE-type during configuration.

At the end of each event sequence, a printout is produced containing the entire sequence of SOE events with the individual events in chronological order, the trigger event highlighted and the time of each event to millisecond resolution.

Every single event sequence is automatically stored by the system in a relational database and/or in a file.

It can also be:

- Displayed on the operator’s monitor through a special HMI page;
- Copied to an external storage unit in any standard format (CSV, Excel, XML);
- Sent to upper level control centers (for example, through IEC 60870-5-104 gateway functions);;
- Automatically printed on the “printout printer”
- Printed at the operator’s request.

It is possible to configure up to 128 different SOE recorders, in which the recordings of the points converge depending on the “area of the plant” to which they belong.

If file based memorization is used, each SOE recorder stores his data in a specific dedicated directory of the SCADA system. It is possible to limit the maximum usage of the disk used for storing them.

When the maximum disk usage is exceeded, the oldest SOE printout is automatically deleted.

It is possible to dynamically enable instant printing of individual SOE events. In this case, each event is also instantly printed in the Daily Report together with the normal alarms. This type of recording does not guarantee perfect chronological reordering of the SOE events.

5.11 Management of system devices

This function manages the status of the plant devices, the commands relating to them and all their changes in status, so that the operator's information is always precise and dynamically correct.

Management of the plant devices is divided into:

- Calculating the current status;
- Alarms inhibition.

5.11.1 Calculating the current status

Calculation of the current status of the device is carried out following each change in status of one of its contributors.

More specifically, each time one of the digital signals that contributes to a device changes, its new current status is calculated and it is checked whether the device underwent a command originating from outside the system or from a system program. The following situations are managed:

- Change on command;
- Spontaneous change;
- Triggering of a device's safety devices.

5.11.2 Alarms inhibition

This function makes it possible to set, for each device, a set of points (measurements, digital points or device points) whose alarms are inhibited when the device reaches a certain status, called "inhibitory status".

Alarm Inhibition cancels the activation of conduction and/or security alarms in the case of measurements, and status change alarms in the case of digital or device alarms.

This function (which we can describe as filtering out redundant alarm events) makes it possible to prevent alarm signals that do not accurately reflect the actual situation of the plant or that are not significant.

5.12 Command management

This function manages the transmission of physical commands to equipment which interfaces with processing and virtual commands to external subsystems.

The commands may be “fixed”, “on impulse” or on “train of impulses”. The actual execution of the command is always performed by the equipment that interfaces with the field.

The transmission of each command involves requesting activation, by an external subsystem interfacing with the field, of one or more digital commands with physical or logical output (activation sequences, etc.).

If a plant device is correlated to the command, a temporal counter (time-out) is initialized on transmission. When this runs out, it is verified whether the plant device has reached the expected status, and an alarm signal is given if this is not the case.

5.13 Reports

The function that manages the production and printing of plant printouts is performed by the Report package described in Chapter 10.

They can be configured in different formats (Excel or HTML) and directed, on output, to system printers or files or sent via e-mail.

5.14 Storing Daily Reports and SOE printouts

The system can manage historical storage of both the Daily Report and SOE printout.

This function is performed using dedicated database tables in circular mode, guaranteeing storage of up to 10 millions of events (obviously with appropriate dimensioning of storage dedicated disks).

It is possible to access the recorded data through special HMI pages or through the *Historian Viewer* application. In both cases, the data can be filtered, viewed in temporal intervals, and saved in classic Office Automation formats (Excel, PDF or XML).

Alternatively, data storage on file-based disk is also available.

Thanks to these functions, storage of the above-mentioned files can be extended to 1 year where it would otherwise be limited to the 8 most recent generated files for each type.

The files are stored in special directories on the SCADA unit, arranged daily using unencrypted file names that indicate the periods in question.

These files are in printable ASCII format and can therefore be accessed, displayed and printed using either the normal HMI interface functions or standard tools available in Windows and/or LINUX.

5.15 Printers management

SCADA provides for up to a maximum of 8 300-CPS printers, 132 bidirectional columns and one or more hard copy printers (centralized and/or local).

The printers can be used for the DAILY REPORT function (up to 8), the SOE function (up to 8) or the REPORT PRINTER function (up to 4).

Several functions can co-exist on one printer.

In the event that one printer fails, its printing functions are automatically reassigned to the remaining printer/s or to a suitable output device (file on a disk) preset by the systems specialist (*fail over* function).

If a single printer is used for all functions, the DAILY REPORT will lack continuity, being fragmented into system printouts.

Two different printing methods are available for printing the SOE events: stream method comparable to the alarms (but with the activation time indicated to the millisecond) and SOE printout.

5.15.1 Daily Report printer

The function of this printer is to record, in chronological order, all the significant events that the system identifies in the plant and/or in the system itself (system alarms).

The SCADA package is responsible for notification, any absolute time association, and storing and formatting the strings of alarms that must be printed.

Each event is recorded on a printer on a single line (132 characters maximum) and contains all the information needed to clearly identify the event, for example: Absolute time (in hours, minutes and seconds), point identification code (TAG), extended description, type of event, status or value, and reference status or value.

SCADA automatically heads each page of the Daily Report with the page number (for that day) and the date, expressed as day, month and year.

5.16 Report printers

The print jobs that the operator requests of the system or which the system generates automatically are normally sent to this printer. These print jobs are normally called “system reports”.

The tasks of generating and preparing the printouts in printable format (ASCII) are performed exclusively by the SCADA package. The HMI package deals exclusively with printing on the device (or devices) assigned to the report, and separation (page breaks) of one printout from the next.

5.17 Hard-Copy printers

These printers are dedicated to producing color hard copies of operator monitors. Ink-jet types are normally supplied, but any printer with graphic functions, in color or black and white, can be used, provided it has the appropriate, operating system supported, driver.

The printer dedicated to producing hard-copy can be any printer (local, networked or shared) recognized by the operating system of the machine that hosts the HMI component. The hard copy printouts are directed to the printer selected by the user, as provided by the operating system.

5.18 Calendar management and external synchronization

The system manages its own internal calendar which is synchronized with that of the SCADA station's operating system.

The move from solar time to legal time is supported. The system keeps both legal time and solar time concurrently. Depending on the configuration, it allocates a legal or solar time tag to all the recordings.

In the case of dual configurations, the Master system synchronizes the Slave system when it connects to the line.

The system calendar is kept to an internal resolution of 1 second.

The precision of the time depends on the hardware platform used, and is generally around 1 min/month.

The system can guarantee a considerably higher level of precision if synchronized though an external clock. The following alternatives are available:

- Synchronization with a GPS with serial interface, connected to the SCADA systems;
- Synchronization with an NTP (Network Time Protocol) server connected to the system's TCP/IP Ethernet network;
- Synchronization with the clock of the connected acquisition stations, using an appropriate time synchronization protocol on the TCP/IP network.

In any case, synchronization with external equipment can easily be achieved using any type of physical connection and protocol.

5.19 User application programs and extensions to SCADA

Thanks to **eXPert**, user application programs performing specific plant calculations and/or management functions can be integrated into the SCADA system. Alternatively, the SCADA functions can be extended by extending the system with extra threads created by the user.

In the first case, using **eXPert SoftLogic Editor**, automation and regulation sequences are created using graphic or text programming in accordance with IEC standard 1131-3. The sequences created are then activated directly on the SCADA system. This solution is the simplest and quickest when it is necessary to set up functions of low/medium complexity. The development environment, integrated into the **eXPert Engineering Station** functions, simplifies and guides the writing of the application and allows direct and secure access to the DBS data.

In the second case, an actual extension of the SCADA system can be created by adding new functions in the form of C and C++ functions. The new functions are activated directly from the SCADA system as extra threads of the system itself. Both accessing the DBS and synchronization functions are carried out through calls to appropriate libraries provided with the development environment. This method requires good programming knowledge and is most suitable for setting up complex applications.

5.19.1 Soft Logic

SoftLogic application programs are written using SoftLogic Editor, a process control-oriented graphic and text tool, based on IEC Standard 61131-5, allowing direct, secure

access access to the DBS data. The tool includes functions for Editing, Compilation and Debugging of the logics produced.

Using SoftLogic Editor, the user has access to a graphic editor that uses functional block symbols, in accordance with IEC standard 61131-3.

In this case, the logics are set by graphically connecting the available functional blocks to create the desired logic/regulation schemes.

Sequential Function Chart (SFC) graphic language is used to set processing sequences. SFC describes a sequence composed of a set number of *steps*. Execution of a sequence (execution flow) can be temporally conditioned by transition events.

A *step* is an basic action (macro-process) whose execution flow is unique and independent of time.

'Function Block Diagram' (FDB) graphic language and 'Structure Text' (ST) text language are used to describe the 'steps' and transition logics.

SFC sequences are always set graphically through the graphic editor, using a specific set of components connected to one another in order, and each component has a specific function described by a set of instructions in ST.

Up to 16 application programs can be set in SoftLogic, each featuring:

- A name that clearly identifies it;
- The activation method (cyclical or on event);
- A typical time schedule;
- Up to 256 independent sequences.

Each sequence can be cyclical, activated by plant events or activated by other sequences or other SoftLogic programs.

Each program can be activated, cancelled or terminated by the operator or by another SoftLogic program.

Examples of possible application programs in industrial process control are:

- Basic command sequences;
- Automatic regulation;
- Security logics;
- Yield calculations;
- Management of the running of the plant.

Using SoftLogic Editor, it is possible to:

- Set, at symbol level, a local database (LDB - Local Database) with data of the same type as in the unit's dynamic database;
- Transfer blocks of data, with READ/WRITE instructions, between local databases (LDBs) and system databases (DBSs), wherever they are situated;
- If required, activate simultaneous execution of parts of the process code (above-mentioned sequences);
- Exchange messages with external processes using instructions such as: SEND and RECEIVE
- Enable/disable external processes allocated to the same or a different unit;
- Trigger execution of a sequence following change in the status of one or more points in an DBS;
- Perform operations such as:
    - Logic (e.g. PLC) AND, OR, XOR, etc.;

- Arithmetic on whole and real numbers (+, -, *, /, sine, cosine, tangents, logarithms, etc.);
- Program flow control;
- Subprogram call-up;
- Functional block activation;

- Set functional blocks logically equivalent to hardware modules used to create conventional regulation systems;
- Use preset calculation blocks such as:
  - Regulators (of various types)
  - Maximum and/or minimum selector
  - Displacement measurer
  - Ramp generator
  - Selector of one of two measurements
  - Non-linearity
  - Etc.

5.19.2 Extensions to SCADA (PAG)

The extension functions are threads activated and synchronized by SCADA and written in C/C++, which use the functions of a special library to access the data housed in SCADA's own system database (DBS) in a secure and ordered way.

Thanks to SCADA, up to *16 slots* can be used to insert extension functions.

In theory, there are no limits to the functions and complexity of the extension programs developed, although their impact on the system's overall performance will need to be assessed given their close interaction with the SCADA system.

The extension programs are integrated and coordinated by SCADA through special synchronization functions or cyclical or "on event" activation.

5.20 Duality management

If a redundant configuration is used for the SCADA stations then the duality management functions must be activated.

Two different way of managing duality are available, which differs in the execution of master/slave arbitration, that can be achieved by direct negotiation between the two network connected SCADA of the dual couple or using an external device (called iEWDS).

In the first case, the management of duality is based on a protocol message exchange (application layer) between the two SCADA through a single or double Ethernet connection. The watch-dog updating function is based on an information exchange between the two units. To ensure maximum efficiency the exchange of information is done by using the UDP protocol.

In the second case, that can be used when the two SCADA stations are adjacent, the duality can be managed through the use of an external hardware device, called iEWDS, which provides to arbitration and watch-dog functions. The iEWDS acts also as a switch respects to the serial lines or USB lines (i.e. lines connecting the peripheral devices to the PC with Master functions).

An iEWDS is connected to each PC of the SCADA pair through serial lines. Also, the other serial lines (or USBs) used by SCADA to connect individual peripherals are connected to the iEWDS connectors provided for switching the serial lines to the Master unit.

These lines are used to control the *system* printers or to acquire data from devices connected to the serial (for example, connections via modem to telecontrol devices connected by telephone line).

The two PCs are kept synchronized and aligned through a network connection, using a dedicated 100 Mbit Ethernet TCP/IP network.

The following section describes the Master/Slave arbitration logic using iEWDS, for a description of the same logic in case of absence of external arbitration unit is provided in Paragraph 5.20.3.

5.20.1 Master/Slave arbitration Logic

The duality management software, present in each SCADA, controls the correct functioning of the software functions and of the hardware components of the STADA station itself. If no functional abnormalities are found, it periodically (every 100 milliseconds) sends a *watch-dog* message to the iEWDS equipment.

In the event of failure, SCADA stops sending the periodic *watch-dog* messages.

iEWDS notifies both the SCADAs (using three serial line signals) of the following information:

- Whether the SCADA should be in Master or Slave function;
- Whether the watch-dog refresh rate is correct;
- Whether the SCADA connected to the other serial line is refreshing the watch-dog correctly.

iEWDS performs the following switch logic: if both the SCADAs send the watch-dog messages at the established intervals, the Master SCADA signal will be sent to the first SCADA that connected. Consequently, the second SCADA will be assigned the role of Slave SCADA.

When the role of Master is assigned, the iEWDS connects the extra serial lines (or USB ports) to the Master PC.

If the Master SCADA stops periodic sending the watch dog messages, the iEWDS automatically assigns the role of SCADA Master to the other SCADA, while the faulty SCADA is declared offline.

The Master/Slave switch logic therefore allows the Slave to take over from the Master in the event that the latter fails. When the switch takes place, the extra serial lines are also connected to the new Master.

5.20.2 Hot Back-up function

During normal running of the system, one of the two SCADAs functions as Master and the other as Slave.

The Master SCADA (through the relevant I/O Server) acquires signals from the field and performs the server functions in relation to all the other **eXPert** system components (HMI, Historian and connectivity services with other systems).

The Slave SCADA performs the function of *hot back-up* to the Master station, which means that the Slave SCADA, being fully aligned to the Master SCADA, is always ready to take over its functions.

Perfect alignment between Master and Slave is ensured by the following functions:

1. Master/Slave updating;
2. Master/Slave alignment.

Both these functions are performed through exchange of data via the TCP/IP connection between the two SCADAs.

5.20.2.1 Master/Slave updating

Master/Slave updating is always active when the two SCADAs are functioning correctly. This enables the Slave SCADA to carry out the same operations as the Master even though it is not communicating directly with the external acquisition devices or the client stations such as HMI, Historian, etc.

As far as the variables acquired from the field (or from external devices in general) are concerned, the Slave SCADA is updated directly by the Master processor through the TCP/IP connection between the two SCADAs.

The same Master/Slave connection is used by the Master to send the Slave requests received from other system components with client functions. These include requests for alarm acknowledgement, pages relating to HMIs, command transmissions, etc.

In this way, the two SCADAs are kept fully updated with one another, and switches between them are completely transparent to the connected client.

5.20.2.2 Master/Slave alignment

The alignment function is performed each time the SCADA functioning as Slave reconnects to the Master SCADA.

This occurs on system start-up or when the Slave SCADA comes back online after being switched off (due, for example, to maintenance requirements).

The aim of the alignment function is to bring the two SCADAs to the same initial state. For this purpose, the following are copied to the Slave SCADA:

- The complete system database (DBS);
- The alarm database (DBA).

Any SoftLogic functions active on the SCADA system are also synchronized. This also means that automation sequences that are carried out on the Slave when it is connected to the Master will begin from the same execution status as that of the Master.

5.20.2.3 Master/Slave switching

Thanks to the hot back-up function, when a Slave SCADA station has to take over the functions of the Master, there are no repercussions on the running of the system. From the operator's point of view, the display of the plant remains congruent with regard both to the pages displayed and the status of the alarm databases.

The only occurrence that could cause a loss of data is the potential change of a signal at peripheral level at the precise moment of the switch.

For this reason, when a switch takes place, the ex-slave, now the Master, queries the acquisition nodes connected to SCADA, which transmit the status of all contacts and signals acquired by the plant in order to prevent any incongruence between the SCADA database and the field signals.

5.20.3 Duality management without iEWDS unit

In the case of systems for which is not provided the connection to the external iEWDS apparatus, is available a master slave management through the direct TCP/IP connection between the master and the slave SCADA.

A different form of duality management is therefore used, based on a protocol for exchanging messages between the two SCADAs through a single or double Ethernet connection.

The watch-dog updating function is based on exchange of information between the two units. In order to maximize efficiency, the exchange of information is carried out using the UDP protocol.

Unlike the TCP protocol, the UDP protocol is package-oriented. This protocol adapts to the required functions because:

- It does not require a connection management phase and is therefore always active;
- The information passed is contained in a single package (< 1500 bytes);
- It is essential to process “instantaneous” data;
- The flow of packages is in the order of 2-3 messages/second in each direction;

To avoid potential deadlock situations, the priority in assigning the Master function is assigned to one of the two units, denominated the Primary unit.

It should be remembered that this solution involves greater switching times than the corresponding iEWDS solution.

5.20.3.1 Watch-Dog management

On start-up, the unit assumes Slave status and begins sending “watch dog” updating packages and waiting to receive packages from the dual system.

From a logical point of view, two cases can occur: messages are received from the dual system, or messages are not received from the dual system.

5.20.3.2 Dual system present

In the first case, the functioning mode to be activated can immediately be identified:

- If the message received from the dual system indicates that the dual unit is Master, the unit will continue to function in Slave mode.
- If the dual unit is the Slave and the processing unit is Primary, it immediately begins functioning in Master mode.
- If the dual unit is the Slave and the processing unit is not Primary, it waits for a period of 10 seconds after which it begins functioning in Master mode.
- If the dual unit is Master and the processing unit is Master, if it is not Primary it immediately declares itself Slave, while if it is Primary it waits for a period of 5 seconds after which it declares itself Slave.

5.20.3.3 Dual system absent

If no message is received from the dual unit then, after a maximum preset period, the unit becomes Master. The waiting period is 10 seconds if the system is Primary, or 2 * 10 seconds if it is not.

The possibility of having two Master systems is therefore reduced in cases where the connection between the two units is lost. If a double connection is used, the probability of this event occurring is sufficiently low.

6. I/O Server

6.1 General information

I/O Server is the component that communications with the peripheral acquisition and regulation devices (PLCs, telecontrol equipment, **eXPert STAR** stations) and sends/receives data to/from SCADA in a format that is independent of the type of peripheral and protocol adopted.

The software is structured on four interconnected levels (see Figure 6-1):

- **Level 1:** communication with SCADA;
- **Level 2:** spontaneous management of requests from SCADA and signaling;
- **Level 3:** spontaneous line pool management and reception;
- **Level 4:** protocol management;

Figure 6-1: I/O Server software structure

For the top three levels, the type of I/O Server is the same.

The top level manages communication between SCADA and I/O Server, permitting acquisition of data by SCADA and transmission of commands to the peripherals.

The second level manages requests by SCADA relating to management of acquisition and control nodes and lines (request for node connection/disconnection, request for round activation, request for line activation/deactivation). For telecontrol applications, this level also handles signaling to SCADA in the event of connection to a node for a *spontaneous* call. Round setting (activation timetables and groups of affected peripherals) is performed by the operator at HMI level and notified to SCADA (see Figure 6-2).

The third level is used for telecontrol equipment (or any equipment connected by switched line). This level optimizes management of the available communication lines (modems).

I/O Server uses a line pool concept which makes it possible to set which modems should be used to reach groups of peripheral equipment. During rounds (or any simultaneous calls), the SW parallelizes the calls to all the available modems in the pool. This

technique also makes it possible to reserve one or more modems for receiving (*spontaneous*) calls originating from the peripherals signaling alarm conditions.

The line manager also performs diagnostics on the connections and functions of the nodes. Any faulty modems are automatically excluded from management of the pools.

All diagnostic information on the lines and nodes is stored in the SCADA database. This means that the operator can view the functional details of the communication that takes place on the peripheral lines and acquisition nodes.

The maximum number of modems that can be managed using multi-serial cards is currently set by the operating system at 255 units.

The fourth level is dedicated to protocol management and contains the specifics of implementation of the protocol itself and the functions that transform the acquired data into the formats provided by SCADA. The introduction of a new type of protocol not among those currently manages but necessary in order to acquire data from a particular type of peripheral, requires the modification of this sole level of the I/O Server SW.

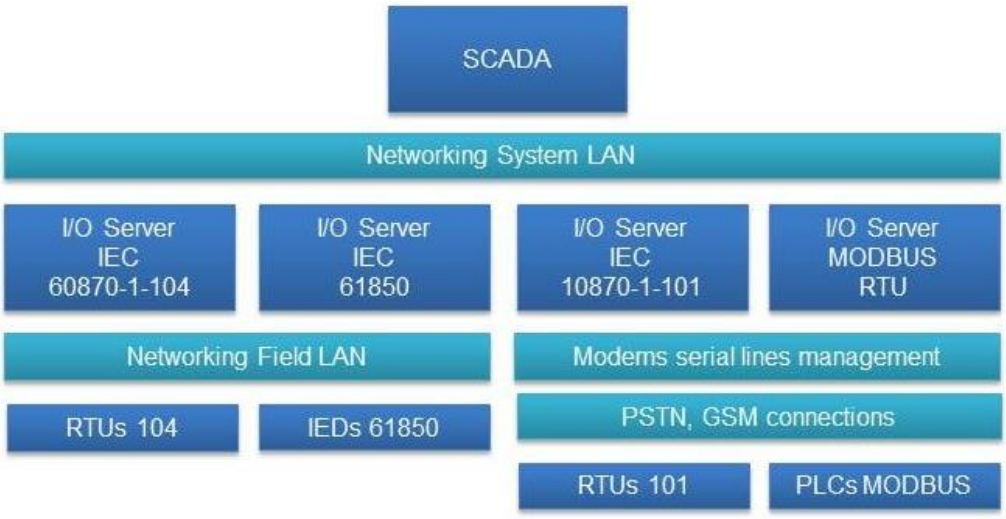

Figure 6-2: Multiple I/O Server use

The modular structure of the I/O Server component and its standardized interfacing with the SCADA system means that the system can be expanded by adding new types of protocols and/or communication lines to the remote equipment without compromising the stability of the system. Indeed, I/O Servers dedicated to different types of line/protocol can be used simultaneously (see Figure 6-2). The different I/O Servers can be housed on the same PC or installed on PCs dedicated to them.

6.2 Dual configuration

I/O Server can be implemented in duplicate configuration. In this case it is installed on two PCs and duality management is activated. The watch dog and Master/Slave switching functions are performed from extra IEWDS hardware units.

Watch dog's logic is identical to that of the SCADA component (see Paragraph 5.17).

If I/O Server and SCADA are active on different network nodes, their respective duality managements will be independent, each managed by a different iEWDS unit.

If I/O Server and SCADA are active on the same platform, a single iEWDS unit is used and the diagnostic functions will control the correct functioning of both the Front End functions and the SCADA functions. In the event of a malfunction, the Master functions will be switched (for both the SCADA and I/O Server components) to the other PC.

I/O Server takes full advantage of the iEWDS equipment as far as switching of the serial lines is concerned. These are generally used for connection to peripheral acquisition and control equipment or to modems through which this connection is made.

Depending on the connection requirements, connections of the following standards can be used: RS-232, RS-485, RS-422, USB.

If a large number of lines are managed by I/O Serve, it is possible to use up to a maximum of 12 pieces of iEWDS equipment connected to one another in a cascade (for a total of 48 lines). The Master switch logic is performed by the first piece of equipment only. Line switching is performed by all the iEWDSs as set by the first piece of equipment.

6.3 Nodes and lines diagnostics

Diagnostic information on the status of the peripheral nodes and communication lines is displayed on diagnostic pages on appropriate HMI stations.

The peripheral node diagnostics pages contains a list of the configured or available nodes for which it is possible to call up a details window that display the current status of communication with the peripheral. This window displays information on the status of the communication and current corresponding traffic.

Similarly, it is possible to analyze the status of lines (and/or modem) used within the system.

7. Historian

7.1 General information

The Historian application allows historical plant data to be stored. Historian's functions can be activated directly on the SCADA station and on specially dedicated stations (usually known as data storage stations).

Historian works by communicating with SCADA (TCP/IP protocol), from which it receives data to be saved and requests for access to data already stored in the archive (requests made directly from SCADA applications or from HMI stations).

Historian makes it possible to store data on various types of database. It also allows simultaneous management of multiple databases (including of different types).

It is possible to use several simultaneously active Historian stations connected to SCADA.

Figure 7-1 shows the architecture of a system that uses *n* Historian applications at the same time. It also shows the details of one of the connected Historians, which generates 4 separate databases (each individual database is managed by functions called Archiver), and how the four databases can be of different types.

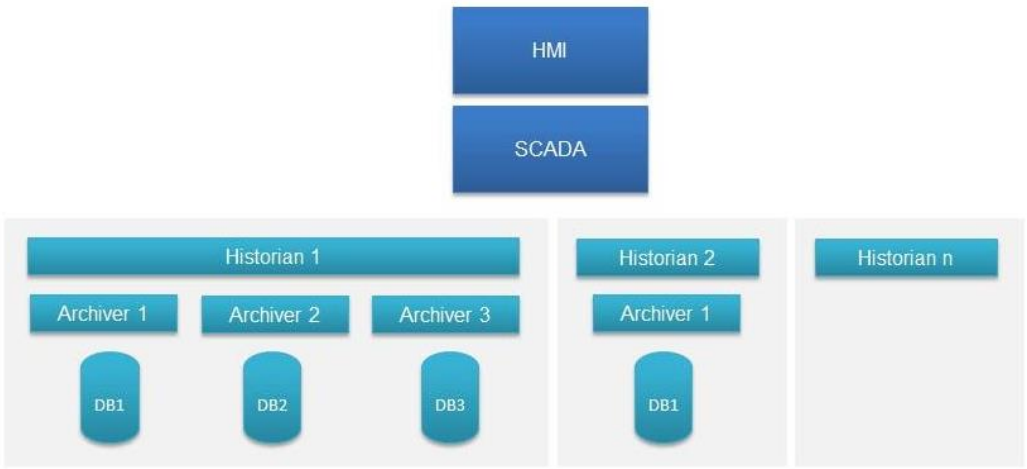

Figure 7-1: Historian - data storage system structure

7.2 Types of historical data storage

There are two main categories of data storage:

- Oriented towards real time performances (*file* archives);
- Based on commercial databases (*relational database* archives).

The first category involves storing the data in a proprietary format, which allows data storage with minimum expenditure of CPU resources and also favors fast access to the data where it is displayed in historical trends on the HMI stations. This type is particularly suitable for storing historical data that needs to be displayed on HMIs as measurement trends for the purposes of running the plant.

The second allows you to save data in Oracle relational database.

In relational databases, the data is saved in tables and structures belonging to the architecture of the database. This tabular structure is public and documented to allow interfacing with the databases of other external applications.

This type is particularly suitable for storing historical data and data necessary for post-processing or for use in MES systems.

Historian allows both types of data storage to be present, and makes it possible to archive some measurements in faster, higher-performing file-based archives and other, more global ones in relational databases (if applicable, using a server employed, for example, for MES/ERP functions).

7.3 Dual configuration

Historian can be provided in a dual configuration whatever the storage mode chosen, in relation to the type adopted the redundancy feature is implemented in a different way.

Where *file archives* are used, two Historian applications are installed on two PCs controlled by iEWDS units, redundancy is managed in a similar way to the SCADA case (see 5.20).

In this case, to keep the two stations aligned, the Master Data Storage Station queues the data received from SCADA to the Slave Data Storage Station using a dedicated TCP/IP connection.

The Slave Data Storage Station is aligned on start-up by the Master Data Storage Station, both with regard to configuration files and files relating to stored data.

If a relational database is used, redundancy is achieved in two different levels: using a redundant Historian application, that manages the data storage function toward a single relational DB, or/and using a redundant relational database.

When the system is composed by a redundant SCADA along with a single relational database installed on a separate server, it is possible to install the Historian application directly on the SCADA servers.

In this case, the Historian running on the server currently in master role, connects to the relational database, performing data archiving tasks; if database connection problems arise, data are buffered on the SCADA server, for further transfer when the connection will be restored.

Where *relational databases* are used and highly reliable architecture is desired, it is advisable to use duplication mechanisms such as mirroring and/or clustering, generally available for products in the medium-high market bracket.

In these cases, adoption of suitable hardware and operating systems (e.g. RAID disks and Server version operating systems) should be considered.

7.4 Data archives

Independently of the type of data storage (type of database) used, the historical data is organized in a conceptually identical way.

Each data storage process (Archiver) in the system stores groups of DBS points, known as archives.

For each archive, the codes of the measurements to be stored are set, with a retention and a duration.

Up to 100 archives can be set per archiver, with a potentially unlimited number of points per archive[6].

Each archive constitutes a locigal grouping of points. For data storage in relational databases, the archive index is stored in a special field of the archived measurement. The archived measurements are, in any case, stored in the same tabular structures regardless of which archive they belong to. It is therefore possible to construct data extraction queries, which may or may not (depending on requirements) take into account the groupings used to define the archives.

It is possible to alter the configuration of the archive by adding, removing or altering the points stored in it. These alterations can made even after the archive has been activated. In this case, data already archived is kept, even if it refers to points now removed from the archive.

The records constituting the binary file or the database are stored according to the sampling period and contain the values and flags of the point to be archived along with the date and time of storage.

Any type of point can be input into the archive except for output analog points and digital commands.

The values to be stored can either be taken from the system database (operating DB) or provided by external equipment in vectorial form (date of the first sample and one or more consecutive values).

The latter is the case for telecontrol equipment with local data storage capacities, which is connected to SCADA during periodic rounds. SCADA sends the blocks of data to Historian, where the temporal tag (recorded by the telecontrol peripheral at the time of acquisition) is noted for each value. The items of data are then archived, each with the correct temporal tag.

7.5 Data storage methods

Data storage can be carried out using two different methods:

- Periodic at fixed frequency (*periodic data storage*);
- Periodic with automatic frequency change on event[7] (*slow/fast data storage*).

7.5.1 Periodic data storage

For periodic data storage, the data sampling frequency and the duration of the archive itself are set at individual archive level.

For the sampling period, this can be expressed in seconds, minutes, hours and days. For data storage in relational databases, there are no limitations to the choice of period/duration pairs while, for data storage *in files*, a series of admissible pairs are set, as shown in Table 7-1 (limiting the maximum sizes of the files used).

When storing data in files, the number of files (32 maximum) used for storing single data archives must also be specified.

The total capacity of storage in files depends on the number of files used for one archive.

[6] For databases on binary files, there is a limit of 100 points.

[7] For archives in files only.

Frequency	Individual File Capacity	Maximum Capacity (Use of 32 files)
1 sec.	1 hour / 8 hours / 1 day	32 hours / 10 days / 32 days
5 sec.	8 hours / 1 day	10 days / 32 days
15 sec.	1 day / 1 week	32 days / 8 months
30 sec.	1 day / 1 week	32 days / 8 months
1 min.	1 day / 1 week / 1 month	32 days / 8 months / 32 months
5 min.	1 day / 1 week/ 1 month	32 days / 8 months / 32 months
10 min.	1 day / 1 week/ 1 month	32 days / 8 months / 32 months
15 min.	1 day / 1 week/ 1 month	32 days / 8 months / 32 months
30 min.	1 day / 1 week/ 1 month	32 days / 8 months / 32 months
1 hour	1 day / 1 week/ 1 month	32 days / 8 months / 32 months
8 hours	1 week / 1 month	8 months / 32 months
24 hours	1 month	32 months

Table 7-1: File-based data archives: period/duration pairs

7.5.2 Slow/Fast data storage

In a slow/fast data archive, as well as the archive duration, two different sampling frequencies are set.

The following pairs of Slow/fast period values are available: 1min./1sec., 5 min./5 sec., 15 min./15 sec., 30 min./30 sec. and 1 hour/1 min.

The respective durations allowed for of file-based archives are shown in Table 7-2.

S/F Frequency	Duration
1min./1sec.	1 hour
	8 hours
5 min./5 sec.	8 hours
15 min./15 sec.	1 day
30 min./30 sec.	1 day
	1 month
1 hour/1 min.	1 day
	1 month

Table 7-2: File-based data archives: period/duration pairs for slow/fast archives

The slow frequency is used to sample all points continuously over time. Instantaneous values are stored for Digital, Device and String points, while average values are stored for Analog points. These values are calculated by sampling the measurement using the fast frequency specified during setting of the data archive.

For samples of this type, the only significant *flags* are the **Estimated** *flag* (which indicates an average value) and the out of **Unreliable** *flag* (which indicates that at least half the samples contributing to the average were either not scanned or not reliable).

If (for analog points) one or more points being stored exceed the high/low and/or extremely high/extremely low limits, or if (for digital points) the status becomes 1, storage takes place using the fast frequency until all the alarm conditions have been resolved.

Therefore, during configuration of the archive, the user is obliged to set at least one of the following fast data storage activation criteria:

- **For analog points**:
  - Activation due to the high/low limits being exceeded;
  - Activation due to the extremely high/extremely low limits being exceeded;
- **For digital points:**
  - Activation if at least one of the archived digital signals is at 1.

Since the criteria set in this way apply to all the points input into the data archive, it is the system specialist's responsibility to appropriately subdivide the archives intro groups of correlated points.

7.5.3 Management of obsolete archive data

A typical problem associated with storing historical data is the need to control and limit the use of disk space available for data storage.

Historian uses two different management policies for *file-based archives* and *relational archives*.

7.5.3.1 File-based archives

Archives of this type are composed of one or more files (up to 32) used in circular mode.

When a file is full, a new one is created and, when the maximum number of available files is reached, the file with the least recent date is deleted. All files are considered full when the duration specified during configuration is reached.

For binary files, the sampling period and duration cannot be chosen arbitrarily but must be selected from a set number of pairs, as shown in Table 7-1. Consequently, the disk space used by the archive, at full extension, is preset.

7.5.3.2 Relational database archives

The policy adopted is to periodically delete the oldest data to prevent the system from running out of disk space.

Indeed, for data storage in relational databases, a process that deletes obsolete data is activated periodically.

Obsolescence is defined according to the following two criteria:

- The data is older than a set time interval (e.g. one month);
- The oldest data exceeds the size limit (in number of samples) set for the archive.

The activation frequency of the "database cleaning" procedure and the time interval (or number of samples) to be kept in the database are set by the system **eXPert**, whose job it is to mediate between operating requirements and availability of data storage system resources.

Historian makes it possible to set the moment of activation and the frequency of the procedure (e.g. once a week on Mondays at 14:30).

7.6 Diagnostics

The Historian application has a special user interface which allows the functional status of the data storage activities to be viewed.

It is possible to inspect the status of the activated archiver functions, the types of database being used, the archives and the measurements recorded by each archive.

Diagnostic information on the data storage stations (status of the connection to SCADA and activation status) are reported at SCADA level and can be used at HMI level to animate the pages of the system.

Using the appropriately configured “List” tool, it is possible to display the following information on the HMI station:

- List of Historian Stations and Substations (Archivers) connected to the SCADA unit;
- A list of archived points and their retention for each Station and Substation.

7.7 Displaying historical data

Historical data is normally viewed using the HMI application, which provides a series of tools for displaying historical data aimed at the automation and control system operator.

Of course, where relational databases are used, all the data display and integration tools (supplied together with the chosen database) can also be used, from reporting to display via WEB browser, allowing implementation of more management-oriented applications.

Where HMI is used, three main display categories are provided:

- Real-time trends initialized with historical data;
- Historical trends;
- Tabular formats.

The first two categories include tools for graphically displaying trends. These make it possible to display and analyze the data extracted from the historical archive; In particular the first category allows you to plot graphs of measurements of the plant in real time mode from the time series stored, so as to provide the operator an immediate indication of the tendencies of the measures monitored.

On the client stations with Microsoft Internet Explorer you can view the archive data in graphical format (using the same interface used by HMI).

The third category includes tools that display the archived data as numeric values in a table, in a spreadsheet (like Microsoft Excel) or in a page in HTML format.

With regard to the tabular data, you can export the information in the following formats:

- HTML;
- Excel;
- PDF.

The methods used for extracting the data from the archives are the same for both formats.

A series of criteria for extracting the data is available. These criteria share the concept of identifying the item of archived data using the index of the data storage station and the identifier of the *archiver* (substation) process. These two items of information clearly identify the source of the data needed to extract the historical values. The individual measurement is then identified by its DBS TAG and by the data storage frequency. If the latter is not specified then the items of archived data with the highest frequency for that measurement are extracted. The quantity of data extracted is set according to a time interval (otherwise all the data in the archive is extracted).

8. HMI

8.1 General information

The HMI package performs operator-plant interfacing functions using a series of video pages prepared during configuration of the application.

In general, the application uses a series of standard pages that can be used without particular personalization: pages of **eXPert** system diagnostics, alarm pages, pages for point forcing, and pages of real-time and historical trends.

The pages describing the specifics of the plant are created and installed through the engineering station which uses the tool *Page Editor*. Modification and/or addition of new pages is performed when the system is completely online. Simply calling up the modified page from the HMI station makes it possible to use it fully.

The HMI package performs purely graphic/interactive interfacing which allows the operators to interact as simply, quickly and easily as possible with the plant. The package acts as a client with regard to SCADA, requiring updating only of the data displayed on the current page.

It therefore requires the SCADA package to be present on one unit (or two if the system is dual).

Each unit of the **eXPert** system that performs the functions of operator interface must have an HMI package installed on it.

If PCs in configuration with multiple videos is used, it is possible to choose between two possible methods of using the HMI package:

- Use of a single HMI session that uses the available videos as though they were a single screen of a size equal to the sum of the available videos;
- Use of multiple HMI sessions, each of which uses one of the available screens.

The HMI package can also be installed on units that perform SCADA functions.

A particular case of use of HMI is the realization of control rooms video-walls, allowing the display of large synoptic pages on multiple monitors tiled together contiguously.

In addition, the HMI functions can also be activated on stations connected to the intranet/internet via an ordinary WEB browser. In this case, **eXPert WEB HMI** (described in Chapter 9.) must be used.

8.2 Features

The HMI systems are designed to display all the information needed to the plant conduction, the operator is informed about the current status of the field and may perform the necessary commands.

Through video, the operator can

- Be warned of the onset of alarms on the system;
- Display plant video pages: synoptics;
- Display measures values in numeric format, histograms or trends;
- Send commands;
- Change plant parameters: set points, parameters, alarm thresholds;

- Set up control loops;
- Request hard copy of HMI pages.

All functions are available to the operator by selecting from the menus or buttons on the video pages.

8.2.1 Video pages

The video pages on which the HMI interface is based, can be constructed using the special *Page Editor* tool, in the most suitable format for for the representation desired.

The video page is fully user configurable and allows greater freedom of information representation, both as design, animation, and as mode of interaction with the operator.

Some pages have specific characteristics based on their information content or the type of use. In **eXPert HMI** are provided the following predefined types of video pages:

- System page;
- Background pages;
- Overlapping pages;
- Alarms pages;
- Events pages;
- SOE lists pages.

Using the different types of page, the video is organized so as to allow the operator to maximize the available video area, maintaining always displayed, all the information necessary for the running of the plant.

Specifically, video pages can be created in different sizes to that of the physical monitors, taking advantage of the zoom, scroll, pan and decluttering functions that are available to whoever designs and constructs the HMI interface.

It is currently possible to create video pages for virtual monitors in sizes of up to 50 x 50 (2500) monitors.

The following elements, which comprise individual video pages, are unlimited in terms of quantities:

- Animated graphic elements or objects;
- System database points used to animate the page;
- Complexity of the animation.

With regard to the size of the pages, the system has been validated to manage pages that contain up to 200,000 graphic objects, animated based on the values in the database.

System performance can be assessed against the following test cases, including a page of average complexity (the case is a page representing an electrical transmission substation with high and very high voltage made up of 26 bays) and a high complexity video page (a topological page representing a MV/LV distribution system, used in a DMS system, is considered).

Page property	Medium Complexity Page	High Complexity Page
Objects	4.000	100.000
Measures linked	2.500	20.000
Code lines	70.000	1.000.000
Graphical part size	1 Mbyte	12 Mbyte
Code size	2,7 Mbyte	36 Mbyte
File size	2,5 Mbyte	50 Mbyte

For these pages were found the following performance, on a PC with 2.70 GHz Intel I-5:

System Property	Medium Complexity Page	High Complexity Page
First loading of the HMI page	0,5 seconds	12 seconds
Page compilation time	10 seconds	15 minutes
Refresh time for a variation of the 50% of linked measures	Less than one second	1 seconds

Each video page has its own size and basic properties, such as:

- Initial size;
- Initial position on the screen;
- Method of on-screen display: in a window that is mobile/fixed, resizable, iconizable, full-screen, etc.;
- Enabling of individual zoom, scroll, pan, detailing and decluttering functions.

8.2.1.1 Zoom

8 zoom levels are permitted (from 1 to 8, where zoom level 1 shows the image in the size set during its creation). Display layers of the objects can be linked to each zoom level in order to alter the detail of the information.

8 levels of layers are permitted. It is possible to link the layers to the zoom levels, as desired, to generate sophisticated “detailing” and “decluttering” functions.

Various zoom control and selection methods can be enabled, in any combination, during creation of the video page:

- Through one or more push-buttons dedicated to the general functions, outside the page in question. These buttons can lead directly to a preset zoom level and/or perform zoom in/out functions;

- Using the mouse scrolling wheel to move in both directions from one zoom level to another; the position of the mouse cursor identifies the centre to zoom in;
- Using the mouse to identify the rectangular area to be enlarged.

8.2.1.2 Scroll

The scroll function is performed using the horizontal and vertical scroll bars. These are automatically displayed when the area to be displayed is larger than the whole video page. Using the bars, it is possible to scroll through the page and view all parts of it.

8.2.1.3 Pan

The pan function makes it possible to view the page in a continuous movement. It is automatically activated when the area to be displayed is larger than the whole video page.

The pan function can be activated/deactivated using a special push button in the video area, dedicated to the general functions.

Once it has been activated, the operator “moves the video page" within the display window simply by holding down one of the mouse buttons and moving the mouse.

8.2.1.4 Detailing e Decluttering

These functions make it possible to set, during creation of the page, which animated graphic details will be displayed (detailing) or made to disappear (decluttering) depending on the layer active at any given moment.

The display of one or more Layers can be linked to each zoom level. This creates sophisticated levels of interaction depending on the zoom level used by the operator.

8.2.1.5 Calling up the video pages

In general, access to the pages is done using navigation buttons that link the different pages of system. Each video page is still identified by a *name*, this identifier can be used to invoke the page from a list displayed in a selection window.

The video pages can be organized in *sequences* so that we can move from one page to the next in sequence (and vice versa) using the *PageUp* and *PageDown* keys. In this way all the pages in the list can be scrolled in a circular manner in both directions.

You can also use the function Save/Call-up to store the currently displayed page (via the *Home* key); it can be reopened at any time of the session with the function Retrieve (*End* key).

8.2.1.6 Advanced multi-monitor management

There are a number of functions that allow greater freedom in positioning the graphic pages of HMI in a multi-monitor environment.

You can also view a page, recalling it from a HM, and sending it to another display device (typically a video wall or a multi-monitor HMI)

8.3 Video organization

The graphic/alphanumeric information is organized into “video pages” with fully configurable sizes, features and content.

In the following, the typical layout used for control systems is described; take into account that the type and arrangement of objects in the pages is freely configurable, in relation to the needs of the customer.

The video pages are displayed in windows and are constantly updated in real time with the plant data, whatever their position on the video.

As well as making the graphic pages fully configurable, the system guides the system **eXPert** through the creation of an operator interface governed by the following criteria:

- Not to allow the operator to open too many windows that would not all be visible and would overload the system;
- To always keep certain areas and/or information, which is of vital importance to the running of the plant, visible and/or always in the same position;
- To ensure easy and instant access to the information that the system makes available, in the form of video pages.

Typically the interface is structured to keep always on top, in the upper part of the video, called *header*, the most important signals (for example, signaling the presence of alarms) and the buttons invoke the most important pages.

The central part of the video is used to represent a portion of the whole plant. When you make a change of page the new page occupies this portion of the screen. If considered useful, you can represent this part of the video accompanied by scrollbars that allow you to move to a virtual area larger than the window.

In some cases it is also used a fixed part in the bottom of the screen, called *footer*. This part is left always in view, and contains controls and commands that you want to have always available

Summarizing, the operator interface is organized into different windows:

- *Main window* (System): always open and fixed, including header and (optionally) footer;
- *Background window*: from time to time contains the schematic representation of the desired; switching from one representation to the next via links or references (i.e. previous/next buttons);
- *Overlapping windows*: pop-up windows used to display equipment detailed information or control panels allowing commands and interaction with plant devices.

8.3.1 Main (or system) window

This is in a fixed position and normally occupies the entire screen. It is unique for each HMI station. It acts as a container for all the other windows. Generally, an area of it is always visible (the system reserves an area of 20% of the screen, at the top, by default) to contain information of a general nature and/or crucial to the running of the plant.

In order to better clarify the possibilities provided by the interface HMI, in the following is a particular case of implementation referred to a control system dedicated to the management of electric substations, in particular:

- Figure 8-1 shows an example of organization of the always visible area in the upper part of the screen;
- Figure 8-2 shows an example of organization of the area located at the bottom of the screen.

Figure 8-1: Main window header – electrical substation example

Figure 8-1 shows an header page example. For each button the function or pages recalled are the following:

- "*Plant*": allows the call up of the substation graphical representation (visualized by default at startup);
- "*Diagnostics"*: allows the call up of the automation and control system diagnostic page;
- "*Events*": allows the call up of the events list page
- "*Fault Recorder*": allows the call up of the fault-recording file list
- "*Alarms*": allows to invoke the plant alarms page; the button indicates, based on the coloring, the presence of active alarms and/or to recognize them;
- "*SOE*": allows retrieval of the page containing the list of registered Sequence Of Events.

In the upper part of the *header* other general purposes function buttons are present:

- User login/logout button
- Panning enable button;
- Hard copy button;
- Page selection button;
- Point "substitution" button.

Are also present the following indications (header right side):

- Current date and hour;
- Workstation name indication; SCADA connection status diagnostic (green color indicates that the workstation is correctly connected to the SCADA system and data communication is on line);
- User name of the currently logged in user.

Often, also the lower part of the screen is used as a *footer,* containing important functionalities.

Figure 8-2: Main window footer – electrical substation example

In this case the *footer* part is dedicated to the control and status information buttons relating to automation functions.

The following display/buttons are present:

- Plant alarms display;
- System alarms display;
- Display/button for command mode selection (the electrical sunstation can be managed in automatic local/remote or manual local/remote command mode);;
- Buttons for alarm panel call up (general alarms, auxiliary services alarms, plant general alarms);
- Button that allows the access to automation commands menu.

The symbol "A" at left on the footer is animated as follow:

- If rising alarms are present the background of the symbol "A" is flashing red;
- If only acknowledged alarms are present the background of the symbol "A" is fixed red;
- If no alarms are present the background of the symbol "A" is gray.

Some buttons can activate an attached popup menu, as shown in the following Figure 8-3.

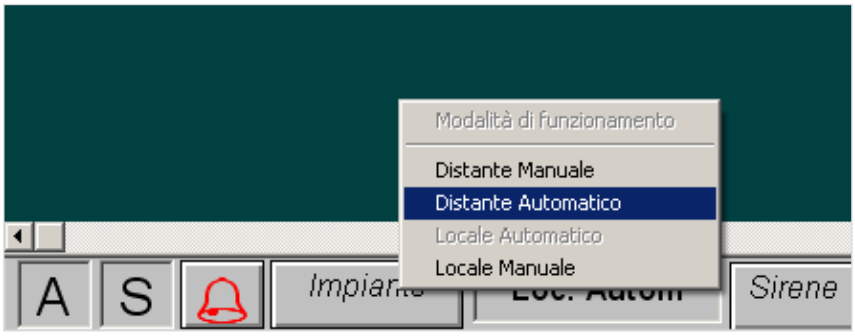

Figure 8-3: Example of popup menu

8.3.2 Background windows

These are contained within the main window and “rest" against the background. They can be positioned anywhere except in the area always visible in the main window.

Up to 8 background windows can be opened at the same time, provided they are adjacent and not overlapping. In any case, it is not possible to open more than 8 of the background windows and super-imposable windows.

If a background window overlaps with a previous one, the previous one automatically closes instantly.

Video pages of any kind can be displayed in these windows. Each individual window may (or may not) have a border, a standard top line with a title, and a series of attributes that make it possible to personalize the window depending on plant requirements and operator level. These features are set during configuration of the individual video pages.

Normally, the pages displayed in these windows cannot be dynamically moved or resized by the operator.

Figure 8-4 shows an example of a background windows that displays, at full size, a plant synoptic.

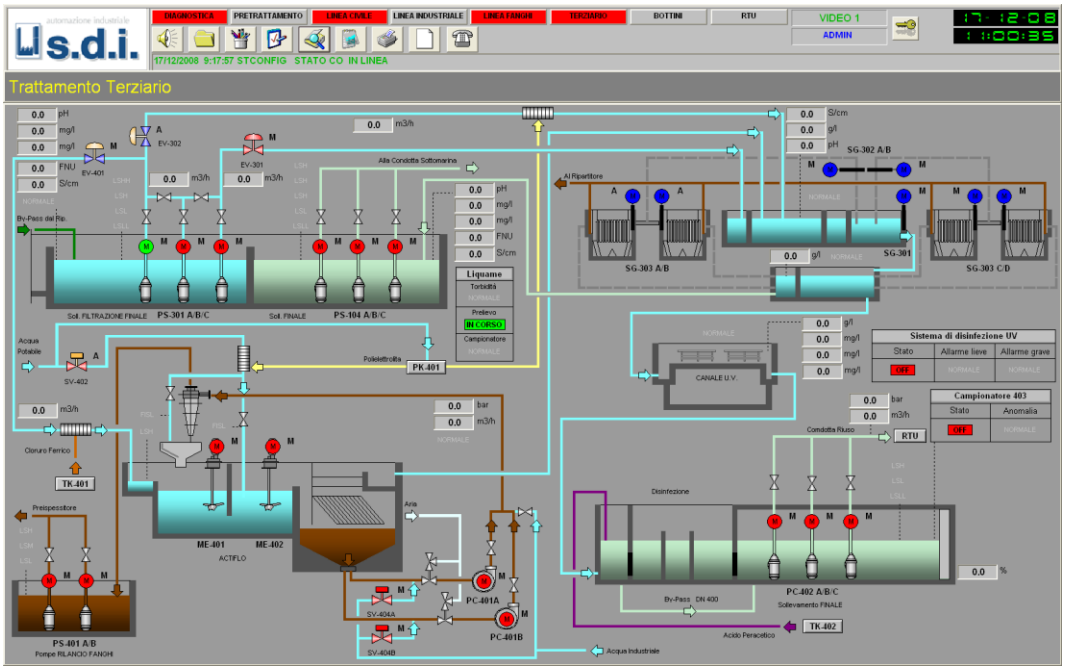

Figure 8-4: Background window – waste water treatment plant synoptic

The background window is often used to contain tabular summaries containing important information.

The example in Figure 8-5 shows a tabular summary page, that contains the indication of control logic blocks currently active in a gas compression station.

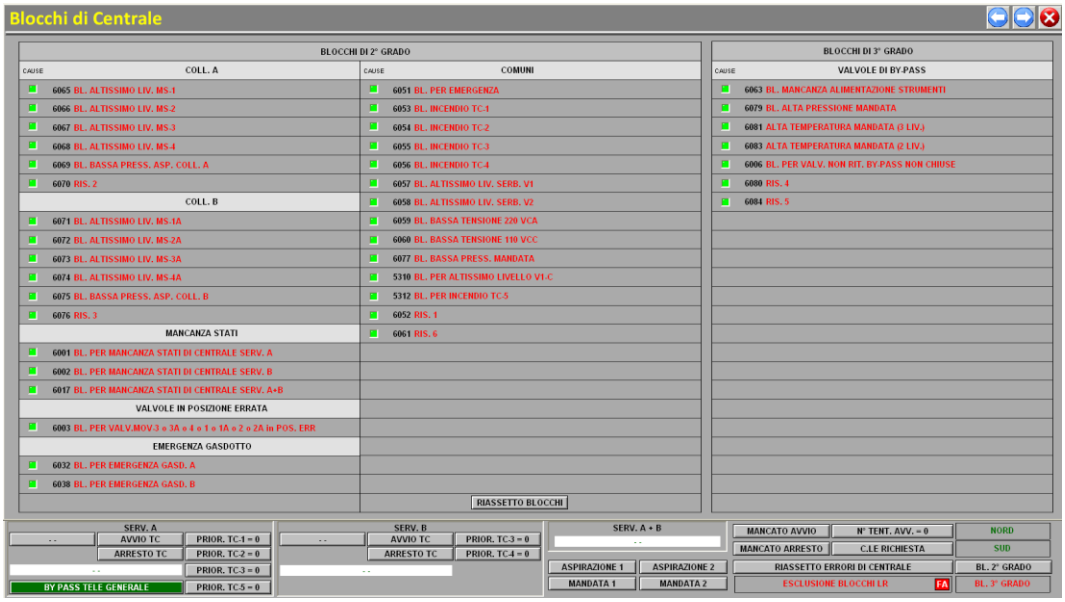

Figure 8-5: Background Window - Example of a tabular page for a gas compression station

8.3.3 Super-imposable windows

These windows overlap with the background windows and any other super-imposable ones.

Up to 8 super-imposable windows can be opened on the video screen at the same time. In any case, it is not possible to open more than 8 of the background windows and super-imposable windows.

They can contain any type of video page. The operator can be move and resize them using the pointing device. If they can be dynamically resized and/or moved, they must always show a frame and a title line on which the cursor must be positioned in order to use the movement and resizing functions. These functions are enabled at engineering level.

Normally, the super-imposable windows are used for functions connected to selecting dynamic elements (pumps, valves, menu buttons, etc.) on the background video page underneath. In this way, they create command cards, option menus, entry data for commands or special functions, detailed views, display of the progress of analog dimensions, etc.

In order to clarify the possibilities provided by the HMI interface, the following is a concrete implementation example referred to a dedicated control system that operates on a hydroelectric power plant.

Figure 8-6 gives the example of a page ("GR1 COM. EXCITER") displayed in a superimposed window (popup) over the background window that displays, in full format, the plant synoptic.

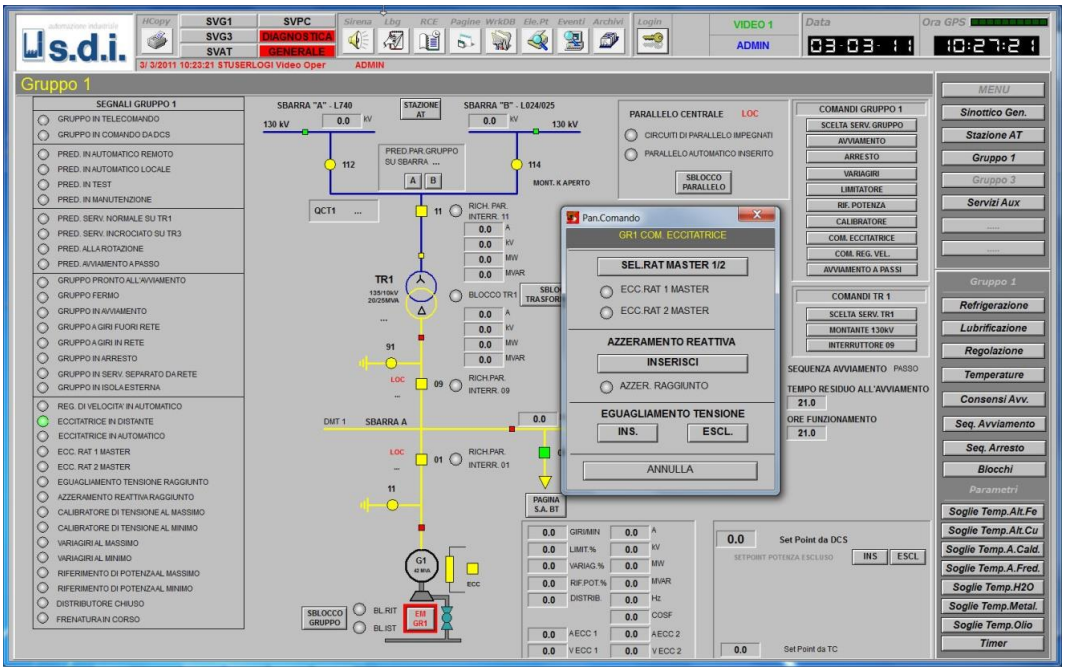

Figure 8-6: Super-imposable Windows – example of a popup control panel for a hydroelectric power generation plant

8.4 Calling up video pages

Access to plant information (contained in the video pages) can be fully designed and modified by the user directly on the online system. Indeed, the video pages can be called up on the video screen using any combination of the following methods:

- Using function keys that can be programmed by the user (or using a combination of programmable keys);
- Using programmable function keys whose function (in this case, the video page called up) depends on which video page is on the video screen when the key is pressed;
- From video pages, by selecting appropriate graphic elements (buttons, menus, graphic objects, etc.) on the pages themselves;
- By calling up ordered sequences of video pages (lists of pages). The video pages in a sequence can then be displayed using the <Page Up🡅> and <Page Down🡇> keys on the standard PC keyboard to move around the list in both directions;
- By saving the pages temporarily in a stack and later calling them up in reverse order;
- By calling them up directly from a program or programs on external systems or on the station itself;
- The operator calling them up directly using the name of the page in question (each video page is identified in the system with a name composed of a maximum of 10 alphanumeric characters).

8.4.1 User-configured video pages

The information contained in the items of plant data is organized into video pages. These video pages can be configured by the user, on stations equipped with the **eXPert Engineering Station** package, while the system is online.

The user therefore has the option of adding, deleting or modifying any video page directly at the plant.

The video pages display, in real time, the status of the plant, using data supplied by external systems or generated internally.

The station manages the video operator in window mode (Windows), using the normal functions provided by the Operating System.

The windows can be manipulated as follows:

- Opening:
- Movement;
- Closing;
- Resizing;
- Etc.

Windows manipulation function, if desired, may be kept to a minimum in order to make the system simple and efficient to use.

During configuration of the video pages, it is possible to restrict or disable some of the typical functions of window interfacing.

For example it is possible to:

- Set a fixed size for each video page on the screen;
- Set a fixed position for each video page on the screen;
- Set whether a video page should appear at background level (closing the previous page/pages) or be superimposed on the other pages displayed;
- Alter the position or size of a video page depending on plant variables;
- Limit the number of video pages that can be displayed simultaneously in superimposition.

Each video page is configured as desired on the Development station using a special interactive graphic program called *Page Editor*. This program is composted of graphic and alphanumeric elements with fixed or dynamic features (color, flashing, size, appearance, etc.).

The elements with fixed features constitute the static part of the video page and represent the "background" of the video page itself.

The elements with dynamic features constitute the variable part of the video page and represent the dynamic status of the plant.

During construction of each individual video page, the user can connect the dynamic elements to the video page as desired, choosing the following from an appropriate library:

- Basic symbols available in numerous fonts of scalable sizes;
- Strings of characters in various formats and character formats;
- Complex diagrams;
- Plant elements (such as valves, pumps, switches, etc.);
- Command/control elements (keys, buttons, cursors, etc.);
- Digital displays of measurements;

- Histograms;
- Graphics with measurement progressions (trends), both real-time and historical;
- Representations of X/Y measurements;
- Spreadsheets compatible with Excel;
- Etc.

These elements vary in color, attributes, size, position, visibility, etc. depending on the plant data.

As well as the dynamic elements, the user can also insert ActiveX objects into HMI pages, which perform specific additional functions.

8.4.2 Animation logic of video pages

The logic with which the dynamic elements vary depending on the plant data is not fixed or in any way preset, but can be personalized for each page during its construction.

Generally, the animation logic of each individual dynamic element is implicit and depends on the type of component: valve, pump, switch, tank, regulator, string of alarms, button, key, etc.

The user only specifies the plant variables that must be used in animation of the element.

It is, however, possible to personalize the animation logics of the dynamic elements, in order to generate new dynamic elements not provided by the standard library.

In order to create more complex video pages with more sophisticated animation (pages to help with the running of the plant, prescriptions, setting of plant parameters, etc.), it is possible to specify, on each page, an “animation logic” which makes it possible to personalize all functional levels of the video page.

In any case, it is possible to add (simply and instantly using objects that can be personalized using forms, in a more complete and flexible way by directly specifying the animation logic) more sophisticated and completely configurable interaction functions, such as:

- Calling up other video pages from the page itself;
- Activating selection menus;
- Activating pop-up menus;
- Activation/deactivation of applications within the system;
- Reading the disk file;
- Executing even relatively complex calculations and logics;
- Input/output to video;
- Managing selections on video;
- Selecting and controlling zoom levels;
- Displaying ASCII files (such as Daily Report and SOE Printout files, etc.);
- Etc.

It is also possible to set (or reset) the functions relating to the functional keys of the keyboard (keys that can be programmed by the user) temporarily (only while the page is displayed).

8.4.3 Previous assets views pages

You can define synoptic pages that can load both data acquired currently from the plant and historical data previously stored in the archives.

In this way you can go back to view the previous plant assets stored in the database, using the same video pages that are used to represent the current state of operation.

This feature is used both in simulation systems and in supervisory and control systems where historical analysis of the plant assets is provided.

8.5 Alarm display

The plant alarms are managed centrally at SCADA level. The HMI software only provides the functions of displaying and managing the alarms (acknowledgement, searches, saving or copying to external support tools, etc.)

The alarms are described by a “type”, a severity level (out of 3), a processing level (out of 9) and an area of the plant (out of 128).

They are stored in different “alarm databases” (DBAs), depending on the area/areas of the plant they relate to. Subdivision of the alarms into different DBAs is a result of the need to "assign" supervision of different parts of the plant to different operators.

Each DBA can store considerable quantities of alarms, in chronological order, up to a maximum of 32,000 alarms per DBA.

When activated, the alarms are classified as *“rising"* and must be acknowledged by the operator according to specific procedures. Acknowledged and still active alarms, classified as *"acknowledged",* are stored in a part of the DBA known as the *“active alarm archive”* until the cause of the alarm is resolved.

It is also possible, at individual alarm level, to request that cancellation of the alarm cause (*alarm deactivation*) be notified and acknowledged by the operator in the same way as activation of the alarm.

Alarms are displayed using special video pages (alarm pages), one per DBA. The alarm page functions as a “window” into the DBA, through which it is possible to view the alarms to be acknowledged, acknowledge alarms and scroll through the contents of the database, including the “active alarm archive” section.

The system is normally supplied with preconfigured alarm pages that can be personalized, just like any video page, using *Page Editor*.

A color code is used in the display to indicate the seriousness and/or type of the alarm.

Alarm acknowledgement, through the alarm page, can be performed individually for each alarm or in groups of 16 alarms (per page).

If the page is not full (less than 16 alarms displayed), acknowledgement is takes place on condition that the user has activated the button to “freeze” the alarm situation displayed .

This device ensures that, at the time of acknowledgement, no new alarms are highlighted which would be acknowledged without the operator taking due charge of them.

The most recent alarm in each DBA can be displayed on any video page. It is normally displayed on a line in the main window.

8.5.1 Alarm strings on video

Each alarm is displayed in a single line on the video screen, organized in the following fields:

- Indication of the current status of the alarm, dynamically updated every second:
  - flashing/fixed = rising/acknowledged alarm
  - colored = current status of the alarm;
- Indication of the time the alarm occurred, in [DD/HH/MM] or [HH/MM/SS] format;
- Code (or TAG) of the alarmed point;
- Description of the alarmed point;
- Status of the point following the alarm;
- Unit of measure, for measurement alarms, or expected status, for device alarms;
- Value of the alarm threshold (for measurement alarms only);
- Current value of the measurement updated in real time (for measurement alarms only);

Each alarm string has a color that depends on the type of alarm, the level of seriousness and the status of the alarm.

It is possible to modify the color assigned - level of seriousness – type of alarm simply by modifying a special file on the SCADA station.

Each alarm page can contain a maximum of 16 alarms at one time. Scroll functions in both directions make it possible to view all the alarms in the DBA.

8.5.2 Dynamic filters on the alarm page

The alarm page can filter the alarms using a suitable logic that can be applied to any field of the alarm string.

In particular, it is possible to configure the filters using logical operators such as:

- AND, OR
- >, < , =, <=, <=
- !like, …

It is also possible to control the colors of the strings based on the same types of filter.

The filter operations can be automatically applied when the page is called up, but it is also possible for the operator to directly enable construction of the filters in run-time.

8.5.3 Management of the alarm page

The alarm page is divided in three main parts:

- Title
- Header
- Alarms scrolling list

The *title* indicates at which plant area are referred the listed alarms.

The "*title*" area contains the page description and a pull-down menu with following items:

- "*Save*": save the current view of alarm list in an Excel or XML file;
- "*Print*": print the current view of alarm list;
- "*Filter*": activate view filters;
- "*View*": allows you the choice between the view of arising alarms only, acknowledged alarms only or all alarms (arising plus acknowledged).

The header area contains the following indications:

- Number of rising alarms
- Number of acknowledged alarms
- Number of alarms in the alarm list
- Total number of alarms (greater than the previous if more than 200 alarms are present)
- Active filter (if the list is currently filtered)

The "*Alarms scrolling list*", contains up to 200 alarms strings (one row for each alarm).

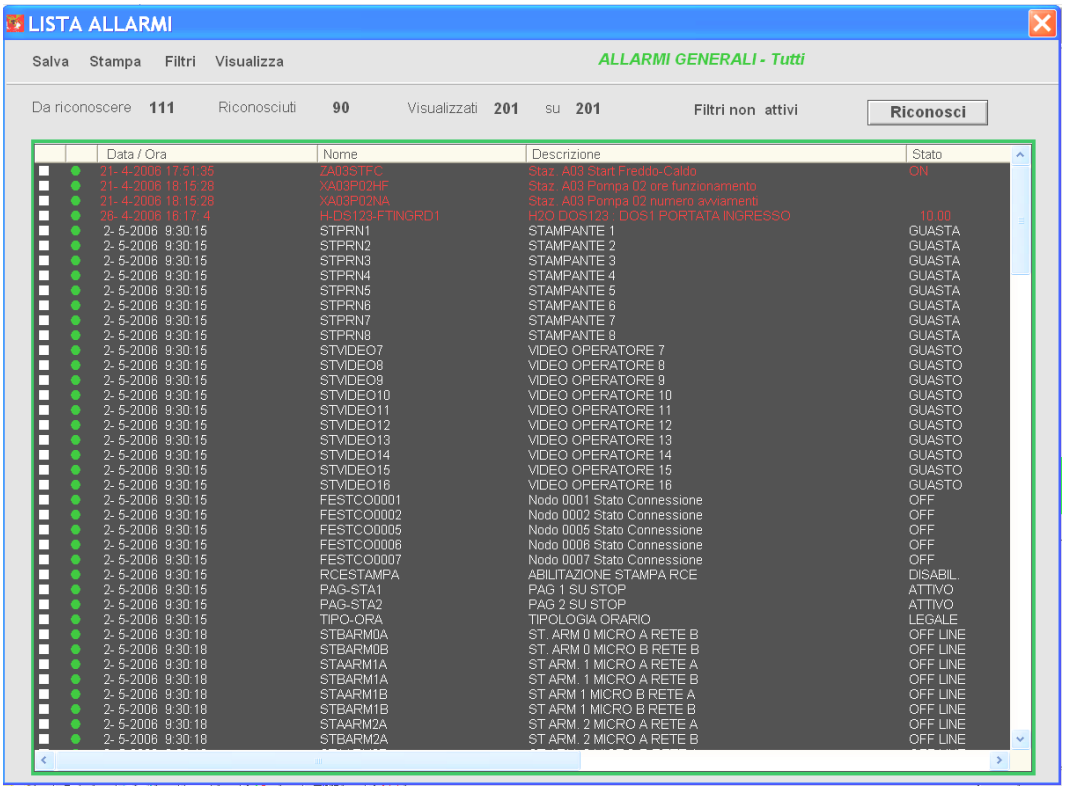

Figure 8-7: Simultaneous display of arising and acknowledged alarms

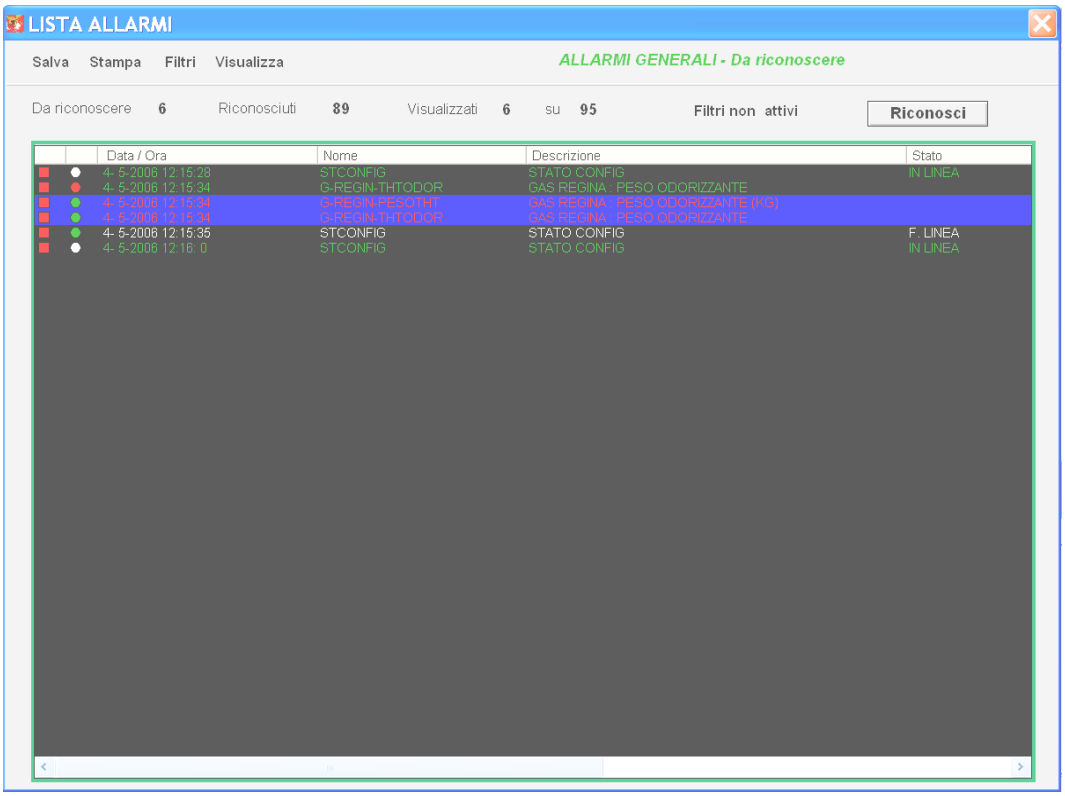

Figure 8-8: Selection of alarms to be acknowledged (in arising alarms list)

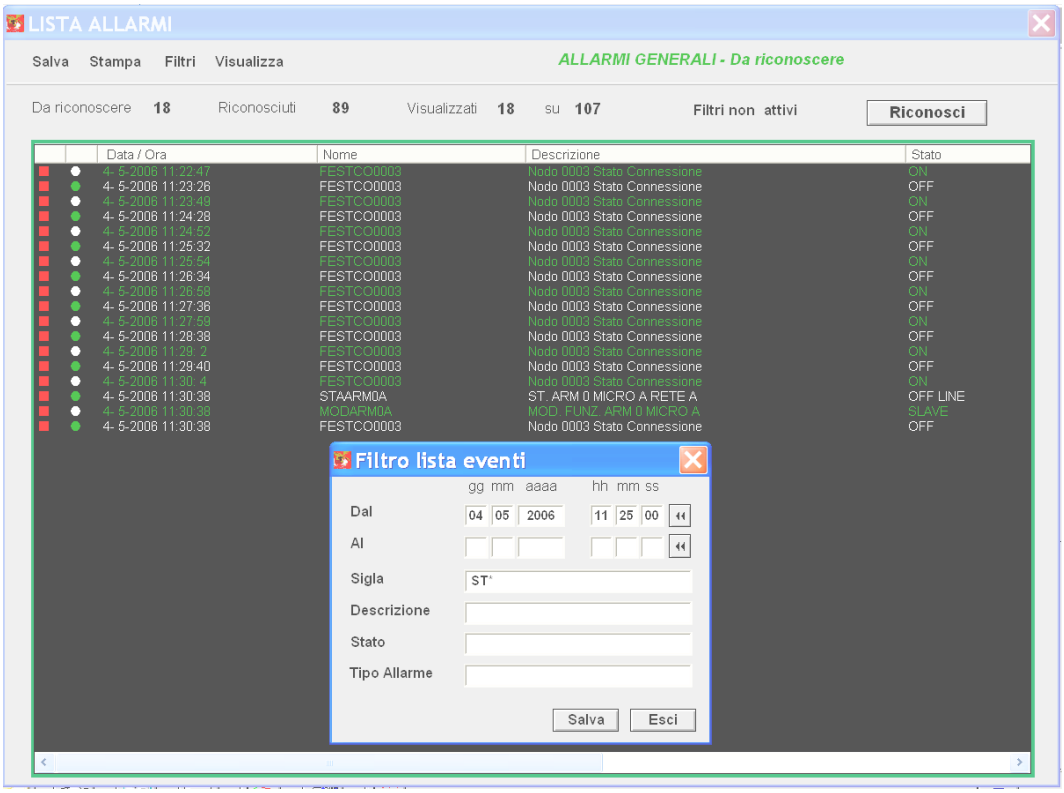

Figure 8-9: Alarms filtering functions

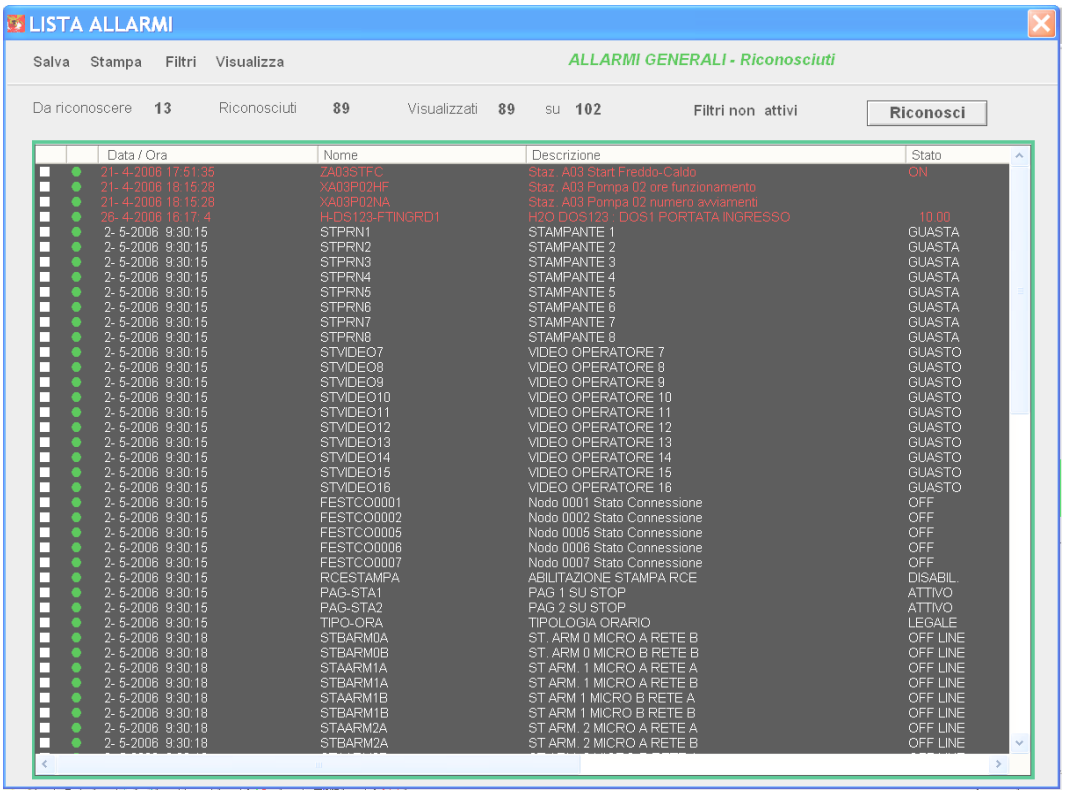

Figure 8-10: View of acknowledged alarms

The alarm list can be filtered using the command “Filter”; you can apply the filter on the tag, description, or date fields; wildcards are allowed.

The alarms list can be sorted by one of the fields:

- Date/Hour;
- Name;
- Description;
- Status;
- Alarm type;
- Zone.

Sorting is achieved by selecting the column header of the the field to be ordered.

The acknowledgement is possible only for the alarm currently selected in the list. The selection mode follows the Windows standard: single click of the mouse to select, click Shift key for multiple selection. You can select all the alarms using the multiple selection to adjacent rows.
After making your selection, you can acknowledge alarms selected using the "Acknowledge" command.

Within the system it possible to enable a locking mechanism that provides the alarm acknowledging functions (on a specific alarm page) only to one operator at a time.

In this case, if the alarm page is used by another operator you can only view the alarm list but acknowledging functions are disabled (the alarm page is locked).

If the user has the needed privileges, he can send the command "enable" to unlock the alarm page (the other user will have the page locked in turn).

8.5.4 Alarm panel management

Managing display panel representing alarms is easy using synoptic video pages.

A classic example of this is integration of the alarm pages with a summary background page, positioned in the lines at the top and bottom of the screen, displaying the alarm status of the various areas of the plant through cards that change color depending on the number, status and seriousness of the relative alarms.

From this summary page, it is possible to call up the alarm pages and/or synoptics relating to a particular area of the plant simply by selecting the card corresponding to the area whose alarms the operator wishes to view and/or acknowledge.

8.5.5 Alarm management in a hierarchical structure

The video pages can be equipped with indicators as to the presence of alarms in the different areas of the plant according to a hierarchical subdivision in part/sub-parts of the plant itself.

In this case, an appropriate graphic symbol will change color to indicate the presence of rising or acknowledged alarms in the parts/sub-parts of the plant.

This graphic indication will normally allow a more detailed page to be opened, where any sub-parts showing alarm signals will be highlighted further.

Hierarchical subdivision of points of the plant is carried out at PointEditor level, associating each point of interest with up to 10 hierarchy indexes.

The hierarchical structure can extend to up to 6 levels with a maximum of 256 branches per level.

8.5.6 Events and SOEs lists stored in relational databases

SCADA uses a relational database for events and sequence of events (SOE) storage.

Events and SOE lists are displayed on pages organized into lists. An events page and an SOE page are provided. These allow filtering and ordering of the displayed fields in the same way described for the alarm page. The pages can relate to the entire plant or be specific to a certain area of the plant and/or a certain identifying hierarchy.

The events page contains the signals “printed in the Daily Report”, and is a “user-friendly” method of consulting the Daily Report. The SOE page contains the records from the chronological event recorder and therefore contains signals enabled for recording in event sequence.

Thanks to the list of events, it is possible to display all the operations carried out at the plant. In this case, too, the display can be filtered, particularly based on a relevant time interval.

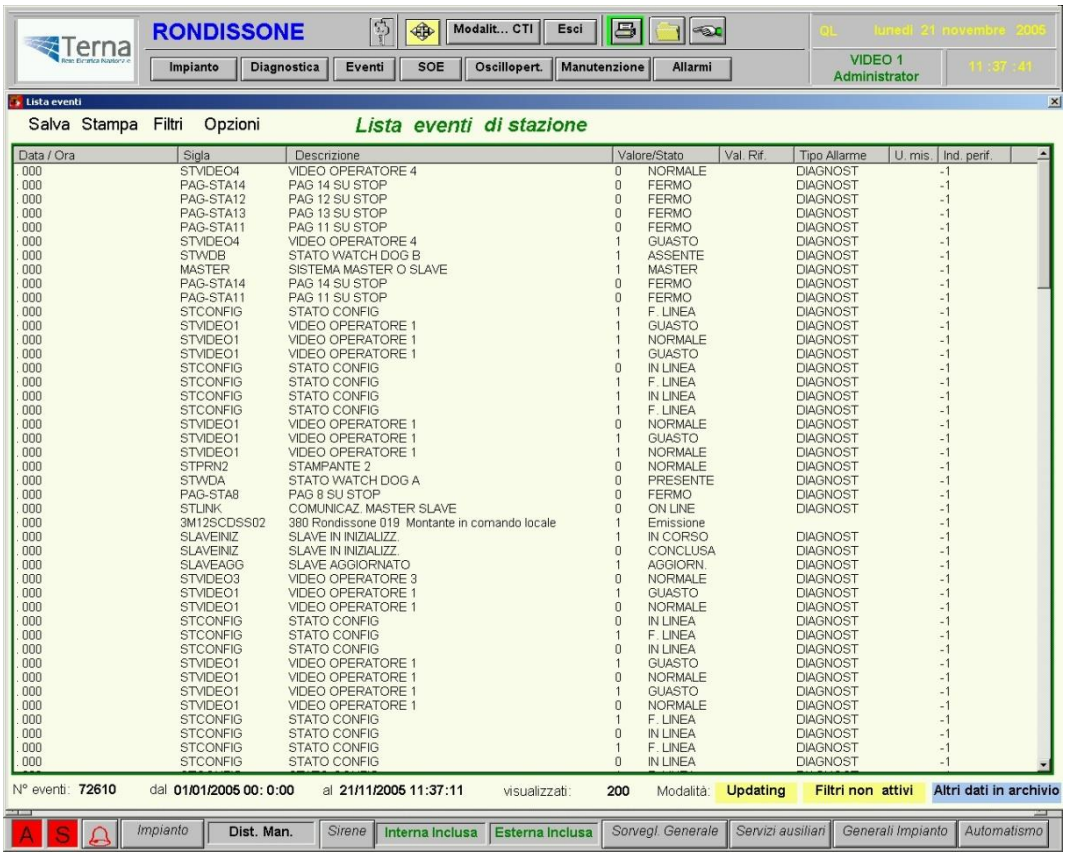

Figure 8-11: Events page

Both lists can be organized by areas of the plant controlled and/or by type the of event displayed (for example, distinguishing plant events from events relating to the automation and control system).

These pages allow activation of filters (by tag, by description and/or by time interval) and ordering by each type of column in the list.

The menu contains the functions of printing (active in any filtered and ordered lists) and saving in files in text, Excel or XML format.

8.6 Online diagnostics

The HMI station has extensive online diagnostics functions. All the information collected is stored in real time in the SCADA station DBS and made available to all units and all users.

Most of this information is digital and is processed in the same way as events and/or alarm signals. Alarms generated by system diagnostics are stored in special databases and undergo processing, on display and printing, which differs from that used for plant alarms.

The status of the automation and control system and of the main connections with the field acquisition peripherals is normally presented to the operator using diagnostic synoptics, as shown in Figure 8-12. This specific case shows a DCS system composed by:

- A couple of process server (redundant configuration);
- Two **eXPert STAR** control nodes;
- Five HMI stations (top);

- A plant RTU and other serial line connected third party apparatus (on the left).

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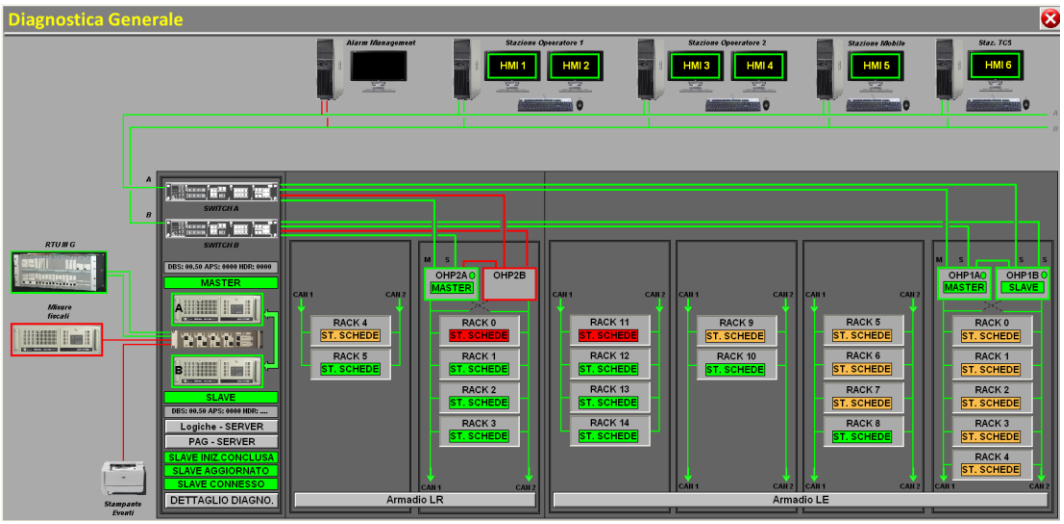


Figure 8-12: Example of a general system diagnostic page

Figure 8-13 is an example of a diagnostics page showing an **eXPert STAR DualBus** station, detailed down to individual I/O board level.

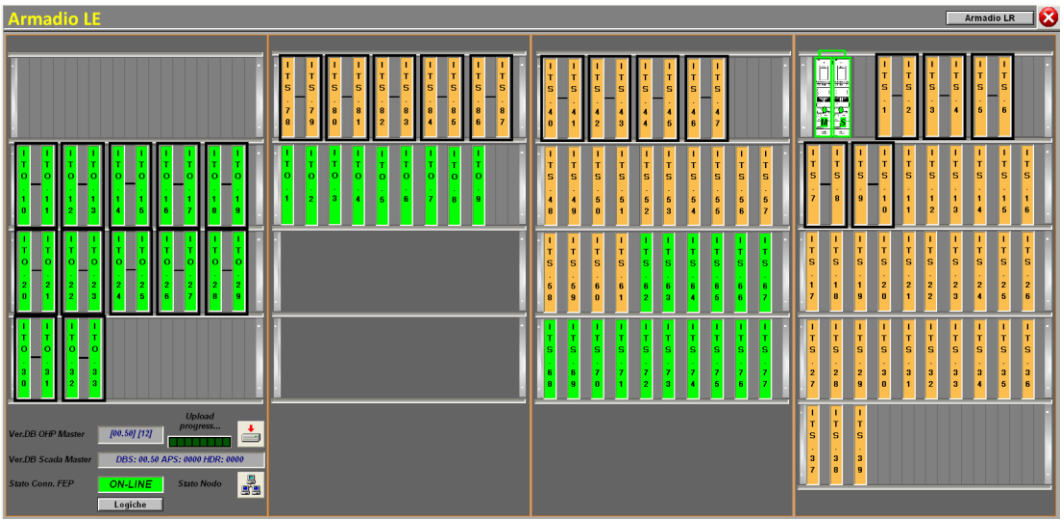


Figure 8-13: Diagnostic page for an eXPert STAR DualBus node

From the page displaying the **eXPert STAR** station, it is possible to access another level of detail relating to the individual I/O card, which shows the status of each individual signal.

In Figure 8-14 is shown, as an example, the detail diagnostic page of the **ITM** board (8 analog measures), one of the I/O boards of **eXPert STAR** product; it shows the values of analog measures, acquired in real time, and related diagnostic information.

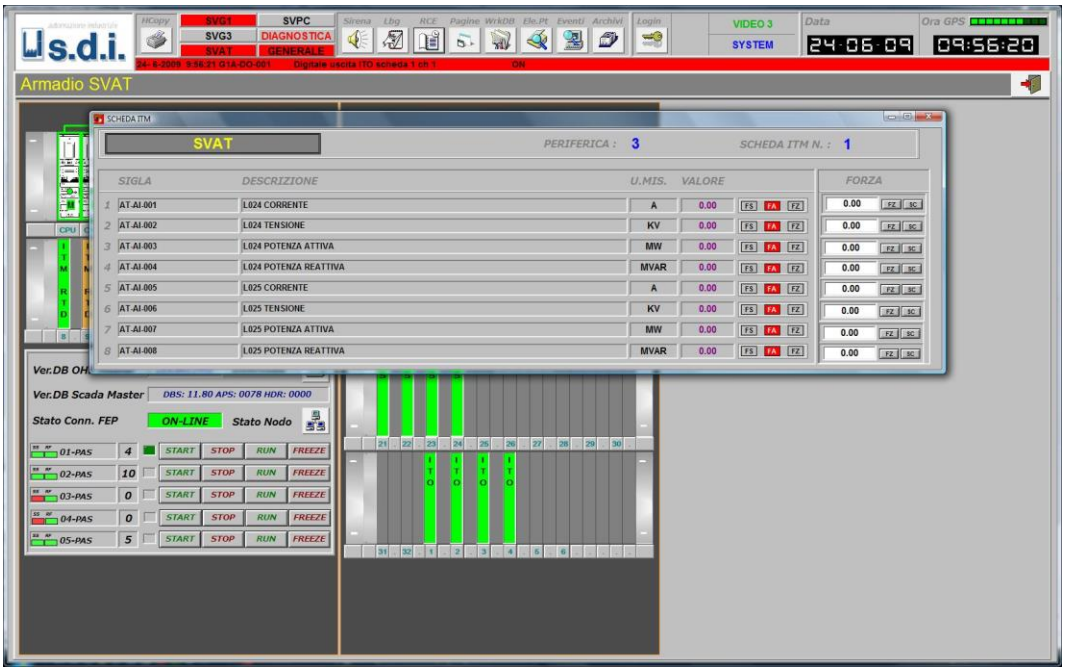


Figure 8-14: Diagnostic page for a single I/O board

It is possible to integrate the diagnostic information described above, which properly belong to the automation and control, with information on network devices and server operating status, using information available through the use of SNMP protocol.

It is possible to insert in the SCADA system references, via its OID, to any diagnostic information, made available by the devices that are equipped with SNMP.

In Figure 8-15, for example, using the information managed by SNMP, you can monitor, for the two servers, the redundant power supply, the status of network adapters, disk and CPU temperatures; you can also monitor the status of the managed switches that, in this case, manage the system and the field networks.

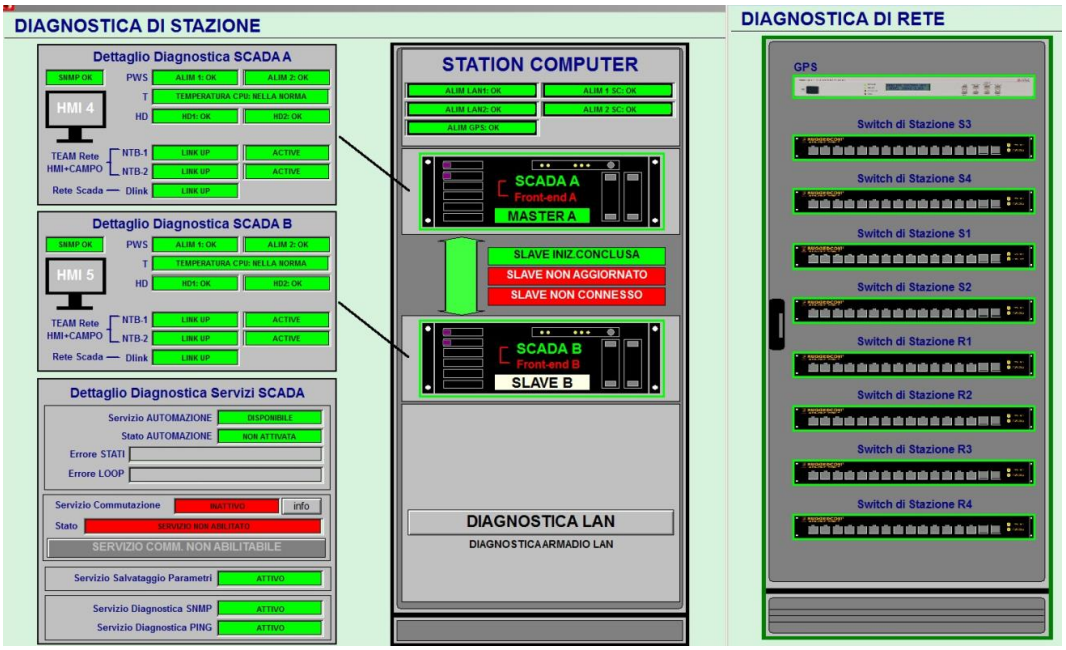


Figure 8-15: Diagnostic page that uses information acquired by SNMP protocol.

9. WEB HMI

9.1 Remote HMI connections via WEB HMI

WEB HMI is an HMI (Human Machine Interface) product, oriented towards interaction between the operator and the plant from a remote location.

The supervision and control system can be accessed through an Internet or Intranet connection. In the latter case, the WEB HMI functions are also available when accessing the corporate or system network through a dial-up connection.

This product allows the operator to access all restricted functions using an ordinary web browser, depending on the information to which the operator's account is granted access.

Each connected user can activate their own WEB HMI Client session without having to install special software on their own station or upload the latest changes to the operator interface configuration.

Management of access to the supervision system and maintenance of the synoptics pages accessible to each user are centralized on a station that has server functions for the remote HMI (WEB HMI Server) stations. This station may be combined with the platform dedicated to SCADA functions or it may be a special station connected to the former through the local network. The choice depends on performance considerations relating to the size of the supervision and control system and the number of planned user connections.

9.2 Development system and compatibility with traditional HMI

WEB HMI is fully compatible with the configuration tools provided with the **eXPert Engineering Station**. The video pages are created using *Page Editor* and can be used on any traditional HMI station or WEB HMI Client Station, with no need for recompilation/installation.

The fundamental difference with traditional HMIs is the fact that all the information on the pages available to the user, and the pages themselves, are on the WEB HMI Server station. As well as the advantage in terms of management and maintenance of the pages themselves, the user can, of course, connect to the system from any PC enabled for this function and access the supervision and control system.

9.3 Supported operating systems

WEB HMI is based on Microsoft's Remote Desktop Services technology. The following operating platforms are therefore necessary for stations with WEB HMI Server functions:

- Windows 2008 Server
- Windows 2003 Server

The stations that connect with WEB HMI Client functions can use both operating systems from the Microsoft Windows/Windows CE family and systems based on Linux or, more generally, UNIX.

More specifically, the following operating systems are supported for **WEB HMI Client** stations: Windows 7, Windows Vista, Windows XP and Linux[8]

Clients can therefore consider using platforms already present in their machine park, leading to clear savings and optimal use of resources.

The protocols used depend on the operating system installed on the client station. For all Microsoft operating systems supported, the RDP 5.0 protocol is used while, for Linux and other Unix systems, Citrix XenApp is used (formerly known as Citrix Metaframe™).

9.4 Activation of WEB HMI Client functions

WEB HMI Client functions are activated on the Client station following installation of the software that enables remote terminal functions. This software can be downloaded directly and installed, if being used for the first time, by connecting to the WEB HMI Server station.

Once the station is enabled for remote connection, no further updating is required, as all system and/or configuration activities (e.g. installation of new video pages or modification of the operational level granted to the user) will be performed at WEB HMI Server administrative functional level.

The WEB HMI Client functions are available as both ActiveX and “full-screen” applications.

In the first case, WEB HMI Client function can be integrated with any WEB browser that supports the presence of ActiveX in the pages displayed. The second alternative performs HMI functions as a classic full-screen human-machine interfacing application.

9.5 System architecture

The following paragraphs describe some of the possible system architectures that can be constructed using WEB HMI.

WEB HMI Server services can, in any case, co-exist with other applications such as SCADA, HMI and their relative engineering tools.

9.5.1 Minimum configuration

The minimum configuration is shown in Figure 9-1.

In this case, both SCADA functions and WEB HMI Server functions are performed on the same platform.

The following products must be installed on the server station:

- SCADA (with relative I/O Server for interfacing with the plant);
- WEB HMI Server.

Stations that host WEB HMI Client services can vary in terms of the hardware and the operating system used.

[8] CitrixXenApp is used with Linux, which requires a Windows 2008 Server add-on to WEB HMI Server. WEB HMI is also available in full-screen mode for Linux.

Figure 9-1 shows the use of WEB HMI CLIENTS in a system allowing access via the internet. Note the option, of using both traditional HMI stations and WEB HMI Client on the plant's LAN network.

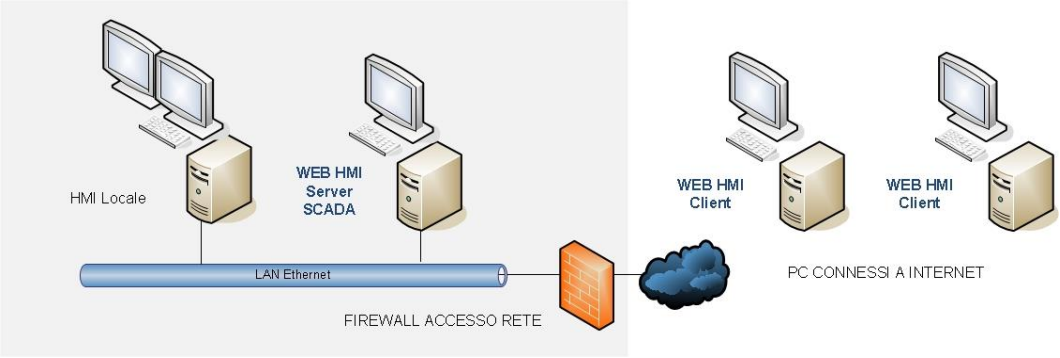


Figure 9-1: WEB HMI connection trough Internet

9.5.2 Configuration with station dedicated to WEB HMI SERVER

If a large number of WEB HMI Clients need to be connected, it is advisable to dedicate a machine exclusively to WEB HMI Server functions. This machine will be connected to the LAN through the SCADA server. In this case, the logical connections will be those between SCADA and the WEB HMI Server, plus the connections between each WEB HMI Client and WEB HMI Server. Where traditional HMI is used, a direct connection with SCADA is present.

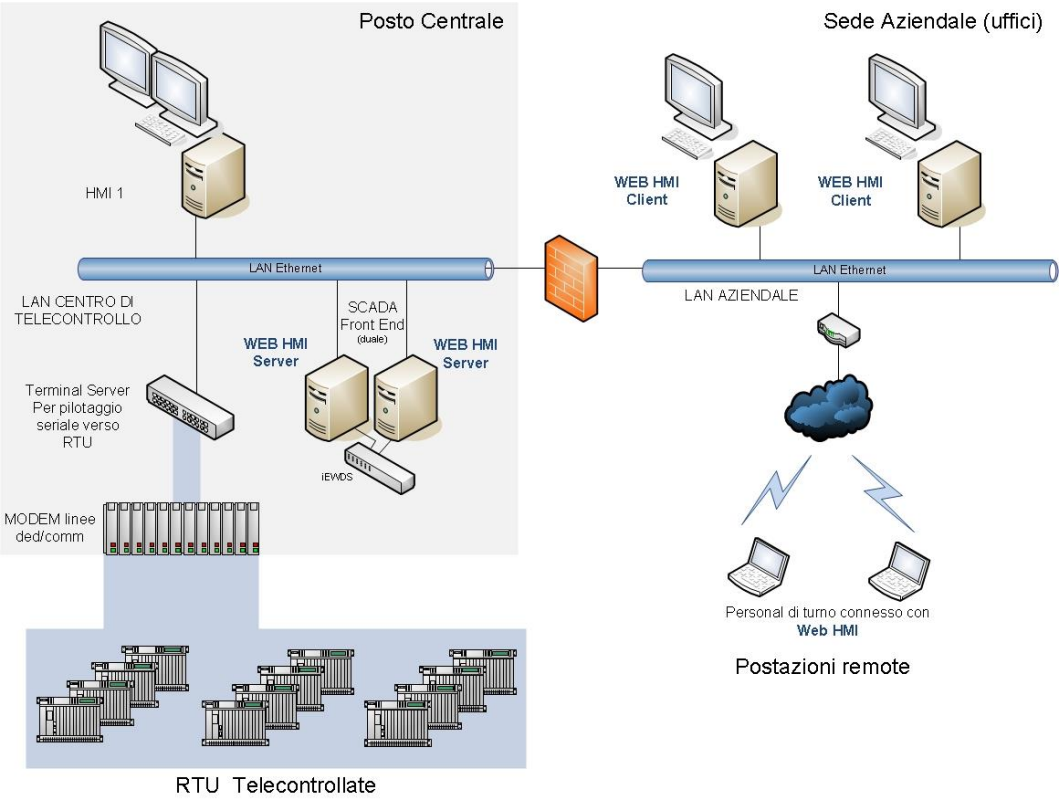


Figure 9-2: Deployment of WEB HMI Server directly on SCADA Server

9.5.3 High reliability configurations

If high levels of system reliability need to be guaranteed, it is possible to adopt dual configurations as in Figure 9-2 and Figure 9-3. In these figures a configuration using SCADA and I/O Server stations (dedicated to field acquisition) in duplicate configuration is shown.

In Figure 9-2 WEB HMI Server functions are deployed on the same servers that have SCADA functions.

In Figure 9-3, instead, a station entirely dedicated to WEB HMI Server role is shown.

In both the solution WEB HMI Server acquires the necessary data to the WEB HMI Client stations from the SCADA station with Master functions, and can switch to the hot back-up station in the event of failure.

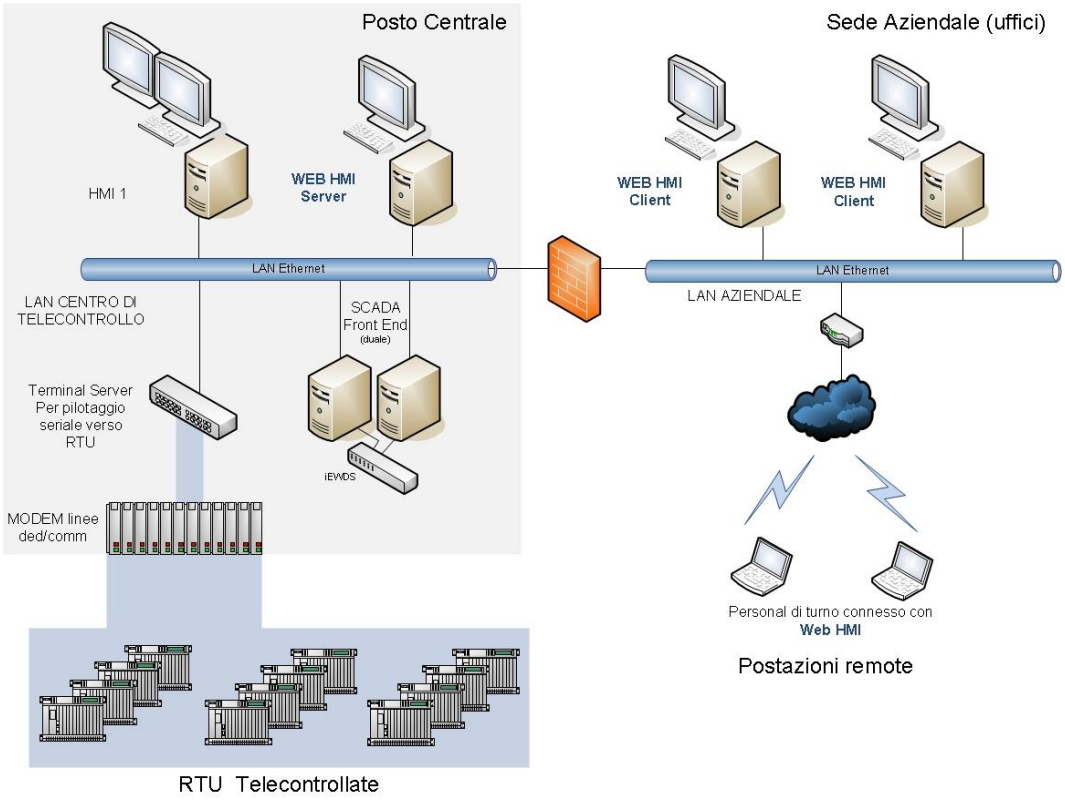


Figure 9-3: WEB HMI solution with redundant SCADA and dedicated WEB HMI Server

10. Historian Viewer & Back-up

10.1 Off-line data archive management

The archive data stored by the system **eXPert**, using the component Historian, are stored in relational databases, using the policy to periodically delete older records to avoid running out of disk space available.

When is required an high frequency storage, of a large number of SCADA points, for durations of several years, it is available the additional **Historian Viewer & Backup** storage feature. In this case the data are transferred to additional media thanks to a series of tools to facilitate both storage operations and data retrieving.

The tools available have also the capacity to operate simultaneously analyzing archived data from multiple SCADA systems.

10.2 Displaying historical data via the Web

The **Historian Viewer** application allows protected access to historical information stored in the **eXPert** system through a web interface.

The information accessible is the data stored by Historian, in the form of measurement and signal archives, and by SCADA, in the form of event lists and SOE lists (SOE lists).

An ordinary browser (e.g. Internet Explorer) and access to the server where IIS is hosted are sufficient to access the information remotely.

10.3 Backup and post hoc analysis – the Storage module

Storage is an **eXPert** system optional module, dedicated to long-term archiving and retrieval/analysis of data previously stored; it may be activated on a dedicated PC or on one of the PC used for the **eXPert** system.

The use of the Storage module is recommended when the management of the plant requires historical long-term storage (years) of significant events (events log and sequences of events) and values of groups of significant measures. Compared to the features of the Historian module, Storage module is more backup and recovery oriented for the analysis of historical situations of the plant.

Storage operated in connection to a maximum of 4 SCADA nodes; providing the data transfer of:

- Archived measures;
- Daily report (event and alarm log);
- SOE log.

SCADA nodes can be in single or dual configuration.

The data transfer activities are scheduled according to an activation period set by the user, specifying also the destination on the mass storage devices available.

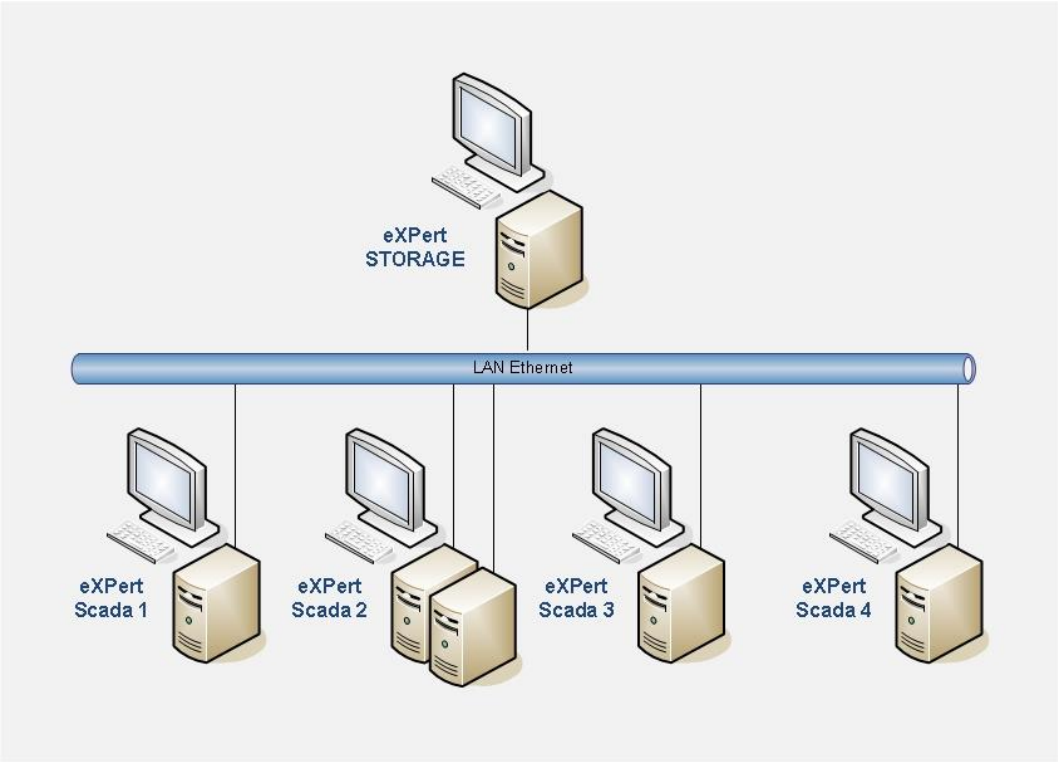


Figure 10-1: A Storage station connected to 4 SCADA hosts one of which in dual configuration

The user interface of Storage appears as a browser from which are visible (in a directory tree structure) items on the **eXPert** system that may be subject to long-term storage and the corresponding elements of local storage (referred to as archives, SOE logs, events and alarms logs).

In Figure 10-2 is shown the case of a Storage station connected to two SCADA systems (system 1 and system 2).

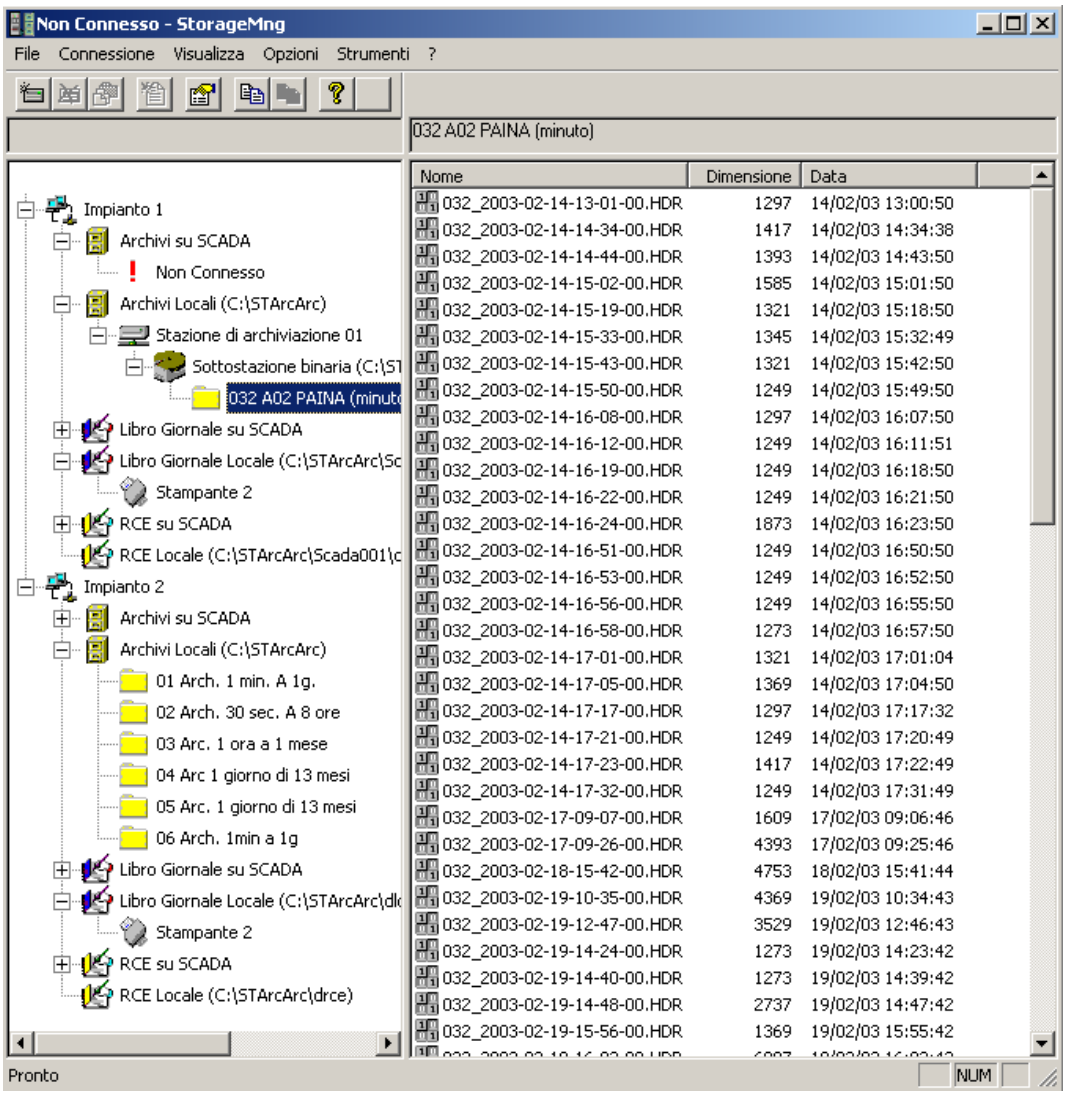


Figure 10-2: View of the items in the Storage station

11. Reporting

11.1 General information

The **eXPert Report** package is used to produce reports[9] based on the plant data stored in the real-time database or in the **eXPert** system historical database.

The reports are produced automatically (activated periodically or on event) or can be manually requested directly by the operator through the **eXPert** HMI stations.

The report produced can be sent directly (even simultaneously) to one of the following types of output device:

- Disk such as files on Excel or HTML format;
- Physical printer (local, networked or remote);
- E-mail.

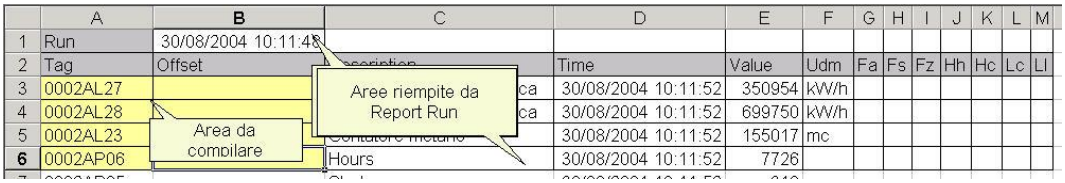
Where reports are sent by e-mail, the report is generated as a file (Excel or HTML) and attached to the e-mail sent.

The content and layout of the of the individual report are simple and clear to configure using commonly used IT tools and procedures.

There are two different possible methods:

- By creating Excel files;
- By creating files in HTML format.

Figure 11-1 shows an example of Excel spreadsheets produced by the Report package.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Run	30/08/2004 10:11:48											
2	Tag	Offset		Time	Value	Udm	Fa	Fs	Fz	Hh	Hc	Lc	Ll
3	0002AL27			30/08/2004 10:11:52	350954	kW/h							
4	0002AL28			30/08/2004 10:11:52	699750	kW/h							
5	0002AL23			30/08/2004 10:11:52	155017	mc							
6	0002AP06		Hours	30/08/2004 10:11:52	7726								

Figure 11-1: Example of reports on an Excel spreadsheet

All types of printer (black & white or color) are supported, provided that they have a driver for Windows 2000/2003 or XP or can be connected directly on the LAN network and are visible from the station on which the **eXPert Report** package is installed.

[9] Traditionally, reports were sent to the printer and were called printouts. This function still exists as a special case of the more general reporting function.

11.2 Composition of the eXPert Report package

The package consists of two principal components:

- *Editor*: sets the report's activation and generation characteristics;
- *Runtime engine*: collects data from the SCADA database (real-time and historical), fills in Excel spreadsheets and performs printing, saving and/or sending via e-mail.

eXPert Report is designed so that it can be installed on distributed **eXPert** architectures.

The main modules can therefore be installed on any computer connected via the LAN network to the other computers on which the remaining **eXPert** modules are installed.

As a special case, the packages can also be installed on a single computer.

11.3 Runtime engine

The **Runtime Engine** module of **eXPert Report** is equipped with a window interface which makes it possible to:

- Monitor the progress of operations;
- Display the list the reports installed;
- Force the production of a report (Test)
- Monitor and modify the module's settings online.

The following figures show the windows relating to the functions listed above.

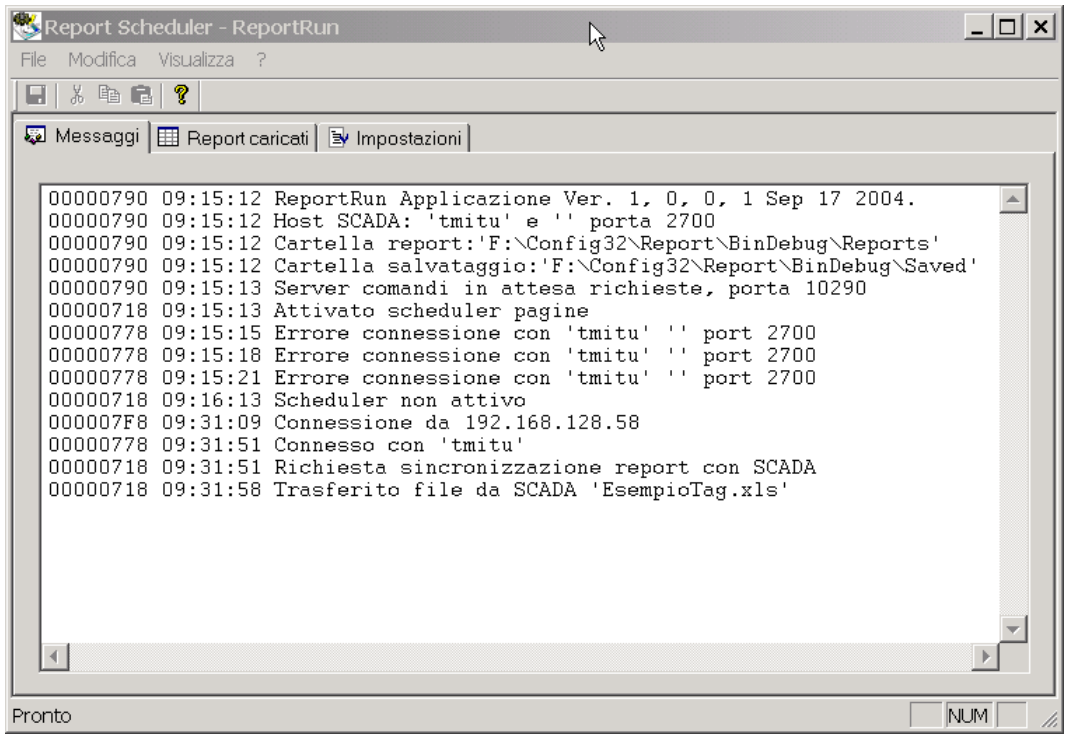


Figure 11-2: Operations logging

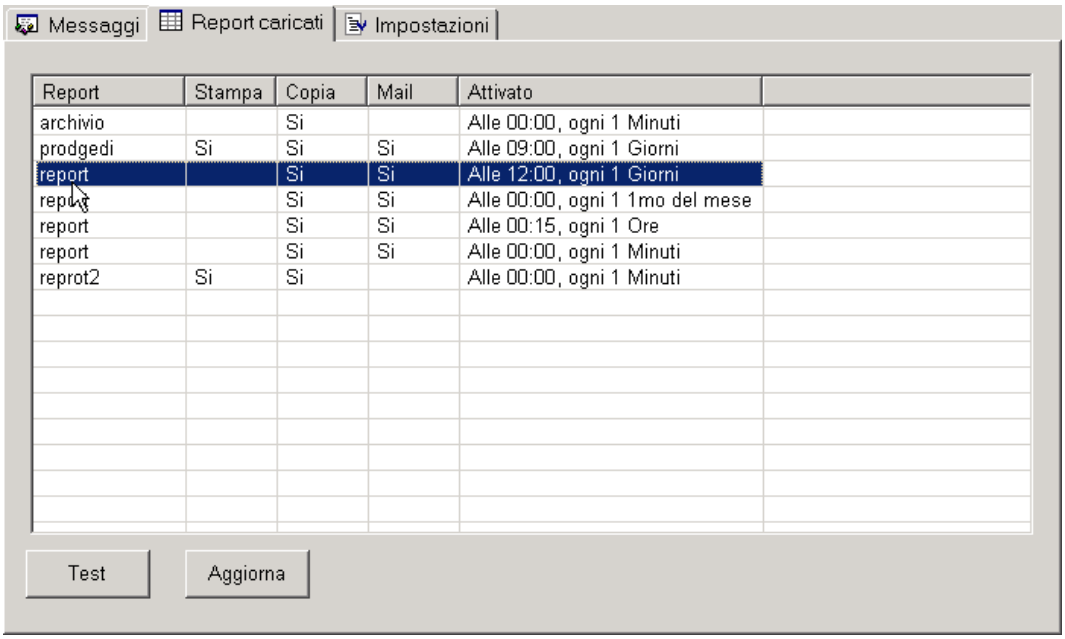


Figure 11-3: List and status of reports installed

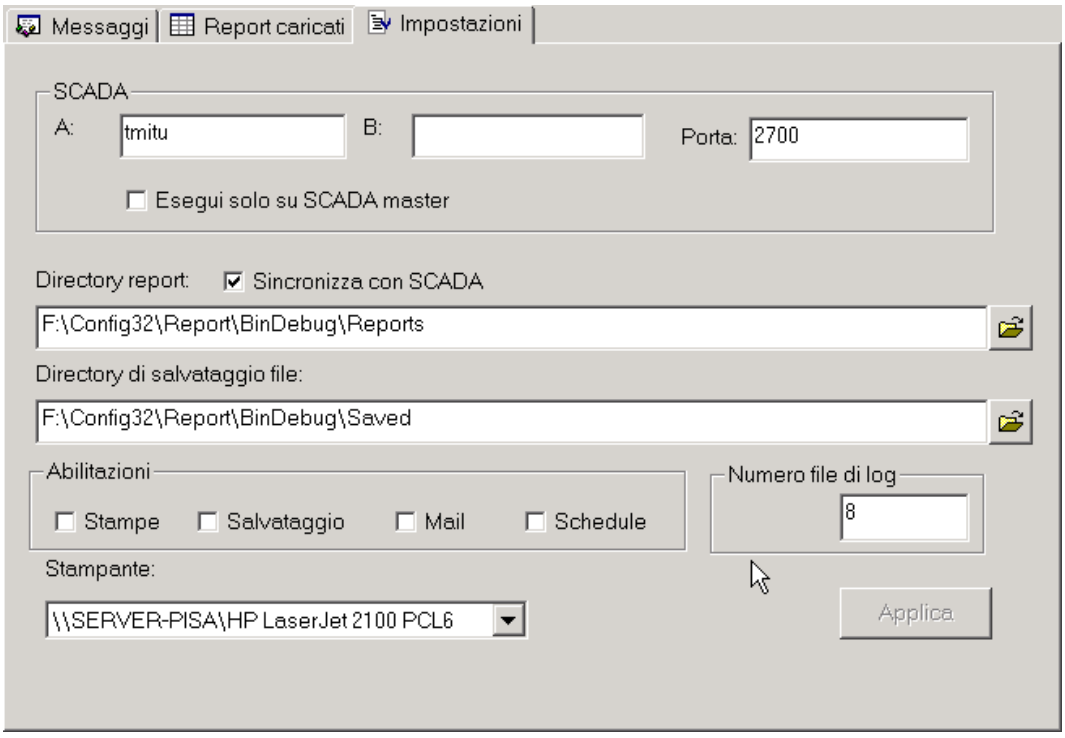


Figure 11-4: Module settings

11.4 Information accessible using report

11.4.1.1 Access to data in the SCADA real-time database

It is possible to access all the information stored in the **eXPert** SCADA real-time database.

The TAG of the individual point is used as an access key. The following specific fields can be accessed:

- Values and quality/alarm indicators (Flags) of analog points (acquired, non-standard calculated, standard calculated and diagnostic);
- Binary status, unencrypted status and quality/alarm indicators (Flags) of digital points (acquired, non-standard calculated, standard calculated and diagnostic);
- Binary status and quality/alarm indicators (Flags) of device points;
- Unencrypted strings and quality/alarm indicators (Flags) of string points;
- Description and time of sample for all point types;
- Unit of measure for analog points;
- Unencrypted statuses for digital points.

11.4.1.2 Access to data in the archive database of the Historian station

All the information in the **eXPert** archive database on the HDR station can be accessed.

The TAG of the individual point and the time of the sample requested are used as an access key.

The time can be specified as an absolute or as relative to the report production time.

The following specific fields can be accessed:

- Values and quality/alarm indicators (Flags) of analog points (acquired, non-standard calculated, standard calculated and diagnostic);
- Binary status, unencrypted status and quality/alarm indicators (Flags) of digital points (acquired, non-standard calculated, standard calculated and diagnostic);
- Binary status and quality/alarm indicators (Flags) of device points;
- Unencrypted strings and quality/alarm indicators (Flags) of string points;
- Description and time of sample for all point types;
- Unit of measure for analog points;
- Unencrypted statuses for digital points.

12. Remote Alarming

12.1 General information

The supervision and telecontrol centre can be equipped with an SW package, called **Remote Alarming**, to automatically send telephone calls, text messages (SMS) and e-mails regarding alarm signals to contactable personnel during periods when the centre is not manned.

The Remote Alarming application lets you send voice messages to staff on duty for the acknowledgement of a specific on SCADA alarm. The operator can inhibit the alarm and undertake a series of procedures. Voice messages, previously recorded as audio file or inserted as text and converted using Text-To-Speech, can be sent.

Use of remote alarming functions is interfaced with SCADA and is highly configurable to adapt to the requirements of the specific plant in which it is being used.

Configuration involves both SCADA, with the option of defining which alarms will be notified by telephone call, and also HMI, where it is possible to configure a series of video pages with which to organize lists of contactable personnel and shifts of contactability.

12.2 Hardware/software prerequisites

The hardware requirements to use the Remote Alarming application is to have a compatible device that allows interfacing to an analog telephone line for playback of voice messages.

Furthermore, the device must provide for the recognition of DTMF (Dual Tone Multi Frequency) for inhibition of alarms.

12.3 Main functions

The Remote Alarming system may be considered, for all intents and purposes, an additional function to the **eXPert SCADA** alarm management system.

It is possible to select a subset of SCADA points, hereafter referred to as *points undergoing remote alarming processing*, so that any alarm status found for these points will trigger a telephone call to the contactable personnel on duty.

Please note that management of these points is completely independent of the management of points alarmed by SCADA.

It is possible to set, depending on the type of point, which point statuses should trigger a telephone call (e-mail or GSM) to the contactable personnel, and what the voice (or written) message sent should say.

The choice of personnel to call, the telephone numbers and the information regarding shifts are managed by a group of specially dedicated SCADA points. In this way, the personnel management policy can easily be set appropriately for specific cases by writing an application (PAS or PAG) created ad hoc.

12.4 Vocal messages

The *remote alarming* function can operate in two different modes:

- Using a Text-To-Speech engine (TTS);
- Using pre-recorded messages.

In the first case the alarm message is automatically translated into a voice message, in the second case it is necessary the recording of voice messages in PCM format wave, single channel and with a sampling frequency of not higher than 128 Kbit per second.

Message recording can be done with utilities supplied with the operating system.

The maximum number of managed voice messages is 1500.

12.5 Organization of staff on duty

Remote Alarming integrates functions for managing the contactable personnel to whom the calls must be sent.

The SCADA points provided make it possible to subdivide the personnel into 8 *sectors*. Each sector is used as an *area of expertise*.

It is possible to set which area of expertise (sector) each point subject to *remote alarming* belongs. This means that the telephone calls are made to personnel who are contactable at that moment and belong to the correct area of expertise.

Each sector can be divided into up to 8 teams composed, in turn, of 8 members of contactable personnel. The teams establish which contactable personnel are on duty at any given time. The system establishes (based, for example, on the day of the week and of the timetable) which team is operating at that moment for each sector.

For each team the type of notification is defined, giving the possibility to choose (not exclusively) voice call, SMS and/or an e-mail.

It's also possible, in case of use of voice calls, to enable a notification mechanism that allows you to receive SMS and/or an email when one operator of the staff on duty has taken charge of the alarm. It is also sent a notification in the case of failure to take charge of the alarm after a configurable timeout.

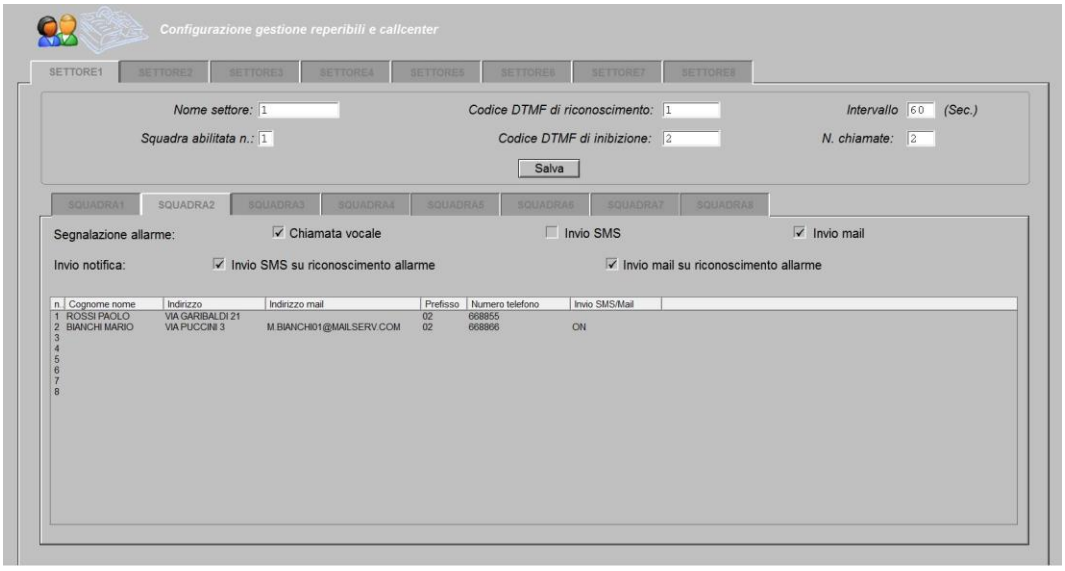


Figure 12-1: Configuration of staff on duty

12.6 Telephone-call management

The following applies to *vocal* telephone calls.

The calls are managed using the following procedure:

- Composing the voice message and inserting it into the list of messages to be sent;
- Identifying the personnel on duty, depending the sector set for the point generating the call and on the team contactable at that moment;
- Calling the first operator listed among the personnel of the team on duty;
- If the operator responds and acknowledges the call, deletion of the message from the list;
- If, after a certain number of attempts the operator does not respond or does not acknowledge the alarm signal, the next contactable operator on duty is called.

The operator assuming responsibility for the alarm signal by typing an agreed DTMF acknowledgement code, specific to each sector, into the telephone keypad.

Management of telephone calls is controlled by a series of SCADA points which make it possible, on one hand, to access the information on the telephone call in progress at any time and, on the other hand, to modify the authorized team, the telephone numbers of the members of contactable personnel, or the time interval that must pass between one call and the next.

The following parameters can also be configured by setting the content of SCADA points created especially for this purpose:

- The DTMF alarm response and acknowledgement code for contactable operators from the particular sector;
- The number of call attempts to be made to the telephone numbers of the relevant sector;
- The waiting time, in minutes, between one call to the operator and the next;.

These parameters can be set at different values depending on the sector to which they relate.

12.7 Call request and types of points

The types of point that can be selected for *remote alarming* are:

- Digital;
- Analog;
- Device.

For digital points, the following point statuses can trigger a call to a contactable operator:

- Not Reliable;
- Return to Reliable;
- Change of Status.

It is possible to request a call due to one or more of the statuses listed above.

For analog measurements, a call is issued for points in one of the following statuses:

- Not Reliable;
- Return to Reliable;
- Exceeding High Limit;
- Exceeding Extremely High Limit;
- Exceeding Low Limit;
- Exceeding Extremely Low Limit;
- Return within High Limit;
- Return within Extremely High Limit;
- Return within Low Limit;
- Return within Extremely Low Limit.

For device points, the following conditions can trigger a call to contactable personnel:

- Spontaneous variation;
- Command failed.

Up to a maximum of 4096 *remote alarmed* points can be set.

When one of the points enters a status for which signaling to contactable personnel is requested, the SCADA system sends the information on the point to the system that signals to the contactable personnel responsible for creating a voice and/or text message to be used in the call.

It is possible, for *remote alarmed* points for which it is deemed necessary, to inhibit transmission of the message depending on the status of an additional point set during configuration.

This function is automatically enabled for *remote alarmed* points where the code of the inhibiting point is configured.

To make this function effective in cases where the inhibiting point is subject to change during the moments following the point variation triggering the signal, the option of delaying the reading of the status of the preventing point has been introduced, based on a configurable time interval (inhibition timeout).

In the most general case where an inhibiting point is present, the call request sequence will therefore be as follows:

- Point managed by contactable personnel enters a state that triggers a signal;
- Wait for inhibition timeout;
- Reading of the inhibiting point's status;
- If the inhibiting point is at zero, composition and transmission of a message.

12.8 Calls to team on duty

In relation to the configuration adopted, the module will start the Remote Alarming call sequence to the available personnel whenever a specific alarm arises.

The call can be ended with the acknowledgement of the alarm, by the called personnel, with the introduction of the exact DTMF recognition code, otherwise the call will be terminated without alarm acknowledgement.

The module allows you to configure Remote Alarming with two different calling modes. The first method requires that before you can hear the alarm (and hence to recognize it) it is requested to enter an access code, in the second mode the alarm message is

immediately notified followed by the request of introduction of the acknowledgement code.

For each alarm that is not acknowledged by the staff on duty are provided a certain number (configurable) of subsequent attempts to call.

The number of calls set on the teams and sectors configuration panel specifies instead the number of attempts that must be made on the same phone number before moving on to the next, if available, belonging to the same team on duty.

12.9 Faults reporting function

In the Remote Alarming module is also available the fault reporting function, which allows a user to make calls to the module itself, to indicate a failure or problem in the plants controlled.

This type of call, defined as 'user calls', are designed to allow a user to record a voice message. The module Remote Alarming finished recording a new message, forward a call request to the module which will provide SCADA to start a new round of calls to the available personnel in order to allow him to play the message previously recorded. To make the message recording the user is asked to press a particular key telephone, recording will start as soon as it recognized the correct DTMF code.

Recorded messages and users will also be replayed off-line as they are still saved to audio files available on request.

12.10 Alarm inhibition

In the configuration of signals that trigger a call to the available personnel, you can define a digital SCADA point that acts as a trigger inhibitor.

This digital, according to its status, can inhibit the alarm call.

This mechanism is commonly used to inhibit a succession of alarm calls that would be an immediate consequence of the first alarm recognized; the result will be the call related only to the first alarm.

13. Connectivity

13.1 General information

This chapter deals with the with external and third-party systems connectivity, available with **eXPert**.

The various connectivity options offered cover different needs and types of data; usually there is a correspondence between the type of connection you choose and the functions performed by the connection.

Without wishing to establish a single criterion of choice, the table shows the type of service and type of connectivity functions/requirements it fulfills, in addition to its common use.

Type	Characteristics	Functions	Typical use
Web Services	Easy to implement, general purpose and widespread. Easy access through firewalls and routers (Web) Platform-independent	To read the summary data and diagnostic To read the important information stored	Interfacing with management systems or in any case with higher level systems. Implemented on LAN, WAN.
API	Implementation using C or C++ code development.	System customization or special functions that requires the development of an extension to the SCADA system. For particular time-critical extension to the system	Creation of custom systems, VAR extensions made by customers
OPC (OLE for Process Control)	Communication standard in industrial automation and control systems Usually available in third-party SW and HW components.	Interfacing between industrial process automation systems. Complete SCADA variables communication toward superior level systems or acquisition devices.	Automation and control system components inter-communication; used specifically for automation and control devices. Implemented on LAN, WAN.

Type	Characteristics	Functions	Typical use
MODBUS	Usually used in third party hardware components to exchange data with upper level systems.	Interfacing control devices (PLC, DCS). Interfacing other industrial automation external systems	Interfacing to the component level of automation and control system. Born for serial lines, sometimes used on TCP network in peer to peer connection.
IEC 60870-5-101/104	Born for energy distribution and transmission it is today widely used for telecontrol system in general (including GAS distribution)	Complete as the type of information carried in SCADA and DCS systems. Optimized for speed and network load.	Connection with the remote control centers. Connection with other devices. Implemented over serial lines and LAN/WAN.
SNMP (Simple Network Management Protocol)	Born for the management of network devices and servers in IT. Allows in particular diagnostics of network equipment (switches, routers, firewalls)	To integrate in the SCADA system diagnostic information of the network equipment. To provide the management tools of the corporate network with additional information on apparatuses dedicated to automation and on SCADA servers.	Diagnostic about the network status and about status of server, workstation and devices connected to it.

Table 13-1: General characteristics of connectivity

13.2 eXPert Web Services

eXPert Web Services allows the access to the SCADA database from a remote Client using the SOAP standard.

Web Services allows interoperability between the SCADA and external Clients based on different hardware/software platforms.

Using an XML based format, the messages exchanged with SCADA are more comprehensible and easier to use for developers and independent from the operating system and hardware used.

Being based on the HTTP protocol, Web Services, do not require changes to the security filtering rules used by firewall.

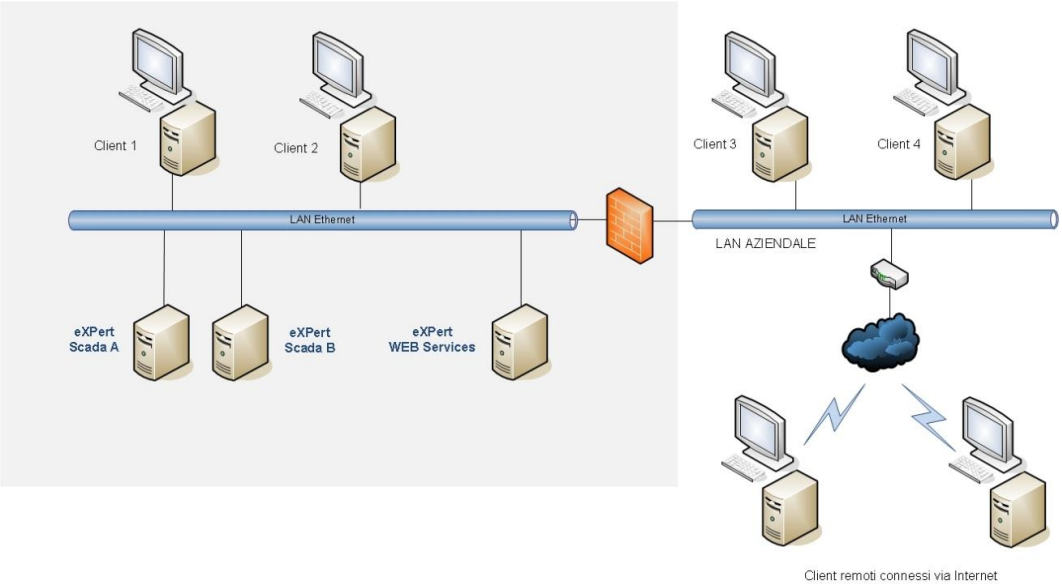


Figure 13-1: eXPert Web Services architecture

The architecture used is illustrated in Figure 13-1, the interface is published by web-services provided by the station identified as **eXPert WebServices** that allows access to services from outside (client on the network or connected via the Internet) and forwards requests to the SCADA which currently has the role of Master.

The Web Services allow access to both the values of the SCADA that the values stored in the stations **eXPert Historian**.

13.3 eXPert APIs (ISA Library)

eXPert APIs are composed of a C library (called an *ISA library*, with a Standard Access Interface). This can be used to establish a connection, via TCP/IP, with the SCADA and Historian systems. Through this connection it is possible to interact with the system, read the DBS and/or archive variables and write appropriately restricted variables.

Using the **eXPert API** library functions, it is also possible to copy/transfer Daily Report files and binary storage files.

The **eXPert API** library is currently available for the following platforms, as well as for systems from the Microsoft Windows family: HP-UX 11i v2, Linux, Digital Vax/VMS, Digital Alpha UNIX, IBM RS6000 AIX

Additional versions can easily be developed on request from the client.

13.4 OPC

OPC (OLE for Process Control) is an industry standard for interfacing applications, established by the OPC Foundation. Through the OPC interface, it is possible to develop applications that can access systems made by various manufacturers without modifying the software.

OPC sets interfaces for accessing data, historical data processing and management of alarms and events.

OPC sets standard objects, methods and properties according to the COM (Component object model) standard so that real-time servers such as DCSs, PLCs and field equipment can send their data to OPC clients.

From the point of view of an OPC client, it makes interfacing “Plug and Play” by guaranteeing inter-communicability between the different hardware and software platforms.

OPC is based on Client/Server architecture, so client applications can query several servers at the same time. The servers can be housed either on the same machine or on remote machines (via DCOM).

The **eXPert** system provides OPC interfaces on both the client and server sides.

13.4.1 eXPert OPC Client

eXPert OPC Client is used to connect third party equipment (or systems) to the SCADA/HMI system.

From the point of view of the **eXPert** system, it is therefore a specific type of I/O Server (see Paragraph 6.) which establishes a connection with a third party OPC Server.

13.4.2 eXPert OPC Server

The OPC server for **eXPert SCADA** consists of an independent application (EXE) that can be housed either on the same SCADA machine or on a third machine. For dual configurations it is possible to use a single server that connects automatically to the Master SCADA. The server functions as a Local or Remote server and supports access to data for both the 1.0 and 2.04 versions of the Data Access Custom Interface Standard specifications.

The server supports three data exchange methods:

- Synchronous: reading/writing;
- Asynchronous: reading/writing (in accordance with releases 1.0 and 2.04);
- Refresh: reading (in accordance with releases 1.0 and 2.04). If the data to be monitored has been modified, the server automatically sends the modified points.

eXPert OPC Server’s main features are:

- Support of the Local activation method (Client on the same machine where the server is installed) and the Remote method (client working on a machine connected to the network);
- Interfacing with SCADA systems in Single and Dual configuration via ISA connections;
- Support of OPC Data Access Specification 1.0;
- Support of OPC Data Access Specification 2.04;
- Up to 100 Clients connected simultaneously;
- Up to 51200 I/O points per client;
- Minimum point updating period: 250 msec;
- Support of differentiated updating frequencies for groups of points, with management of the variation percentage;
- Flat space for setting point codes;
- Support of point attribute display;

- Support of Data Access Automation interface standard 2.02.

13.5 MODBUS

The MODBUS protocol is used to connect to **eXPert** SCADA, data acquisition devices (typically PLC), and third-party control system; it is also used to provide data acquired and processed by SCADA, to external systems.

In the first case on the SCADA will be installed the I/O Server MODBUS Master module, in the second case the SCADA will be equipped with a MODBUS Slave component.

MODBUS protocol is applied for the interfacing of numerous types of devices and has been adapted to different types of communication lines. It has as its limitations, the fact that only uses the polling as a method of interrogation and the adoption of a numerical method for data access addressing.

13.5.1 eXPert MODBUS Master

The MODBUS Master is one the protocols, made available as I/O Server module part of the platform **eXPert** SCADA: it allows data acquisition and commands sending to devices provided with a Modbus Slave RTU/ASCII/TCP (typically PLC equipment).

From the point of view of the system **eXPert** it is therefore a particular type of I/O Server (cf. par. 6) which realizes a connection to equipment that use the MODBUS Slave communication protocol.

The I/O Server with MODBUS Master capability is available to handle the following types of physical connection with the type slave devices:

- Point to point connection of RS-232;
- If multidrop RS485 serial connection, optionally with the use of modem for leased-line (the case of long distance connections);
- PSTN or GSM dial-up connection;
- Ethernet connection over TCP/IP, in which case the node is identified by its IP Address.

13.5.2 eXPert MODBUS Slave

This module allows to insert an **eXPert** SCADA system as a slave in a network of peripheral interrogated with MODBUS.

The MODBUS Server module can also be used in dual configurations, in which case the module on the slave system is not responding to external requests.

The module MODBUS server can be configured to allow connections over serial line or over Ethernet TCP.

To allow, if they are required, the use of external RS232/RS485 converters, on the serial port is managed the RTS control line for transmission enabling.

13.6 IEC 60870-5-101/104

The IEC 60870-5-101 standard protocol is commonly used in telecontrol applications providing remote serial connections (point to point or multi-drop); the IEC 60870-5-104 protocol is its extension implemented over Ethernet TCP/IP.

The standard implementation distinguishes between master side (or primary) and slave side (or secondary): the master side is responsible for the initial request for connection and is typically implemented at the level of remote control center, the slave side is typically deployed on peripheral devices or on local SCADA that acts as a gateway to make remote controlled the automation and control system.

13.6.1 eXPert IEC Master

The Master side is implemented in the system **eXPert** as an I/O Server component to be used for SCADA systems provided in telecontrol monitoring centers connecting to external RTU or DCS systems that use this protocol.

13.6.2 eXPert IEC Slave

The slave side of the protocol is implemented by the component **eXPert IEC Slave** which has the purpose of making a station SCADA interrogated and/or controllable by a remote control center via the protocols IEC 60870-5-101 or IEC 60870-5-104

You can interface the same SCADA platform with multiple remote monitoring centers sending different sets of plant data, this function is performed by instantiating multiple IEC servers (up to a maximum of 4); the interface can be made via serial connection (870.5.101 IEC protocol) or via a network connection (protocol IEC 870.5.104).

The configuration of the flow of data towards each center is specific and thus allows to differentiate the variables exchanged according to the functions of each of them.

13.7 SNMP

The SNMP (Simple Network Management Protocol) protocol is a protocol defined by IETF (Internet Engineering Task Force) for the management of the apparatuses in the network.

It has been integrated inside the product **eXPert** for two specific functions:

- to make available within the SCADA system, diagnostic information relating to network devices (managed switches, routers) and to make them directly viewable as alarms and / or to complete the diagnostic pages presented by the HMI module, inside of which the status of operation of the apparatuses can be displayed;
- to make available diagnostic information regarding modules of **eXPert** SCADA to IT system management and network management tools (SNMP browsers or other SNMP-based diagnostic tools).

The first function is realized by the SNMP client component, the second by the SNMP agent for SCADA.

13.7.1 eXPert SNMP Client

eXPert SNMP Client is the **eXPert** system component, that is enabled at the SCADA module level and captures through the SNMP protocol the diagnostic information regarding the network devices in the LAN / WAN of the control system.

The variables to be acquired are identified by network device IP address and the OID identifier of the SNMP variable.

13.7.2 eXPert SNMP Agent

It is possible to enable the **eXPert SNMP** agent on the stations that host the following **eXPert** components: SCADA, I/O Server, Historian and HMI. Since on the same machine can also be present more than one **eXPert** component (i.e. SCADA and I/O Server on the same machine), they are identified by different branch of the MIB tree.

13.8 eXPert SCADA Data Link

A common requirement of geographically distributed systems is the capacity to exchange data between different SCADA nodes interconnected on a WAN. One example is that of railway SCADAs, where one station's SCADA acquires local data and exchanges it with the SCADAs of the neighboring stations and the central SCADAs responsible for the link. Another common case is that of telecontrol systems with hierarchical structures, where local territorial sub-centers exchange data with one or more higher-level global centers.

Thanks to the **eXPert** system, it is possible to manage communication between different SCADAs connected via local or geographical network. The SCADA software data link makes it easy to configure the flows of data between the SCADAs and perform communication between the interconnected systems.

The software module **eXPert SCADA data-link** makes it possible to connect SCADA nodes to the TCP/IP network or to dedicated/switched lines (IEC870-5-101 protocol), and to transfer the values of the variables stored in the local database of one SCADA to another SCADA.

In this way, each SCADA connected to the network can simultaneously send and receive data to/from other SCADAs.

Data transmission is carried out by variation for digital and string measurements, and periodically for analog measurements.

The configuration of this system architecture is realized through the Distributed Plant Loader (DPL) tools of the suite **eXPert Engineering Station** (for more information sees the document "*eXPert Engineering Station - Product description*").

14. SoftPLC

14.1 General information

The SoftPLC package makes it possible to perform common acquisition and automation station functions using a PC.

The PC is connected directly to a field bus (e.g. Profibus, using a Profibus PC card) from which the I/O can perform acquisition/commands.

On the other hand, the PC on which the SoftPLC software is installed is connected, via the TCP/IP Ethernet network, to the node with SCADA-I/O Server functions.

SoftPLC is programmed in Soft Logic using the Soft Logic Editor program, which makes it possible to set (graphically or in code, using the standard formalism set in IEC 61131-3) the logics to be performed.

SoftPLC also acquires signals from the I/O equipment connected to the field bus and stores them in a local database. The data is processed to add the appropriate diagnostic reports (on the data's reliability or lack thereof) depending on the status of these I/O devices.

14.2 Functions

The main functions performed by SoftPLC are:

- Single or dual field network management functions;
- Management of application messages for access to network services;
- Acquisition of input from the field;
- Processing of input;
- Management of output to the field;
- Management of the SOE function on fast signals, and local storage and transmission of the recorded data to the centre;
- Management of communication with other SoftPLC nodes;
- Creation of a dynamic database (DBS);
- Access to all the system's dynamic databases;
- Command management;
- Soft Logic procedures (regulations, logics, blocks, etc.)
- Monitoring of Soft Logic procedures;
- Precision synchronization with an external clock (normally a GPS);
- Automatic management of the dual configuration.

14.3 Configuration

The SoftLogic station, like all the components of the **eXPert** system, is fully configurable. Broadly speaking, two levels of configuration can be set:

- I/O signal configuration;
- Application function configuration.

14.3.1 I/O signal configuration

At the first level of configuration, it is possible to individually set the physical and logical I/O signals that the SoftPLC station acquires, the processing they undergo and the associated processing parameters. The structure of the dynamic database housed on the station is also set at this configuration level. In this way, the SoftPLC station can provide the SCADA station or other SoftPLC stations with the data it acquires, and correctly process the commands relating to the analog and digital outputs it receives from the network.

Each signal is individually configured, using the functionalities of *Point Editor* tool (belonging to **eXPert Engineering Station**). During this phase, each signal is equipped with all the information necessary for handling and processing it, both on the SoftPLC station and on the SCADA/HMI station/stations that use it.

The settings of the dynamic database are very similar to the settings of the SCADA system (see Paragraph 5.2), each signal is being clearly identified in the system using a unique code (TAG).

14.3.2 Application function configuration

At the second level of configuration, it is possible to set the applications that will be performed locally at the SoftPLC station.

These applications, encoded in SoftLogic, make it possible to specialize the station and create logics, regulations, automation sequences and anything else necessary for management of the plant.

14.3.3 Uploading and updating the configuration

Once configuration is complete, it can be uploaded/updated from the development station by connecting to the SoftPLC node.

If the SoftPLC station is in duplicate, the configuration is updated on both units in a way that is fully automatic and transparent to the user. If one of the two units is not updated (due to failure, replacement, etc.), the Master unit automatically aligns the Slave unit's configuration before updating of the two units is begun.

The duality management mechanisms (Master/Slave switch and hot back-up) are similar to those used for the SCADA system (see Paragraph 5.17).

14.3.4 Online monitoring functions

The SoftPLC station is equipped with a complete system for online monitoring of the logics in progress.

The logics are displayed as FBD diagrams (*Functional Block Diagrams*) animated by the current values of the calculated and/or acquired variables. As well as showing the status of the variables, the diagram can also display the internal variables of each functional block.

It is possible to request step by step execution of the logics for development and debugging purposes.

15. Disaster Tolerant systems

15.1 Disaster Recovery system management

Disaster recovery is the process, policies and procedures related to preparing for recovery or continuation of technology infrastructure critical to an organization after a natural or human-induced disaster.

In the telecontrol centre case it translates into the possibility of having two different remote control centers, located in different geographical sites, both able to perform all functions necessary to the operation of the plant.

Using a network connection between the two centers it is possible to maintain *Primary* and *Secondary* centers perfectly aligned. The frequency of alignment tasks can be parameterized accordingly with the network connection characteristics.

15.2 Primary-Secondary alignment

eXPert system, Primary-Secondary Disaster Recovery alignment, is provided with additional dedicated functionalities.

Primary – Secondary alignment covers the following functional areas:

- Alignment of the configuration;
- Alignment of dynamic databases;
- Alignment of historical databases (Oracle database).

The ordinary operation of the recovery system provides for the alignment of all three functional areas defined above.

Also, while acquisition and control of peripheral devices is left to only the primary system, the recovery system provides for the peripheral interrogation in order to diagnose the correctness of the communication functions.

The diagnostic information relating to communication between the center of recovery and RTUs, are then transmitted from the recovery center itself, to the primary system and allows to control if the front end system and the communication vectors are reliable, if the recovery system should take effective control of peripheral devices.

On the HMI stations of the operations center, you can view a page that contains diagnostic information about the status of the system recovery updating, and of the connectivity between system recovery's I/O Server and peripherals.

Schematically the updating data flow, in ordinary operation of the system, are those described in Figure 15-1. The system also manages the duality of the Primary system so that all the information comes from the SCADA master station, and master/slave switching is managed without interruption.

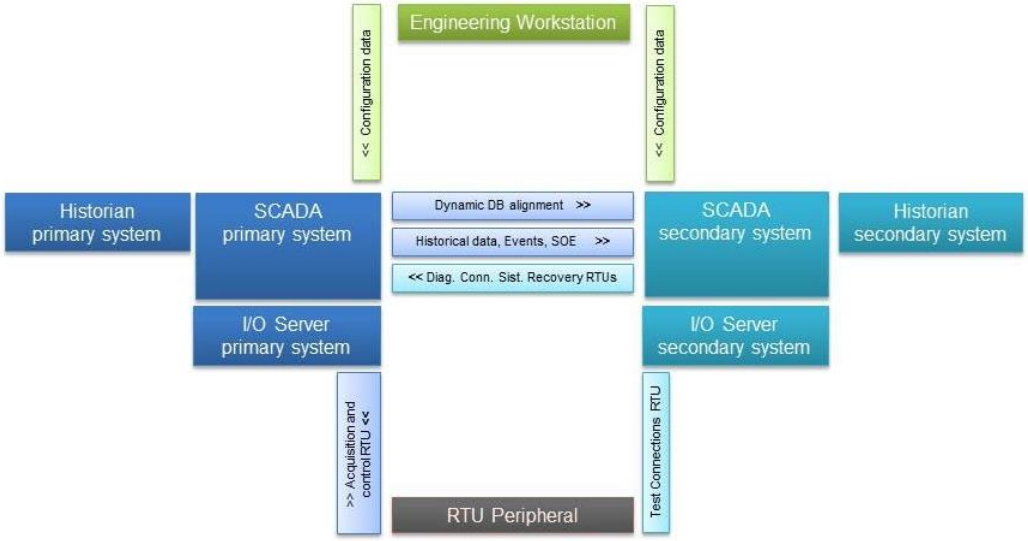


Figure 15-1: Operating diagram for a Primary-Secondary system

If the Disaster Recovery system should take full control of the system, will be activated in acquisition and command mode, following a simple activation by the operator (performed by interaction via HMI).

At this point the secondary system (recovery) takes full control of devices, and when the primary system will again become available, it will be aligned to allow the subsequent recovery.

15.3 Configuration alignment

To maintain the aligned configuration of the two systems is chosen to have a single source configuration residing on the *Engineering Station*; this configuration is transferred, as regards the application part, both the main system that the secondary system.

The following functionalities are provided:

- Online installation of a new configuration (without having to break the functionality of the system) at both sites: using a maintenance upload application, that resides on the **eXPert Engineering Station**; the installation procedures are performed in sequence on the main system and then the recovery system, suspending the operations of real-time update of those system data that can temporarily create problems of inconsistency;
- Exceptions are handled in hardware and software configurations between the primary system and recovery system (network addresses, ports indexes, etc ...).

15.4 Run-time dynamic database alignment

The types of data that are aligned with continuity between the main system and recovery system are the following:

- Initial state of dynamic database points (including calculated);
- Acquired data;
- HMI data;
- Events log data;
- User process file;
- Alarms databases;
- PAG databases.

The diagnostic information relating to communications between remote devices and system recovery are also aligned, with reverse data flow direction, i.e. from the recovery system to the main system.

15.5 Historical data alignment

Alignment is made of archive data, event log journal and SOE lists. All this data are being stored (in both centers) in relational databases (Oracle).

15.5.1 Event logs and SOE lists alignment

The alignment is done by sending, by the primary system, the files containing the SQL query, which realize the inclusion of new data within the database, to be executed by the recovery system. The primary system generates SQL statements for the recovery system. The generated files are then sent to the recovery system, which sequentially executes the queries received

15.5.2 Archive data alignment

The Historian module on the primary system, generates the SQL strings for both the local database and the recovery system. The generated queries are sent to the SCADA recovery system, which shall forward them to its own Historian, that will take care of their sequential execution.

15.6 Secondary to Primary transition

As mentioned above, the switching of the operation mode of the secondary system to that of primary system and vice versa, takes place following an explicit request of authorized personnel.

You can send the switch command from page, PAS (Scheduler Application Process) or PAG (Generic Application Process) with a suitable user command that is sent to the recovery system, that will assume the functions of the main system.

15.7 Diagnostic information

From the primary system, can be viewed the following information:

- Connection status of the recovery center;
- Diagnostic related to the SCADA of the secondary system (master system, database alignment, etc…);
- Release of the recovery center database (both master and slave).

From the secondary system, can be viewed the following information:

- Connection status of the primary center;
- Connectivity status of each device through the I/O Server and the lines (or WAN) available relating to the recovery center.

16. Features summary

16.1 Main features

Are below summarizes the main features of the **eXPert** run-time system platform:

- Client/Server architecture based on SCADA Server, I/O Server and HMI Client;
- WEB HMI for use of HMI stations connected via the Intranet/Internet;
- Historian functions on relational databases or on binary files that can be activated on the SCADA node or on dedicated stations;
- I/O Server functions, complete with line pool management for connections to switched lines, distributable on networked nodes external to SCADA;
- Management of multiple and/or duplicated I/O Servers;
- Great potential for distribution on the LAN network and duplication of SCADA, I/O Server and SoftPLC functions;
- Native management of duplicated network architectures;
- Use of standard operating systems available on the market: Windows 7, Windows Vista, Windows XP, Windows 2008 Server, Windows 2003 Server;
- Management of Master/Slave dual redundancy with hot back-up; hardware logic for supervision and control of SCADA Server, I/O Server and SoftPLC units. Master allocation and automatic Master/Slave switching in the event of Master unit malfunction;
- Management of disaster tolerant configuration for telecontrol centers
- Soft Logic integrated at the level of SCADA or PC dedicated to SoftPLC functions;
- Compatibility with all Windows compatible graphic controllers. Management of multi-monitor configurations, video walls management
- Up to 8 printers for Daily Reports and/or printouts, connected locally or centrally;
- Color hard copy printers, either local or shared on the Ethernet LAN network;
- Connection to acquisition and control stations via single or duplicated networks of the following types:
  - Point-to-point serial;
  - IEC 870.5.101 protocol multidrop serial;
  - Ethernet 802.3 TCP/IP;
  - IEC protocols on Ethernet: IEC 870.5.104, IEC 61850
  - MMS TASE.2;
  - OPC Client
  - BitBus RS 485;
  - SAMP RS 422;
  - Siemens S7 acquisition on Ethernet TCP/IP;
  - Siemens AS511 serial acquisition;
  - SNMP Client;

- Connection to external systems via the Ethernet network and TCP/IP protocol.
  - Web Services;
  - API for accessing the SCADA DBS;
  - OPC Server;
  - MODBUS Server;
  - SNMP Server;
- Management of interconnected SCADA networks on TCP/IP LAN/WAN;
  - Centre/Sub-Centre structures;
  - Relational structures.

16.2 Maximum capacities

Table 16-1 shows the limits currently imposed by the run-rime environment of **eXPert** platform. These limits are conditioned solely by the capacity of the hardware resources (generally, main memory and mass memory) and the calculation speeds of the processors used. They therefore vary from case to case depending on the chosen configuration.

Please note that, for applications requiring a large-scale dynamic database, the limits shown can be extended further. The theoretical limit is:

$$2^{32} = 4.294.967.296$$

tags for each type.

System element	Maximum #	Note
Acquired analog points	262.144	
Output analog points (set-point)	131.072	
Standard calculated analog points	262.144	
Analog points calculated by applications	262.144	
System diagnostic analog points	8.192	
Acquired digital points	1.048.576	
Output digital points (commands)	262.144	
Standard calculated digital points	1.048.576	
Digital points calculated by applications	524.288	
System diagnostic digital points	8.192	
Device points	262.144	
Alphanumeric string points	131.072	
Alarms recorded in chronological order for each DBA (Alarm Database)	32.000	
Number of DBAs	6	Extensible in relation to the type of application to achieve
Maximum number of RTU connected	2040	Extensible
Historically stored points	160.000	
Historical samples for each SCADA point	Unlimited for relational database	Limited only by disk size
Video pages	32.000	Limited only by disk size and “file system” capacity
Max. number of HMI connected to SCADA	127	Extensible
Max. size of videowall matrix	40x40	Resolution of each monitor 1600x1200 pixel
Max. resolution of video page	64000x48000 pixel	

Table 16-1: Summary of the dimensioning of the eXPert run-time system

16.3 System performance

Table 16-2 shows the main parameters relating to the typical response times of the system. The values refer to a single or dual STOP-PC (HMI-SCADA-I/O Server installed on the same computer) based on CPUs starting from Intel I-5 2,70 Ghz class.

The following table refers to configurations with Ethernet 802.3 field network acquisition using TCP/IP protocol at 100 Mbit/sec.

Ethernet field network at 100Mbit/sec.	
Parameter	**Performance (Max. value)**
Speed of analog point acquisition	2000 measure/sec.
Speed (max. per sec.) of digital variation acquisition	2000 variation/sec.
General signaling of new alarm	100 msec.
Appearance of new value on page already displayed	650 msec.
Appearance of new alarm on alarm page	100 msec.

Table 16-1: Summary of performances of eXPert acquisition system

17. Appendix

17.1 Communication standards applied

The standards applied to network connections are:

- ***Ethernet IEEE 802.3***: used for both the field network and the system network. For these types of network, the TCP/IP protocol (which has become the most commonly used standard on the market) is used. It allows transmission speeds of 10/100 and 1000 Mbits/s. For the physical connection, all types of connection are supported:
  - 10BaseT: Twisted Pair Ethernet, for networks with a concentrator (hub) and maximum distance of 100 m. from it;
  - 10BaseFL: Fiber Optic Ethernet, for fiber optic networks with links up to 2 km long;
  - 100BaseTX: Fast Ethernet 802.3u, for networks with a concentrator (hub/switch) and maximum distance of 100 m. from it;
  - 100BaseFX: Fiber Optic Fast Ethernet 802.3u, for fiber optic networks with links up to 2 km long;
  - 1000BaseT: Giga Ethernet 802.3-2000, for networks with a concentrator (switch) and maximum distance of 100 m. from it;
  - 1000BaseSX: Fiber Optic Giga Ethernet 802.3-2000, for fiber optic networks with links up to 220 or 550 m. long;
  - 1000BaseLX: Fiber Optic Giga Ethernet 802.3-2000, for fiber optic networks with links up to 5 km long;
- ***Intel Bitbus***: for the field network. This a standard for industrial field networks, commonly known as “Field Buses”. It uses the RS485 electrical standard and the SDLC “data link” standard. It allows transmission speeds of 2.4 Mbits/s for networks less than 30 m. in length, 375 Kbits for networks up to 1 km in length, and 64 Kbits for networks up to 13 km in length;
- ***RS-422 or R-S485***: for field networks. These electrical standards allow multidrop connections to be made on single twisted pair cables or multiple cables. Transmission speeds of up to 115.2 or 400 kbit/s are provided for lengths of up to 1.2 km. These can also be used in INET/SR networks;
- ***RS-232***: for field networks. This electrical standard allows point-to-point connections to be made on multiple cables. Transmission speeds of up to 115.2 or 400 kbit/s are provided for limited lengths, unless adaptors are used;
- ***IEC 60870-5-101***: for field networks with serial point-to-point or multidrop connections. Sets a standard for telecontrol applications including levels 1, 2 and 7 of the ISO/OSI model. This, in turn, uses IEC standards 60870-5-1, - 2, - 3, - 4 and -5;
- ***IEC* 870-5-104** generally used for Ethernet TCP/IP connections where telecontrol equipment is used;
- ***IEC 61850*** generally used for Ethernet TCP/IP connections where electrical substation automation equipment is used;
- ***MMS TASE.2***: generally used for Ethernet TCP/IP connections where remote management and monitoring are used. Also used for inter-centre communication;
- ***Modbus RTU/ASCII/TCP***;

- ***Profibus DP and PA***;
- ***OPC***;
- ***SNMP***.