Locamation®

Product Guide

SAS2000®

Flexible Control for High Voltage Substations

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1 Preface

Introduction

Over the past decade the electrical power industry has undergone many changes. Vertically integrated utilities have been transformed into smaller companies. Transmission and Generation systems are increasingly relying on advanced digital and computational elements for protection and control of their substation and transmission assets.

Substation automation is a major part of advanced power system management. Better control and faster performance are achieved by performing local tasks in the substation like data acquisition from the power grid via the switchgear. Better control is also achieved by the activation of changes by commands to switchgear like circuit breakers, isolators, and transformers. This automation approach provides better protection of valuable substation equipment.

Internet in its various forms has experienced an enormous growth in people's personal lives as well as in the business world. The Internet is still expanding and the web technology is more and more used in other disciplines. Users demand more features and reliability in their software programs and better ease of use at the same time.

SAS2000

The Substation Automation System SAS2000® accommodate any existing Intelligent Electronic Devices (IED) and fully integrate new technologies and equipment for control, protection, disturbance recording, and condition monitoring. SAS2000 is fully capable of being integrated with a central system that allows utility personnel to monitor, analyze performance or control switchgear throughout their grid. The unique system design diverses SAS2000 from the conventional PLC based substation control systems.

The use of web technology adds benefits, like features and reliability in software programs and better ease of use to the Substation Automation System SAS2000. It represents merely the start of an opportunity that will lead to more flexible and productive aspects of substation control than ever before.

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High Voltage Substations

Introduction

High voltage substations are essential parts of the electrical transmission and distribution network. Since substations link the power generation to the customers, their reliability and availability are important issues. Due to the nature of high voltage and high currents, the safety requirements for personnel and equipment are severe. Besides mechanical and procedural safety measures, the control system guards part of the personnel and equipment safety.

Primary plant

Within the substation we recognise a limited number of different bay types like feeders, transformers, busbar, reactive power compensation, etc. The existence of repeating bay types gives great opportunities to reduce the engineering effort by copying previous designs.

Secondary system

All equipment that is no part of the high voltage plant is considered to be the secondary system. The main functionality of the secondary system concerns the following topics:

- All control functions.
- Monitoring the protection system.
- Metering.
- Alarming.
- Event- and disturbance recording.

Automatic process control functions are also part of the secondary system and can be fully integrated in SAS2000. These control functions are:

- Voltage control.
- Automatic reclosing.
- Automatic switching sequences.
- Synchronising.
- Voltage selection schemes.

Since substations are most often unmanned, the communication interface with remote control centres is an essential and integral part of the control system.

Protections

The protection relays are independent components in SAS2000. In case of digital equipment (Intelligent Electronic Devices or IED), the subsystems are co-ordinated with SAS2000 by means of serial communication. Functional, technical and supplier independency for the protections and IEDs are guaranteed in the SAS2000 co-ordinated control concept.

Co-ordinated control system

SAS2000 takes care of all the control and monitoring functions in the substation and associated data acquisition of the necessary process items. A full graphical user interface presents the control and monitoring functionality. The process interface is distributed in two ways:

- A bay oriented way, with the interface in the bay marshalling cubicles or protection cubicles.
- Distributed in the outdoor switchyard to reduce cabling cost.

The SAS2000 will comprise of as many secondary functions as possible, but mainly depending on needs and customer practice. The economic benefits increases dramatically when more functions are integrated into SAS2000.

Co-ordination with protections and intelligent electronic devices

It is common practice that transmission level substations have separate independent protection systems. For the information exchange between the protections and SAS2000, the market uses more and more serial communication. For this purpose proprietary and standardised communication protocols are available. On distribution level, i.e. medium voltage bays, the integration of the local control function into the digital protection is increasing.

In this case SAS2000 will give its control commands via the serial interface and the digital protection to the primary equipment. Distribution level protections tend to be more like feeder management units with integrated protection functionality, which are co-ordinated with the SAS2000 control system. Disturbance data upload and selecting relay parameter groups is a standard function within SAS2000.

The energy metering for settlement purposes works as fully independent equipment. SAS2000 is interfacing either the pulse outputs of the meter or using a serial interface for communication. A standard software function displays the energy meter quantities.

Communication with remote control centres

The remote control or dispatching centre is the main point for operating the unmanned substation. The communication between the RCC and the SAS2000 system is often based on an existing proprietary communication protocol of the energy management system supplier of the control centre.

A list of available protocols is described in more detail further on in the guide. If a protocol is not yet available in the SAS2000 system, an implementation can be realised within the project realisation time.

More and more customers are demanding the use of standardised communication protocols. The implementation and maintenance cost of standard protocols are low compared with proprietary protocols. Implementations of standardised protocols are available in SAS2000.

Remote interrogation

The change into competitive energy market has created a change in power network operation philosophy. Utilities have been forced to utilise the available data from the network, i.e. the substations, better and more flexible than in the past. Different departments need different data from the substation. The remote control centre subscribes to all this available data in the substations. Therefore it can't supply the other departments with the necessary information.

Using the web server capabilities, SAS2000 offers excellent means to gather the data and information for the different departments within the utility without interfering with the operational commitment of the control system.

Remote data and information retrieval are implemented using standardised interfaces and communication protocols from the Internet. Remote diagnostics and full graphics back-up control are standard supported in all possible system configurations. All information is easily available for further processing. Next, all kind of independent software is able to analyse the acquired information.

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Economic and Operational Benefits

Time reduction to service an installation

Digital control systems provide the benefit of modern information technology with automatic self-supervision and diagnostics for fault finding and tracing. SAS2000 reduces the time needed to find and fix problems in the installation. With the remote diagnostics facility, you can use this service from virtually any location. Even a mobile telephone network can access the substation data.

The tracing and monitoring facilities of the I/O system make it literally possible to browse from the I/O signals through the application software back to the I/O signals and monitor the signals with real time data.

The system diagnostics is able to monitor the system behaviour and supervise the communication protocols. With the proper authority you can also find and fix software problems from remote locations. The I/O system is based on an easy board swap replacement strategy. You can replace boards without taking any other part of the system off-line.

Improved maintenance

Due to the more profound knowledge of the status of the primary equipment, the opportunity arises to change from regular interval base maintenance to state dependant maintenance. To achieve this goal, continuous condition monitoring is needed by logging and storing more status indication data of the primary equipment. To reduce the maintenance effort it is necessary to determine an objective threshold on which the maintenance activity should be triggered. The equipment subject to condition-based maintenance is:

Circuit breakers with monitoring of:

- Pressure diagnostics for SF6 breakers.
- Time distance diagram of the breaking contacts.
- Number of switching operations with interruption current as measure for contact wear.

Transformers with monitoring of:

- Tap changer operating times.
- Temperature.
- Hot spots.
- Partial discharges.
- Monitoring of the disconnecter and earth switch operating times in case of motor operated equipment.

The modern technologies which are applied in the digital secondary equipment are designed to have little maintenance or to be even maintenance free. Our robust industrial designs achieve this requirement. Locamation has paid specific attention to a very high Mean Time Between Failure (MTBF) of the equipment.

Low capital investments

The integration of secondary functions into SAS2000 will substantially contribute to the cost effectiveness. Due to the flexible scaling capabilities of SAS2000 we are able to integrate a wide range of typical substation functions. Most functions only require software configuration and parameterisation effort. No or little additional hardware is needed.

The remote control centre communication is fully integrated in SAS2000. The protocol emulation is done in the software of the system. Therefore the Remote Terminal Unit equipment has become obsolete.

SAS2000 incorporates a distributed process interfacing that decreases signal marshalling and cabling in the substation considerably. You can organise the process interfacing in a bay oriented manner of you can mount it directly on the primary equipment with small interface modules. Serial communication with the digital protection relays gives also a reduction in the interface engineering.

The hard-wired mimic control panel is replaced by the graphical user interface, which is displayed on standard Personal Computer equipment.

The external current and voltage transducers are fully integrated in the analogue input cards of the system. The interposing command relays can be omitted. Because of the integration of heavy-duty miniature command relays on the output card you can directly connect the digital outputs to the primary plant items. The integration of secondary functions and interposing equipment has reduced the size of secondary installation. This has minimised the total number of mounting cubicles.

Minor need of training

The SAS2000 system concept has been designed from the viewpoint of the substation application engineer. The engineering of the application functionality requires very limited computer knowledge and the graphical user interface is self-explanatory. So, engineers need only minor training; it takes only a few hours to work with SAS2000.

Operational decisions

The operational decisions that are taken at the load dispatch centre are heavily based on the real time information or the substations. More accurate and faster retrieval of the data from the substations and therefore from the power grid increases the quality of the network operation. Due to outages, improved access to the substation data limits the impact on customers.

The substation alarm data can communicate with the control centre as compressed high level alarms or realised as retrieval on demand of extensive alarm records for post mortem analysis. The primary plant indications are based on accurate real-time data of the status and position of the high voltage equipment. Line voltage readings and real time data sampling of Watt’s, VARs, Volts, Amps, Cosine phi of the feeders and transformers are important measurements for the operators. Trend recording of important measurements gives inside views on the dynamic behaviour of the power system.

A separate route can perform the remote access to the data stored in SAS2000. The possibility of a remote graphical user interface as a full backup for the remote control centre communication decreases the necessity of a redundant communication link for the remote control centre.

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Process Control & Monitoring Functionality

Introduction

Control and monitoring of primary plant items is one of the main tasks of a co-ordinate control system. The Graphical User Interface performs the process visualisation, showing overviews, control, alarm, trend and sequence of event displays, plus customer designed displays. Control of primary plant or secondary equipment is performed in an object oriented way.

Substations can be operated from different locations. Most common are regional control centres, stand-by control from the substation itself and possibly local control in the bay or in the switchyard. The most important object control functions are described here with their salient features.

The control and supervision of plant items is performed through the use of software objects. For each type of equipment like switchgear and energy transformers or for required functions, a generic software module is already available in the library. These generic software modules are called "Classes". For each individual plant item in the switchyard or required function a copy of the Class is configured for that specific plant item, which is called an "Object". Two major types of Classes and thus Objects are available in SAS2000:

- **Standard Classes**
  The Standard Classes are part of the standard product as non-changeable libraries. Standard Classes are available for controlling and monitoring the most common plant items and functions in the substation like Switchgear, Transformer tap change control with automatic voltage regulation, pulse metering, analogue conversion and limit checking and telecontrol protocols. All Classes are instantiated as objects and parameterised individually for those parameters different than the setting in the class. So they represent the different plant items and/or functions.
- **Composed Classes**
  For functionality not covered by standard classes like software interlocking schemes etc., specific Classes can be created. These Classes are called Composed Classes. Using a very powerful declarative language called APLC can create these Classes. When a Composed Class is created, it is used like a Standard Class.

Generic functions

Some functionality is generic for all types of objects, i.e. apply to them all.

- Each object can be selected from the graphical single line diagrams.
- Each object has its own specific menu bar (the Object Button Bar). The moment an object is selected from the screen the Object Button Bar is displayed.
- Selecting an object from the screen is confirmed to the operator by a message line giving a description of the selected object and colour change of the object
- Information is displayed using the Object Button Bar. The name and description of the object are shown, its status and all its inputs, outputs and parameters.
  Note that all this information is updated real-time and this information is available for all objects in the system without additional configuration work.
- Status acknowledgements: Some status changes are transitional with the need to acknowledge the pre-transition state. For instance when a breaker is opened by a protection the status is "Auto-open" and the symbol on the screen flashes. When

the operator acknowledges this status the status will change to “Open” and the flashing stops (alarm/event in list).

- Assignments of messages: To each object, the operator can assign up to four (this number is configurable) messages giving information on the present state of the equipment such as “In maintenance” or “Out of order”. The messages can be selected from a list, which is predefined in the project database.

Switchgear

Any switchgear such as breakers, disconnecters or earth switches can be controlled and monitored using the Switchgear Class. This Class is fully configurable with the following functionality:

- **Control**
  - Selecting, opening and closing a switchgear.
  - Blocking and unblocking software control.
  - Automatic control can be performed by software functions such as Direct Automatic Re-close (DAR) or Breaker Failure Protection (BFP).
- **Interlocking**
  - Interlocking schemes give release information to the switchgear for securing the opening and/or closing of the switchgear.
- **Monitoring**
  - Position of the switchgear using the position contacts, Open, Running, Close and Fault positions.
  - Opening, closing by an external cause such as a protection relay.
  - External interposing relays activation.
- **Transition time supervision**
  - Running time, command follow up time, external interposing relay running time
- **Additional Settings**
  - Command pulse duration, separate for Open and Close command, possibility of continuous activation until the switchgear reports the position changed properly.
  - Command relay deactivation time, in order to deactivate the relay after a certain period, when no switchgear position transition has been reported back.
- **Statistics of switching actions**
  - Number of switching actions by the operator or by automatic functions (such as the DAR) or by external causes (such as protection relays or manual control).
  - Minimum, average and maximum running time and the deviation to the average. These actions are all in milliseconds.

Automatic Tap Changer Control

Automatic Tap Changer Control (ATCC) software function can control and monitor the substation energy transformers (automatic voltage control, on-load tap-changer).

The ATCC can handle up to six busbars and seven transformers. The six busbars can be interconnected in various different configurations. The busbars will be referred to as busbars or busbar groups (i.e. the joining together of busbars by a switchgear). The main features of ATCC are the following:

- To identify the busbar groups, which can be formed as a consequence of switching operations in the substation.
- To identify the transformers, which are connected to the individual or composite busbar groups.
- To perform automatic voltage control to maintain the busbar group(s) within pre-set limits, referred to as the target voltage.

Analogue inputs

Analogue inputs are read by one of the analogue input cards, such as the LA110 that is meant for multi purpose analogue values and the LA141 that has integrated voltage and current transducers. The Class responsible for process analogue inputs is called the Analogue Input Object. The main functions are:

- **Linear conversion of the raw value** coming from the analogue card to an engineering value that represents the primary measured value. This value is typically displayed on the Man Machine Interface in the one-line diagrams. Some of these values are also used as inputs for the voltage control such as the secondary voltage and current.
- **Supervision of up to four threshold values**. An alarm or event can be generated if the measured value passes one of these thresholds. To prevent small fluctuations of the measured value around a threshold from causing a lot of alarms, the processor can configure a dead band.
- **Supervision of the value change rate.** If the measured value differs more than a configured delta from the previously measured value, an alarm or event can be generated.

Pulse counter for metering

The kWh measurement Class counts pulses generated by an external kWh or kVArh measurement device. In order to let the pulses represent the physical measured value again, and to let the digits on the screen behave equally to the external meter, the operator can set some parameters.

The most important settings are:

- The kWh per pulse (the multiplier).
- The display scale factor or the divider.
- The number of display digits (to create run around counter values).
- Whether positive pulse slopes or negative slopes must be counted.
- The possibility to sum the counter values of different pulse metering objects. Note that this can be performed independently of the display scaling factors of these pulse-metering objects.

Trending

An operator can perform real time and historical trending on any digital signal, analogue signal and derived calculation results. Using the TrendView software, the operator can display the real time curves of these data types on the operator workstation of SAS2000.

The historical trend data is stored on the hard disk in the DOS ASCII Comma Separated Value (CSV) format. This enables to import the data into the commonly used applications as spreadsheets and word processors. The maximum file size and the maximum disk usage can be configured per trend curve. When this maximum disk usage is reached, the oldest file is overwritten. So, disk maintenance is not necessary. This mechanism is used for all historic files on the hard disk such as sequence of event data, disturbance data, etc. The real time dynamic trend appears in the trend screens. Each trend screen can display up to seven curves, each originating from different data sources.

Free configurable functions / composed Classes

With logical building blocks the operator can specify customer specific Interlocking schemes. Based on the position of switchgear or values of analogs, releases or interlocks can be calculated. As for all other object software, the interlock schemes are processed “event driven”. They are calculated upon any relevant input change rather than on a periodic basis. So within a few milliseconds after a change in the switchyard, all the interlocking schemes for all the primary objects are recalculated. There is no dead time between an operator control action and the availability of the proper interlocking result (a release or a lock).

The logic of an interlock scheme is specified with so-called Basic Building Blocks like AND, OR, etc.

Very often the logic of the interlocking of one bay is grouped together in one Composed Class where the position contacts of the plant items (and others) are inputs and all the interlock releases for the plant items are outputs. This Composed Class can be reused for all bays with the same type of interlocking. These well-tested Composed Classes make considerable savings.

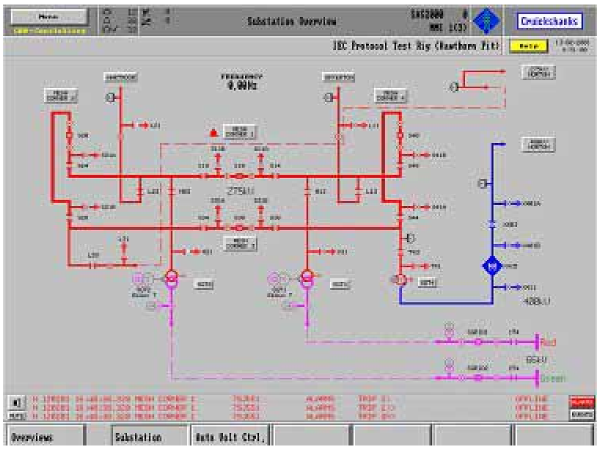
The software function Delayed Automatic Reclose (DAR) is created using a Composed Class that is built up from the logic blocks called Basic Building Blocks. Between different sites the functionality of the DAR can vary considerably. So a composed object is used to give the maximum degree of freedom to adapt the scheme to each individual site requirements.

The creation of a Composed Object Type will realise a voltage selection scheme.

Graphical User Interface (GUI)

The graphical user interface is displayed on a standard PC that minimal runs on Microsoft Windows 98, NT or XP. The PC is connected to the Control Units via an Ethernet network or a serial dial-up connection. The PC acts as a graphics terminal; the graphics are generated in the Control Units. This implies that the PC is not a part of any control scheme and it can be switched off when the substation is unmanned. For small substations you can even use a Laptop and connect it to the Control Unit temporarily.

The communication between the PC and the Control Units is based on the Internet protocol TCP/IP that enables to perform the graphics user interface remotely by a dial-up connection. The protocol even enables to transfer files such as the disturbance data files or the sequence of events files and to use the graphics interface simultaneously.



Normally a remote dial-up connection is configured in such a way that control actions are not possible. This makes a dial-up connection a so-called remote diagnostics facility.

The menu system

The GUI has a very shallow menu hierarchy to display the one-line diagrams or other displays. For normal operation you only need a graphical pointing device like a mouse.

The look and feel

The look and feel of the graphical user interface is presented using modern visualization technologies. The look and feel can be made completely according to the requirements of the users.

The process screens

In the process screens, the process pictures can be visualized such as the one-line diagrams, parameter tables, and trends curves.

The Object Button Bar

The Object Button Bar is available in process screens to control or to get information about objects such as switchgear.

When an object is selected with the mouse or tracker ball, the Object Button Bar appears. This Object Button Bar contains the menu buttons that apply to the selected object only. The Button Bar is configured in the project database.

The Object Button Bar is context sensitive. This means that only the operator can activate the applicable buttons. So, when a switchgear position is Open, the Open button is inactive. Activation or deactivation of the menu buttons is directly derived from the actual I/O status of the selected object. This means that conflicting actions with the actual state of an object are prohibited.

When the operator presses an inactive button on the Object Button Bar, automatically a message appears with the reason of the inactive state. Example: "The object is already open".

Standard buttons can be defined for:

- Information about the currently selected object. Examples; Object Information Screen and Object Element Screen.
- Applying an object command such as "Open", "Close", etc.
- Message attachment screen.

Alarming screens

Five types of alarming screens are available within SAS2000:

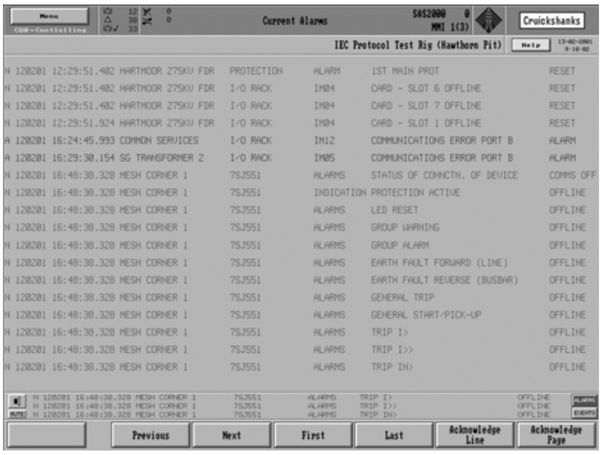
- The Current Alarms screen.
- The Current Alarms screen sorted on priority.
- The Historic Event and Alarm screen.
- The Operator Log screen.
- The System Messages screen.

The operator can browse through these lists with the first, last, next page and previous page buttons.

The *Current Alarms screen sorted on priority* contains the same alarms and functionality as the normal *Current Alarm screen*. In this case the alarms are sorted on the alarm display priorities. There are sixteen priority levels. The highest priority alarms appear at the end/last page of the list. Within one priority, the alarms are sorted on time. The latest alarms are at the end of the list.

All the alarms and events appear in historical order. The *Historic Event and Alarm screen* displays the output of what is known as the Sequence of Event Recorder (SER). The list can contain 2000 lines in memory.

The sequence of events is also stored to the hard disk for later analysis.



The operator log screen

The operator log screen has the following functionality:

- Logs texts for the execution of button bar actions. The text appears in the list after successful execution of the button action. The texts descriptions are defined in the project database.
- Assignment and removal of messages to objects. The messages are assigned by using the messages screen that is available from the object button bar. The messages by itself are defined in the project database.
- Changing of parameters by using the parameter update screen from the graphical user interface.

The operator log is also saved on the hard disk for later analysis.

The system messages screen

Sorted on data and time, the system messages appear in this screen. They are also saved on the hard disk for later analysis

Access and concurrency control

Access

A login procedure performs access to SAS2000 from the PC in the substation. Ethernet physically connects this PC to the SAS2000 Control Units. A user name and a password is required to connect the PC to the Control Unit. The user names and passwords are defined in the password file, which is only accessible by the system administrator. The passwords are saved in a secured way.

Concurrency control

Concurrency control is the way the system protects multiple operators from controlling a plant item, a bay, or a total substation simultaneously. The project database defines whether the concurrency control is set for bay level or for total substation level. The SAS2000 software that protects against concurrent control actions is called the Control Point Administration (CPA).

This CPA guards all operator control actions irrespective of the way that these control actions reach the SAS2000 system. This can be obtained with the Remote Control Software link (from the RCC), from the central control workstation in the substation control building, locally in the bay, or remotely with the dial-up connection.

The principles of the concurrency control are very simple. Based on the login name and used password at one of these possible control points, a Control Point Name is assigned. For RCC protocols that do not use operator login, this is defined per logical connection. Together with these Control Point Names, the database defines the control rights (for a part or for the entire substation) and a priority.

The operator must press a button in a CPA screen to get control over (a part of) the substation. This can be done for one bay, for a group of bays or for all the bays in the substation. The bays, for which an operator is allowed to request control, are grouped in so called Control Sets. Typical control sets are:

- One set consisting of all the bays of the substation.
- One set for the high voltage level bays and one set for the medium voltage bays.
- One bay per set if the lowest level of concurrency control must be the bay level.

When one or more operators request control for a control set, the control is assigned to the Control Point with the highest defined priority that is requesting control (or is already controlling) simultaneously. A control point with a lower priority will lose the control right until the Control Point with the higher priority gives up its rights.

When taking over control or losing the control, a dialogue box warns both operators about each other's identity, priority and intentions. So, by mistake operators can never take over or lose control.

Diagnostics

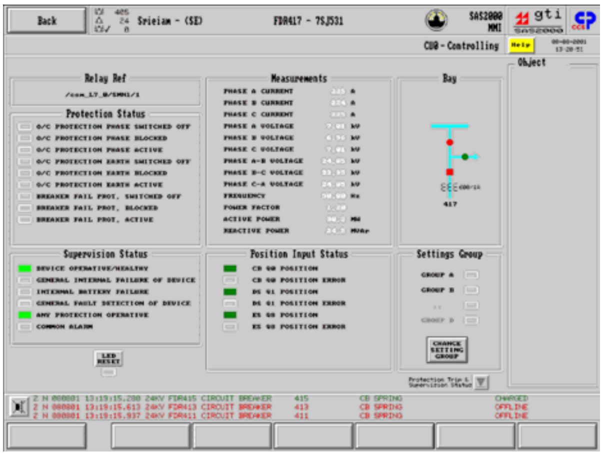
Diagnostic functions are important to determine the state of the process and the process equipment. These functions check the application and examine the state of the SAS2000 system itself.

The graphical user interface (GUI) offers all these diagnostic functions, both in the substation or remote. For example, a system administrator working at the office or at home can perform some diagnostics.

Also, most of the diagnostics functions are available on the RCC, contingent on the functionality of the communication protocol between the substation automation system and the remote control centre.

Process diagnostics

Process diagnostics that comprise all functions that an operator needs to determine the state of the primary process.



The most important process diagnostics functions are:

- The current state of the process inputs. This state appears on the screen in I/O browser screens. These screens enables to see all inputs and connected internal variables (like interlocking scheme results) available in the system.
- Displaying the value and a calculated status. The value is typically used for application logic. The status gives additional information on the quality of the signal and is typically used for alarming and sequence of event recording.
- Monitoring any analogue data in the substation. This can be voltages, currents, phase angles, frequencies, temperatures, pressures, position transducers, etc. These values appear next to the one-line diagrams, or are transferred to the RCC. Derived calculated values such as the power and the appearent power can also be displayed.
- Process data and disturbance data measured by Intelligent Electronic Devices (IED's) like protection relays, disturbance recorders and electronic measurement units.
- Real time and historical trendview. These trendplots can be performed on any type of value in the system, like digitals, analogues and calculation results. The historic trend curves are stored on disk for later analysis.

Process equipment diagnostics

SAS2000 can monitor the status of the primary and of the secondary equipment. There are some typical primary equipment monitoring that can be used for diagnosis and maintenance of state dependent equipment. The following list gives a few examples:

- Switchgear monitoring.
- For each switchgear like breakers and disconnecters, it gives the minimum, maximum, average and standard deviation of the running time in milliseconds. It also counts switching actions commanded by SAS2000 and externally by protection relays or manual control.
- For transformers tap changers it can count the number of movements.
- For IEDs that use the Courier protocol from GEC Alsthom, a browser on the graphical user interface shows all memory elements of the relays connected to SAS2000.

Control actions diagnostics

An audit trail of all operator actions is saved in the Operator Log. Each action has an assigned description of the action, time and Control Point user name. To enable to trace back operator control sequences, the log is saved on the hard disk.

Application diagnostics

During the building and commissioning of the project configuration it is necessary to be able to diagnose if the application works within the specifications. Also during normal operation it is very convenient to be able to analyse the behaviour of certain functionality like interlocking. For this purposes SAS2000 incorporates extensive real time diagnostics. Because software objects perform all process functionality, the application diagnostics is called Object Information. The information on each object appears in its object information screen. You can call this screen by selecting the object from the one line diagram and then pressing the “Information” button.

Using a hierarchical object browser enables to show not visible objects in the one-line diagrams, like interlocking schemes. For each object, the screen shows information on all inputs, outputs and parameters. It displays the real time values, the status and interconnections between objects. By clicking on these links you can also follow them.

Typical interconnections between objects are interlocking object release outputs that are connected to release inputs of a switchgear object and scaled outputs of an analogue output that are connected to voltage inputs of a transformers object (for automatic voltage control).

System diagnostics

SAS2000 has three types of system errors. These are as follows:

- **Temporary errors**. These errors do not require any direct actions because the system operation is not influenced.
- **Errors that the system itself can detect and isolate**.
- **Errors that require action of (maintenance) personnel**. A typical error of this category could be an input card that is malfunctioning and has to be replaced.

Screens are available for system diagnosis. These screens can monitor the status of all system parts like Control Units, Interface Modules (rack), Locnet fibres and I/O cards and are automatically configured based on the actual hardware set-up. All the data in these screens is real time. The browse sequence is based on the hardware hierarchy like optical fibre rings and Interface Modules.

The Application Diagnostics is linked to the System Diagnostics. This means that the software objects that are connected to the physical I/O points can be monitored as well as the physical outputs that are controlled by them in turn.

Time synchronisation

Real-time digital inputs have a scanning rate of 1 kHz and absolute time accuracy within 2 ms of the absolute time. This absolute time accuracy is important when data originating from more than one substation is needed to analyse a network disturbance. The absolute time accuracy can be achieved with a Global Positioning System Time (GPS Time) synchronisation clock.

Communication

Communications to support remote control, remote diagnostics and monitoring and remote file access are very important features. The communication requirements are fulfilled with three types of communication, which are supported by SAS2000.

1. **Communication with the remote control centre** is mainly intended to remotely control and monitor the primary plant items. This link is based on standardised or proprietary protocols. The physical link to the RCC can be connected to SAS2000 with single or redundant communication lines. Multiple remote control centres with possibly different protocols on configurable data sets are supported
2. **Communication with Intelligent Electronic Devices**. These links are intended to remotely read out the process and disturbance data and sometimes control digital relays in the substation. These links are also based on standardised or proprietary protocols. The physical connections are always made to a communication port of any Control Unit type, but are software-wise available to all application function in all Control Units in the total system. Therefore we speak of a virtual system.
3. **Communications intended for remote information transfer**, like sequence of event files, disturbance data files, from and to SAS2000. This communication line is also used for the remote graphical user interface. This communication link is based on the TCP/IP Internet protocol.

Remote access to data

You can access all (historical) data files remotely. The data can be read remotely or it can be copied to a remote site and analysed off-line. In order to access the data, it is necessary to establish a dial-up connection with a desktop PC running Windows and the substation Control Unit on which the data resides.

5

Hardware architecture

Introduction

The hardware architecture is simple and unambiguous. Modules that are distributed in the secondary or even the primary installation realises the process interface. This process interface is made of robust electronics.

The process interface itself does not execute any application software. The main advantage of this arrangement is that there is no dependency between process interface equipment and software releases. This guarantees compatibility of the process interface and the remaining system. The maintenance of the system is simple and it consumes little time.

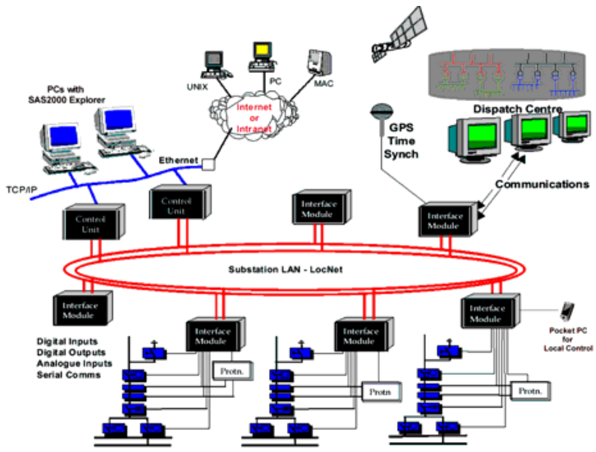
The control system scans the process interface modules by means of redundant fibre optic networks. These networks are designed in such a way that they comply with the highest levels of reliability. The used protocol is synchronous. This means that the load on the network is independent of changes in the process data. The centralised control unit performs the processing of all software. This unit can have a number of processors depending on the size of the substation and the required functional performance. To meet the highest levels of availability the centralised control system can be set-up redundant.

The SAS2000 system concept contains of five hardware groups:

The Personal Computer (**PC**) based graphical workstations with web browser technology.

The Centralised Control Units (**CCU**), without internal process I/O, as typical high performance central substation controller.

The interface modules (**IM**), non-intelligent remote I/O.



Redundant fibre-optic ring networks perform the real time scanning of the process interface. These networks are called Locnet. Normally more than one ring network are required to scan all the process interfaces. This means that the size of the substation, i.e. the number of installed I/O signals, determines the number of required Locnet rings.

The configuration and parameterisation of the system is performed on an **off-line Personal Computer** with the special application tool, the Application Builder. The project database is loaded into the system via a communication link like Ethernet or serial (modem) lines.

Personal Computer

From the graphical user interface PC, the operator can see the mimics such as the one-line diagrams, current alarm lists, etc. The graphical user interface is always realised as a web-browser on a PC. Since the PC is only used as a human interface machine interface, the operator decides if the PC(s) need to be installed on a permanent basis or on portable PCs. Multiple web-browsers or PCs can be connected to the SAS2000 system at any moment. Required printers will be handled by the PC.

Control units

The SAS application software is executing in any type of control unit. Control units can run in a redundant mode and are always equipped with an Ethernet connection and various serial ports for communication to a LAN and /or to directly connected IEDs. The CU900 has powerful processing capabilities and mass data storage.

The Control Unit can be duplicated for redundancy purposes. If the master Control Unit fails, the standby back-up unit takes over immediately without any loss of performance. Under normal operation, the back-up Control Unit can perform all graphic functions. However, it does not give control commands. This is called: the backup Control Unit is in the "standby" mode.

The thin Ethernet LAN is used to communicate with the other Control Unit and to communicate with a (portable) PC where the full graphics are displayed.

The Control Units executes the system and application software completely, resulting in high performances, low system pricing and low software maintenance cost. The only exception is the protocol conversion (which is described in the relevant sections). Not the Interface Modules but the Control Unit performs even functions like time stamping and filtering.

The Control Unit executes completely from memory. After a power up the main processor will load the system software from its flash EPROM's for the Station Processor and the optional Interface Module Processors. At the availability of a newer version of the system software on the hard disk and after power down and up again of the system, it will automatically restart with the newer version. As a result the spare part management is independent of the applied system software version.

The system checks the system and application software on the hard disk periodically using an extensive CRC check mechanism. This checking mechanism applies for all relevant software and configuration data that is stored on the hard disk. When errors occur, alarms are presented locally and in the remote control centre.

From application configuration point of view, the multiprocessor architecture of SAS2000 is fully transparent. This means that the engineer will see the Control Unit as one system.

Distributed Control Units

The DCU130 is the Distributed Intelligent Control Unit for local bay control as part of the SAS2000 system concept. The system has a fixed amount of I/O for small to medium ranged applications.

The DCU130 can act as a stand alone comprehensive substation controller for small substations or as the intelligent bay controller as a subordinate unit of the Central Control Unit, CU900.

Locnet

The data exchange between the Control Units and the Interface Modules must be fairly simple, price worthy, immune to interference and extremely reliable. This is why Locamation has used a serial dual redundant communication ring based on optical fibres.

The behaviour of the data acquisition system must be predictable, or more precisely "deterministic". This means that the system must function properly under the most severe conditions.

The Locnet communication is based on the SDLC protocol in loop mode. This protocol is

Master/Slave based which fits well to the job of highly intelligent Control Units as Masters and fairly simple Interface Modules as Slaves.

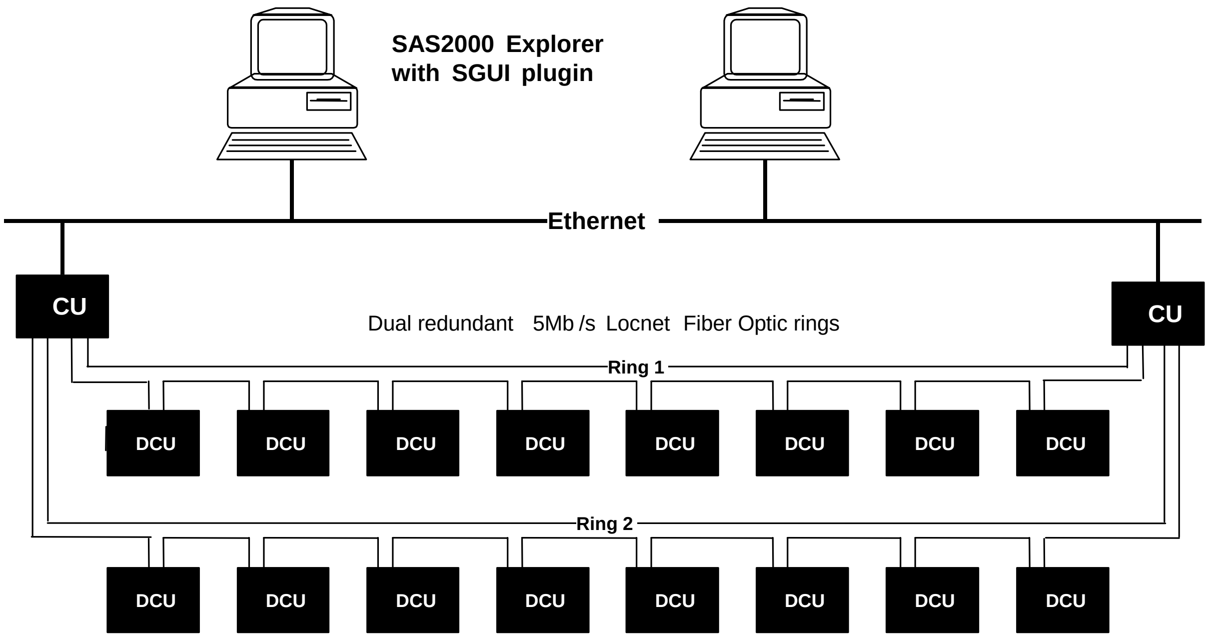
The master/slave relation, the ring topology and the automatic regeneration of the token in case of transmission failures are some of the main advantages of the SDLC protocol in loop mode.

Furthermore the 16-bit cyclic redundancy check (CRC) for data validation is important for the reliability and fail-safe behaviour of the system. All the Locnet rings are dual redundant with fully automatic failover upon cable or module malfunctioning.

You can connect typically five to six 19-inch Interface Modules (IM220) to one ring. In case of the malfunctioning of one node (a Control unit or an Interface Module) Locnet performs automatic rerouting within only 10 microseconds.

An important function of Locnet is to detect errors very accurately, absolutely minimise the chances of spurious operation and recover autonomously and immediately after failures.

The maximum Locnet length between two modes (Interface Module or Control Unit) is 2000 meters.



6

System Specifications

Capacity and performance

The capacity of the system mainly depends on the used type of hardware. The performance is determined by a combination of system capacity and system load. The system load depends on different factors. The most important factors are the following:

- Amount of process signals per Interface Module.
- Total number of Interface Modules.
- Number of serial communication links with external equipment, like protection relays, in conjunction with their respective communication speed.
- The number of protocols, lines, devices and memory elements processed by an LC212 serial card. A calculation spreadsheet is available to calculate the memory requirements.
- Number of serial communication links with remote control centres, in conjunction with their respective communication speed and the complexity of the protocol conversion.
- Number of trend logs in conjunction with their respective logging frequency and time base.
- Number of process equipment to be controlled and monitored.
- Number and complexity of application functions.

The load of the system can be subdivided in three different parts:

- The processing requirements.
- The memory requirements.
- The requirements for the Locnet communication capacity.

After an estimation of the previous mentioned terms, the number of Locnet rings can be calculated. The next sections present some practical figures as rule of thumb for system configuration purposes.

Note:
The tables cannot be applied to a given application without judgement; they only indicate the order of magnitude of influence by relevant load aspects.

Number of Locnet rings

The Locnet communication system is based on a synchronous communication protocol and a fixed scan cycle of 1 ms and a speed of 5 Mbits/s. The capacity of the Locnet ring network to transfer I/O data is also fixed. Therefore the number of I/O cards to be handled by a ring network can simply be calculated. In the calculations of the load on the ring network you must take in account the future required spare I/O cards and possible Interface Modules.

Maximum number of I/O in relation to the application

The maximum CPU load is determined with no additional substation application running. Larger application functionality takes more processing power and thus the need a higher idle percentage of the CPU's. More application functionality allows less I/O.

Typical application functionality that takes processing power is:

- Analogue objects and sequential linked objects.
- An Analogue object connected to an LA110 analogue input card, calculates once every second (3 seconds for the LA141). Thus the connected objects like

transformer voltage regulator, trending and composed objects will also be triggered to calculate.

- Composed objects that contain many Basic Building Blocks, with high concurrent, continuous event rates. Whenever an input change triggers a Composed Object, the object calculates internal Basic Building Blocks and updates interconnecting variables. So an external event rate must be multiplied by the number of events that has been induced by the application software.

Application classification

To obtain an indication of the maximum number of I/O bits in relation to the extend of the application, you must first classify the application. Applications are classified as light, medium and heavy with respect to the expected processor load.

		Number of Analogs		
		0-10	10-30	>30
Concurrent BBBs	>100	M	H	H
	50-100	L	M	H
	0-50	L	L	M

Memory utilisation

The memory utilisation depends on many factors like size and topology of the substation. The memory utilization are divided in two main parts:

The **topology independent memory utilization**. This is the memory needed for functionality that is independent of the topology of the substation, for example for the operating system or for generic application software modules.

The **topology dependent memory utilization**. With the following factors:

- Number of objects to be handled.
- Number of configured alarms and events.
- Number of entries in historical alarm and event lists.
- The configured trend log.
- Number of serial data points.
- Number of RCC data points.

Event capacity

- 400 events in 5 ms, every 3 seconds.
- 240 events/s constantly.

Alarm & Event list

- Current alarm list: the size is equal to the number of defined alarms. In principle the system does not limit the alarms list and it could be several thousands.
- 2000 Historical alarms and events in DRAM memory with a first-in first-out overwrite principle.
- Hard disk for long-term storage of alarms and events. An automatic free space recovery mechanism prevents the disk to get full.

Time resolution

- 1 ms all events and alarms.
- 1 ms in respect of external time like DCF77 (time signal from long wave radio transmitter in Germany) or GPS clock receiver.

Measurements scan frequency

- Scan frequency 1 Hz up for the LA110 analogue card.
- 0.33 Hz up to 1.33 Hz for the LA141 Power Measurement card (depends on the amount of active channels).

Performance of the graphical user interface update

- 0.5 sec for commands.
- < 1 sec dynamic display update.
- < 2 sec initial display call up.

Capacity of the disk storage

A typical capacity of the hard disk of a SAS2000 is 4 Gbyte. The hard disk is partitioned into two partitions.

The first partition contains the SAS2000 system software, the project files and the project screen pictures. During normal operation the system does not write on the first partition. The capacity is 2 Gbyte and is divided as follows:

- 6 Mbytes for the SAS2000 system software.
- About 1 Mbyte for each project database.
- About 5 Mbytes for each project screen.

The second partition is 2 Gb and is used for historic storage of:

- **Sequence of events**
  The space for each event record is 250 bytes. Typically 10 Mb are reserved for these files to give a storage capacity of about 40,000 events.
- **Historic Trends files**
  The space for each trend record (sample) is 40 bytes. Typically 10 Mb are reserved for these files to give a storage capacity of about 250,000 samples.
- **Disturbance data**
  The space for a set (3 files) of COMTRADE files is about 100 Kb (depending on the IED and its settings). Typically 10 Mb can store about 100 disturbances.
- **Operator Log**. The space for an Operator Log is 100 bytes. Typically 10 Mb can store about 100,000 records.

Note:
You can configure freely the maximum disk usage for each type of historical data.

Availability and Reliability

Electricity transmission and distribution applies high standards concerning the reliability of high voltage substations. A single failure will never lead to a total loss of the control of the substation. The capability to withstand a single failure is very important.

The necessity of redundancy in the process Interface Modules is low, considered the fact that the primary system is very often redundant in its self. This means that the single point of failure is not applicable at bay level or it is interpreted in a different way then on station level. The Interface Modules are simple and robust and can withstand the most severe electromagnetic disturbances.

The I/O cards have almost no jumpers, settings or version dependant software. It is very simple to swap a card and to have the system up and running again. Troubleshooting and maintenance of the Interface Modules do not require sophisticated personnel.

The Control Unit is a more complex system and therefore the MTBF (Mean Time Between Failures) is lower than that of the Interface Modules. However due to the redundant configuration the availability is very high. When a problem occurs in a Control Unit, the back-up unit takes over without any loss of functionality.

Control Unit

- Estimate MTBF > 10,000 hours for single unit.
- Full redundant configuration with 99.995% availability (MTTR of 72 hours gives MTBF > 1,400,000 hours).
- Withstands single failure without functional degradation.

Locnet

- Fully redundant configuration.
- Extremely reliable CRC checking and filtering.

Interface Module

- Estimate MTBF > 40,000 hours.
- 99.98% availability (with an MTTR of 6 hours).
- Command outputs are fail-safe.
- The integrated bipolar normally open relays can only be closed by setting two variables within a time frame of maximum 4 ms. When only one input is set, the output card will not close the relay and opens on board closed relays.
- In order to close a relay it must be controlled (bipolar) for at least 3 ms. Each single output command on the Locnet glass fibre system is checked each ms with a 16-bit CRC check. So

the chance of a spurious commons is basically zero.

Environmental specifications

SAS2000 is type tested complying the IEC standards for electronic industrial equipment applicable for substations.

7

Engineering & Configuration

Application Builder

The application configuration is performed on a separate PC that uses a database tool. This can be the PC on which the Human Machine Interface is running or any other one. The database consists of a simple menu system that can access the screen forms. These screen forms enables to perform the setting of parameters. So no software programming is needed. You simply built the application by filling in standard forms and a set of these forms is available for each Object Type. These Object types are the functional representations of primary and secondary plant items and functionality. If you require an other function than available in the Object Type library, SAS2000 provides a tool to create its own "Composed Object Type".

Special functions of the Application Builder to reduce time to configure the Application are the following:

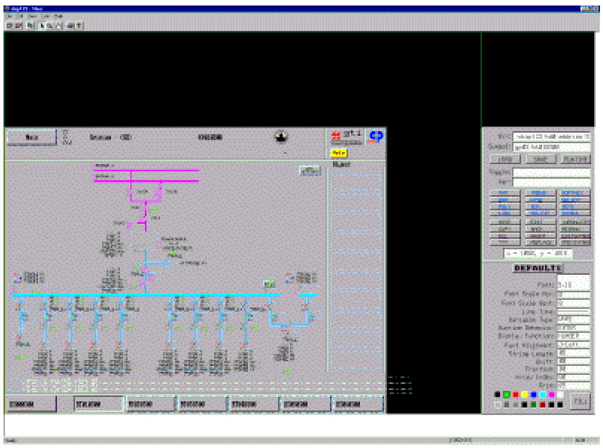
- **Bay Copier and Object Copier**
  You can copy an object (such as a transformer) in another bay when it is already fully configured. Even entire bay configurations can be copied.

- **Project data**
  An application configuration results in one file, called the "Project Archive". This file is transferred to the Control Unit using a graphical drag and drop file manager that is based on the Internet File Transfer Protocol. This means that project changes and transferring these changes to the SAS2000 systems can be done remotely, for instance over telephone lines. Finally, you can easily back-up and restore the project archive.

- **Version management**
  Each project archive must be given a project name and a revision number. The revision change notes can be entered in the project archive. This makes it easy to track changes. When you made a mistake, a simple mouse click on the Control Unit graphical user interface selects and activates a previous project revision.

Graphics Editor

The SGUI graphics are created using the SAS2000 Graphics Editor. With this editor both the static parts and the dynamic parts of the graphical user interface can be created. The Graphics Editor runs on the Control Units.



Some features are:

- Direct switchover from edit to run-time mode. This enables to test any change immediately.

- High degree of reusability. You can simply insert references to symbols that are already created instead of just copying.
- Availability of a library with many graphical plant item drawing objects.
- DOS-ASCII file format. This enables experienced engineers to quickly search and replace drawing items or attributes. They do not need any kind of compilation.
- A complete picture set of a project can receive a project name and a revision that corresponds with the Project Archive.
- Remote editing. The Separate Graphical User Interface Software performs editing. This enables to remotely change graphical user interface pictures, e.g. via telephone lines.

8

Communication Protocols

A protocol is a set of rules that governs how messages, containing data and control information, are assembled at a source for their transmission across the network and then dissembled when they reach their destination. Next, Communication Protocols are the grammars through which different computer-based devices communicate and the way they organise and transmit the bits and bytes of electronic on-off (binary) signals, whose patterns encode data.

SAS2000 performs those specific functions in such a way that it acts like a spider in the control and information web of the substation. The data and information exchange with other systems is serial and it uses dedicated communication protocols. The other systems can be locally situated Intelligent Electronic Devices (IED) or remotely placed control or information management systems. The applied communication protocols vary of nature depending of the make of the other system and the type of information exchange where it is used. The protocols are manufacturer specific proprietary or a defacto standard used within the industry segment and internationally standardised protocols.

Most often the system connections are of a point-to-point or multi drop nature with a clear master-slave hierarchy. Nowadays peer-to-peer and wide area network (WAN) protocols are also available.

SAS2000 has its own real time data structures (RTD-elements) that are converted into the structures of the applied protocols. In the communications hierarchy, SAS2000 is either a slave of an other (remote) control system or a master of a (local) IED like a protection relay. The RTD elements that are updated by the protocol can be used in the same way as other I/O elements (e.g. digital inputs/outputs, analogue inputs, read from conventional I/O cards).

They can be used for:

- Alarming.
- Display on graphical workstations.
- Input or output for (composed) objects.
- Transfer to other protocols who are linked/subscribed to the same data point

All available protocols can work in parallel and multiple instances of one protocol are supported where each instance can subscribe to its own defined data and command set.

IEC 60850-5-101 master & slave

The IEC 60850-5-101 protocol provides a standardized way to communicate with other systems. IEC 60870-5-101 provides a communication profile for sending basic telecontrol messages between two systems that uses permanent directly connected data circuits between the systems. The IEC Technical Committee 57 (Working Group 03) have developed a protocol standard for telecontrol, teleprotection, and associated telecommunications for electric power systems. The result of this work is IEC 60870-5. Five documents specify the base IEC 60870-5. The documents are:

- IEC 60870-5-1 Transmission Frame Formats
- IEC 60870-5-2 Data Link Transmission Services
- IEC 60870-5-3 General Structure of Application Data
- IEC 60870-5-4 Definition and coding of Information Elements
- IEC 60870-5-5 Basic Application Functions

The IEC Technical Committee 57 has also generated a companion standard IEC 60870-5-101 especially for basic telecontrol tasks. The IEC 60870-5-101 is based of the five documents IEC 60870-5-1 to 5. The IEC 60870-5-101 protocol is a companion standard of the IEC 60870-5 standard, used for basic telecontrol tasks. The 101 Slave protocol for SAS2000 makes SAS2000 behave like a 101 outstation, allowing it to handle data requests and commands from a 101 master station. The protocol uses V24 communication lines, which can be connected directly to the Control Unit or to a communication channel. The implementation can handle redundant communication line configurations to increase the availability of the functional communication connection.

Control and monitor direction

The 101-slave protocol for SAS2000 allows a 101 master station to retrieve data and send commands to the SAS2000 system. In unbalanced transmission mode the master station is always the initiator, i.e. the slave station can only send data if requested. The SAS2000 implementation of the 101-slave protocol supports subsets of the ASDUs in both control direction and monitoring direction. The protocol documentation describes the protocol implementation and the interoperability and conformity to the IEC specification.

IEC 60850-5-103 master & slave

The IEC 60850-5-103 protocol is designed for use with data transmission between IEDs like protection equipment and control systems. The protocol defines application service data units that specify the message layout and contents and describe the order and situations in which these messages are sent. SAS2000 uses the 103 protocol to retrieve values from the protection relays, using these values to update RTD elements (internal process variables). Furthermore the protocol is used to download disturbance data from the relays and to store the data to a disk in the IEEE standardised COMTRADE file format. The communication card that runs the 103-protocol implementation provides a V24 interface RS232 at physical level and it can support up to 10 relays on a single line when using an RS485 bus. The protocol implementation enables to map protocol information elements on RTD elements of SAS2000. The 103 information elements to be mapped may be of the following value types:

- Double Point Information (DPI).
- Measurand with Quality Descriptor (MEA). Linear scaling can be used to convert the MEA value to the correct engineering value.
- Short-Circuit Location (SCL). An SCL is a real value that represents the location as fault reactance related to primary values and is valued in Ohms. A linear scaling can scale an SCL.
- Single command.
- Double command (DCO).

Note:
The set of information elements defined by the 103 specification is supported, but the information elements available for a particular relay depend on the type of relay and should be described in the relay interface documentation.

DPI, SCL and MEA information elements can be mapped on input RTD elements. Commands can be mapped on output RTD elements.

Retrieval of Disturbance Records

For relays that support retrieval of the disturbance records, SAS2000 can extract these records and store them on the Control Unit hard disk for off-line analysis. The files are stored using the COMTRADE format. COMTRADE is an IEEE (C37.111) standard that has been developed as a common format for transient data exchange. The disturbance data files can be extracted from SAS2000 with a graphical file manager that uses the Internet File Transfer Protocol (FTP).

Logging of event and fault records

To enable off-line analysis, all event and fault records from the relays are logged into text files on the hard disk of the controlling Control Unit. The maximum size per file can be set in the device configuration for the relay. SAS2000 creates a new file if a log exceeds the maximum file size and files are automatically overwritten if the maximum amount of disk usage for the device has been reached.

Time synchronisation

The 103 driver will synchronise the Real Time Clock of the protection with the Real Time Clock of SAS2000. The interval between time synchronization is set by a protocol parameter. Time synchronization is performed during initialisation and at intervals specified by this parameter. The time used for the synchronization is written into the time synchronization message at the last possible point before sending to ensure that the time is as accurate as possible.

DNP3 master & slave

DNP was originally created by Westronic, Inc. (now GE Harris) in 1990. In 1993, the 'DNP 3.0 Basic 4' protocol specification document set was released into the public domain. Ownership of the protocol was given over to the newly formed DNP Users Group in October of that year. Since that time, the protocol has gained worldwide acceptance, including the formation of Users Group Chapters in China, Latin America and Australia. In January 1995, the DNP Technical Committee was formed to review enhancements and to recommend them for approval to the general Users Group. One of the most important tasks of this body was to publish the 'DNP Subset Definitions' document, which establishes standards for scaled-up or scaled-down implementations of DNP 3.0. DNP 3.0 is an open, intelligent, robust and efficient modern SCADA protocol. The protocol is able to do the following actions:

- To request and to respond with multiple data types in single messages.
- To segment messages into multiple frames. This ensures excellent error detection and recovery.
- To include only changed data in response messages.
- To assign priorities to data items and to request data items periodically based on their priority.
- To respond without request (unsolicited).
- To support time synchronization and a standard time format.
- To allow multiple masters and peer-to-peer operations.
- To allow user definable objects including file transfer.

The DNP3 protocol is a protocol based on the standards of the International Electrotechnical Commission (IEC) Technical Committee 57, Working group 03. This group has worked on an ISO 3 layer “Enhanced Performance Architecture” (EPA) protocol standard for telecontrol applications. It is used to exchange data between RTUs and remote control points. DNP3 for SAS2000 makes SAS2000 behave like a DNP3 Master or Slave. It allows sending data requests and commands to a DNP3 Slave station or to handle data requests and commands from a DNP3 Master station. So it can be used for Control Centre communication and for communication with protection relays or other Intelligent Electronic Devices.

User level

SAS2000 is fully compliant with user level 2 and the most used and important functions of level 3.

Elcom-90 responder

The Elcom-90 protocol provides a standardised way to communicate with Area Control Centres. Elcom-90 for SAS2000 implements all functionality needed for a complete responder system. The Elcom-90 subsystem for SAS2000 consists of user elements and a provider.

Elcom-90 user elements

The user elements supports version 1, class 3 of the Elcom-90 protocol. It only supports responder functionality. The following Functional Units are supported:

- Permanent/Dynamic Associations.
- Test association.
- Group Management.
- Group Definition.
- Group Read-out.
- Requested Data Transfer.
- Periodic Data Transfer.

- Unsolicited (mixed) data transfer.
- Supervisory Control Data Transfer.

The following group types are supported for SAS2000:

- Measure group, to send scaled values of analogue inputs.
- Status group, to send Boolean values and double point indications.
- Discrete group, to send counter values.
- Binary command group, to receive ON/OFF commands from the Initiator.
- Analogue set point group, to receive analogue set points from the Initiator.
- Digital set point group, to receive digital set points from the Initiator.
- Quality codes can be sent and received which give additional information on the data communicated.

Elcom-90 provider

The provider supports the Elcom-90 responder functionality for OSI layers 6 and 7. The implementation of the Elcom-90 Provider follows specifications of EFI as closely as possible. The TCP/IP protocol is supported as lower layer protocol. X.25 is not supported.

TCP/IP and SLIP protocol

TCP/IP is supported as de-facto standard protocol on the substation Ethernet network and on serial lines. Serial lines that are based on V24 connections are used as the physical transmission layer. TCP running on serial lines is supported through SLIP (Serial Line Internet Protocol). The de-facto standard "Van Jacobson compression" is supported for optimum serial line throughput.

All data exchange on the substation Ethernet network is based on TCP/IP. In SAS2000 you can configure TCP/SLIP at two sides of the system:

- At a serial port of the Control Unit.
- At a serial port of one of the LC212 cards in the Interface Modules.

Modbus RTU protocol master & slave

SAS2000 supports both a slave and a master implementation of the MODBUS-RTU protocol. The MODBUS RTU Slave protocol provides a way to communicate with a MODBUS master and visa versa. MODBUS for SAS2000 will support up to four MODBUS interfaces at a time. A separate LC212 card is needed for each interface.

MODBUS function codes

The following MODBUS function codes are supported (depending on master or slave usage):

- Read coil status.
- Read input status
- Read output register
- Read holding register.
- Force single coil.
- Preset single register.
- Force multiple coils.
- Preset multiple registers.

The slave generates exception responses if the master requests an invalid address or function.

A linear scaling does the mapping of RTD elements to registers.

Alstom Courier communication language master

Alstom created the Courier communication language to communicate with their K-series range of protection relays. It provides a means of retrieving and setting data cells in the relay's menu system. In the context of SAS2000, the Courier protocol is mainly used to exchange real-time values between menu cells of the protection relays and RTD elements of SAS2000. It is based on the ISO-OSI enhanced performance architecture (EPA). The Courier protocol layers correspond to the application layer of this model. For SAS2000, the IEC 60870-5 standard is used for the link layer and physical connection.

The Courier protocol implementation runs on LC212 cards. Communication with the relays is performed via a KITZ conversion unit for each communications line that translates the IEC 60870-5 frame format into the K-BUS format that the relays use. Up to 32 relays per serial line can be supported with this configuration.

The implementation of the COURIER protocol enables to map relay menu cells on RTD elements of SAS2000. The COURIER menu cells to be mapped may be of the following value types:

- Binary flags
- Unsigned integer
- Signed integer
- Numeric Number
- IEEE floating point number

Read-only menu cells can be mapped on input RTD elements. Settings cells and password protected setting cells can be mapped on input and/or output RTD elements. For cells that can be reset, the reset cell function can be mapped on an output RTD element. Changing this element from 0 to 1 will trigger the reset cell.

The RTD elements that are updated by the protocol can be used in the same way as other I/O elements (e.g. digital inputs, analogue inputs, read from conventional i/o cards). They can be used for:

- Alarming
- Display on graphical user interface
- Input or output for (composed) objects
- Transfer to the RCC through the RCC protocol

Plant Control

The serial output RTD elements can be connected to the control outputs of composed or standard objects, e.g. a switchgear object. The serial input RTD elements that indicate the switchgear position can be connected to position the inputs of the objects.

The normal switchgear object functionality can be used if serial RTD elements are used instead of digital I/O RTD elements.

Select setting group

A special output RTD element can be defined to select a relay setting group.

Reset trip indication

A special output RTD element can be defined to reset the relay trip indication (front panel LED).

Load shed to level

A special output RTD element can be defined to select the load shedding level for a relay. Changing the value of this element to the desired load shedding level will result in sending a “COURIER load shed to level” command to the device. Note that this function is only available for relays that support the load shed to level command. The facility must be enabled on the relay on forehand.

Load shed to group

A special output RTD element can be defined to select the load shedding group for a relay. Changing the value of this element to the desired load shedding group will result in sending a “COURIER load shed to group” command to the device. Note that these functions must be supported by the relay. The facility must be enabled on the relay on forehand.

Retrieval of Disturbance Records

For relays that support retrieval of the disturbance records, SAS2000 can extract these records and store them on the Control Unit hard disk for off-line analysis. The files are stored using the COMTRADE format. COMTRADE is an IEEE (C37.111) standard that has been developed for a common format for transient data exchange.

Logging of event and fault records

To enable off-line analysis, all event and fault records from the relays are logged into text files on the hard disk of the Control Unit. The maximum size per file can be set in the device configuration for the relay. SAS2000 creates a new file if a log exceeds the maximum file size and files are automatically overwritten if the maximum amount of disk usage for the device has been reached.

Time synchronisation

The COURIER driver on the LC212 card will synchronise the Real Time Clock of the KITZ with the Real Time Clock of SAS2000. The interval between time synchronisation is set by a protocol parameter. The time used for the synchronisation is written into the time synchronisation message at the last possible point before sending to ensure that the time is as accurate as possible. The accuracy is approximately +/- 10 ms.

Dynamic browsing of the relay database

With the graphical user interface browser you can browse the contents of the relay database. The menu cells of the relay database that are presented on screen are read from relay directly before presentation.

RP570 / 571 slave

The RP571 protocol is the intellectual ownership of ABB and is used to exchange data between Remote Terminal Units (RTUs) and a Remote Control Point (RCP). The RTU and RCP are parts of a S.P.I.D.E.R. system. RP571 for SAS2000 makes SAS2000 behave like RTU200 equipment allowing it to handle data requests and commands from a S.P.I.D.E.R. station. Is protocols is supplied under a strict license arrangement with ABB.

G174 slave

The GI74 protocol is developed and used by the National Grid Company Ltd., United Kingdom for the communication between their Area / National Control Centres and the remote outstations. The GI74 protocol for SAS2000 allows a master station to retrieve data and send commands. The master station is always the initiating party in this case; i.e. the master sends requests, which are fulfilled by the protocol handler. The protocol supports a number of requests. The requests can be divided roughly into the following different types:

- **Control requests**
  These are used to send commands to the SAS2000 system.
- **Read block requests**
  These are used to obtain data blocks of up to 7 words
- **Read word requests**
  These are used to obtain a single data word of a block.
- **Send changes requests**
  These are used to obtain the oldest change from the changes list
- **Multiword clear down requests**
  These are used to abort a 3-step command.

TG709/E and TG809 slaves

The TG709/E and TG809 protocols are the intellectual property of Siemens (formerly Landis & Gyr). This is readily available and field proven, licensed proprietary protocol that can be used on special request.

WISP and WISP+ extended slaves

The WISP and WISP+ extended protocols are the intellectual property of Groupe Schneider (formerly Westinghouse Systems Ltd.). This is readily available and field proven, licensed proprietary protocol that can be used on special request.

CDC 8890 Type II slave

The CDC 8890 Type II protocol is the intellectual property of Siemens (formerly Control Data / Empros). The CDC 8890 Type II protocol is used to transfer data to and from an ETAG substation. CDC 8890 Type II for SAS2000 makes SAS2000 behave like an 8890 RTU allowing it to handle data requests and commands from a master station.

The CDC 8890 Type II protocol for SAS2000 allows a master station to retrieve data and send commands. The master station is always the initiating party in this case, i.e. the master sends requests that are fulfilled by the protocol handler. The protocol supports a number of requests. The requests can be divided roughly into three different types:

- **Control messages**
  This includes set point control. For digital control points a select-before-operate function and a direct operation function are supported.
- **Scan messages**
  These are used to obtain input data of a particular type, for example digital status indications and/or analogue data. The scan requests also support the concept of tables. This allows certain data point to be categorized so that all these points can be read in one scan.

Table configuration is performed from the master station and not via the application builder.

- **Memory read/write**
  These are used by the protocol for defining scan tables.

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