S.P.I.D.E.R.

The open platform for horizontal and vertical integration of power control centres

ABB Network Control
& Protection

(SE902288)

Features

- **Extensive SCADA functionality**
- **Complete EMS functionality**
- **Complete DMS functionality**
- **Platform for integrated IT–systems**
- **Versatile MMI – adapted to operators**
- **Open system architecture**
- **Adherence to international standards**
- **Modularized distributed processing**
- **Coordinated data engineering**
- **Incremental system upgrading**

Application

The S.P.I.D.E.R. concept establishes a framework for total information management in a power company. The advanced Energy Management System (EMS), Distribution Management System (DMS) or Supervisory Control And Data Acquisition System (SCADA) of today has become the foundation for the integrated and distributed computing environment of the power company.

The international standardization and the rapid development in the field of open systems and distributed architectures make it possible to design control systems with more attractive features than ever before.

The master station control system does not only constitute the kernel for horizontal integration, when connecting centralized computing resources. It also facilitates the vertical integration, by connecting plant computing resources in power stations and substations to a central position for monitoring and control.

The modern distributed design allows for a full, and integrated, spectrum of functionality for power generation, transmission and distribution applications. Due to the standardized hardware and software platforms and interfaces, it also allows other applications to use the design as its kernel for building advanced non–electrical network control systems.

The S.P.I.D.E.R. system is based on an open architecture. The modularized design makes it possible to tailor each system exactly to the needs of the power company, no more and no less. The range of functions and system capacities is vast. This means that each installed system can enter the S.P.I.D.E.R. concept at any level. As the requirements change the installed system can easily change with them, step by step in an incremental sequence.

The concept of open systems architecture inherently offers an increased control system availability and improved upgradeability. The distributed architecture, of hardware as well as of software, makes it justifiable to meet demanding functional availability requirements.

The design allows for matching the control system to utility expansion needs in power system size as well as in performance. New advances in computer technology may be incorporated, when needed. The functionality of the control system can continually become upgraded and tuned to a dynamic organization for its demand for efficient tools.

Application (cont'd)

EMS	DTS	DMS
• Power System Control • Network Monitoring • Security Assessment • Operation Enhancement • Energy Planning	Dispatcher Training Simulator	• Distributions Operation Management • Distribution Outage Management and Restoration • Load Management • Remote Metering
SCADA		
• Data Acquisition • Man Machine Interface • Monitoring and Event Processing • Report Generation and Calculations • Database Management - Real-time and Statistical Archiving		• Supervisory Control • Inter-Center Communication • Office Connection • Disturbance Data Collection • Data Engineering

(00007–1)

Fig. 1 A functional framework for S.P.I.D.E.R.

A full set of functions

The strength of ABB Network Control and Protection is based on its combined expertise of real–time data processing and control technology as well as from a widespread and detailed knowledge of power systems and their operation.

Consequently, the S.P.I.D.E.R. concept offers the most comprehensive functionality to help operators control and monitor all aspects of electrical networks. From a strategic vantage point, S.P.I.D.E.R. spans the entire network. Its control stretches from power generation through interconnected transmission grids to distribution networks.

S.P.I.D.E.R. EMS offers a full Energy Management System capability. Functions for optimizing energy transmission and operating costs, while maintaining security levels, are offered. The versatile power application packages are combined with a comprehensive SCADA functionality for supervisory control.

In this environment power applications can be used for real–time control or for study–mode planning using a multiple database concept.

Power system control functions keep system frequency and tie–line interchanges constant, irrespective of the actual loading conditions. They control production units according to schedules and operational constraints.

Network monitoring functions provide the operator with the best possible picture of the system. The security level of the actual power system, or a planned configuration, is analyzed by the security assessment functions.

Operation enhancement provides the operator with recommendations on how to improve reliability and economy of power system operation by means of the most advanced optimal power flow schemes.

Energy planning uses forecasts for scheduling hydro and thermal power plant operation in an optimal way. These modules allow the operator to use available generating resources in the most economical way.

S.P.I.D.E.R. DMS offers an integrated system with functions enhancing the operation of medium and low voltage power distribution networks. These functions permit fast access to actual network status and provide the means to achieve improved operation. The operator gets a full graphics image of the distribution network. Geographical mapping systems can also be integrated.

The distribution operations management supports the modelling and analysis of the distribution network. It models the load profile to facilitate presentation of the state of the distribution network. Energized and deenergized parts of the network can be viewed by means of dynamic network colouring.

Load flow calculations estimate the voltage levels and power flows at each feeder based on the total load and statistical load factors.

Handling of switching orders is made easier and more secure by switch tagging and order form production on the operator's CRT. Work protection tagging ensures the safety of the repair crew on duty. Software tools are used to tag groundings and repair sites to enter these on the CRT screen and to issue repair authorization.

Outage management and service restoration detects, administrates and reports whether outages and restorations have occurred.

Load management facilitates the smoothing of load patterns by centralized control schemes and control units located at end–user sites.

Remote metering improves the energy metering services to be more accurate and more frequent.

Statistics management outputs several types of statistics to provide for monitoring of maximum loads and minimum voltages, outage times, etc.

S.P.I.D.E.R. DTS provides the operator with training facilities. The dispatcher training simulator is offered at several levels of ambition up to full–fledged simulation, including machine dynamics and protection equipment.

S.P.I.D.E.R. SCADA offers the most versatile set of SCADA functions. A subset of these can be easily tailored to suit each installation.

The data acquisition functions establish the vertical integration with power system control equipment, a complete family of RTUs and substation control systems. International standard communication protocols as well as third party RTU interfaces are supported.

The inter–centre communication package uses the ELCOM international standard to build control centre hierarchies. Function control and system responsibility may be allocated among several centres. They can exchange and subscribe operational as well as planning data.

Security monitoring and event processing determines and classifies the operational state. The operator can instantly get an overview in order to extract important information. Expert system technology is used for advanced and rapid fault diagnosis.

Event and alarm processing is designed for high capacity which allows process disturbances to be handled with the least possible effect on control system performance.

The control functions include on–off commands, regulation and setpoints with proven security. The operator can interactively define switching sequences that can be activated in several ways – manually or automatically, at the plant control systems or at the master station.

Disturbance data collection coordinates the data collection with local plant equipment, stores it in the master station and presents disturbance sequences in order to improve and speed up fault analysis.

The full graphics man–machine interface offers high resolution display presentation, combined with straight forward dialogues. The operator interacts with the system through well–structured pull–down menues, a mouse and a keyboard. It combines high performance, advanced technology and user friedliness. The result is improved operator interaction giving enhanced power network control.

The authority function enables the power utility to assign operational responsibility among operators for defined geographical areas or subsystems, such as transmission and generation. This is done irrespective of the physical location of the operator workstation, i.e. in the control center or in a remote location.

The Avanti database management system manages the distributed S.P.I.D.E.R. database. This contains an image of static and dynamic properties of the supervised power system. Avanti also handles time–tagged data, statistics of the past and schedules for the future.

The archiving functions, together with the time tagged database, give the user extraordinary possibilities to store statistical data.

By using the report generator, the operator can interactively create his own reports, including their calculation schemes.

Building of an integrated system (cont'd)

The vertical integration implies the coordinated monitoring and control between a control centre and the local plant control equipment. It involves local plant controllers, protection devices etc. as well as centralized software functions for optimization and enhanced monitoring. The vertical integration also involves the interconnection features of control centres in hierarchies. The horizontal integration implies the establishment of an integrated utility–wide distributed computing environment. This interconnects all computer applications of a utility, with its master station control system as the foundation.

The horizontal integration facilitates optimal solutions for the coordinated monitoring and control of the whole chain from power generation to power distribution and load management.

The open systems architecture provides an integration of separate and decoupled hardware and software modules. Each module can thus operate in a distributed fashion, be maintained and further developed with minimal impact on other modules.

The data engineering services constitute a contradiction to this decoupling. To minimize data input for the total amount of data, a certain degree of coordination between functional modules has to be built in to the data engineering environment. In addition, the use of common style guides for an MMI–interface, makes it easier for users to be familiar with all levels of the integrated control system.

Distributed computing environment

To provide a distributed environment for software applications, it must be supported by both a flexible hardware configuration and by a software platform.

This can be seen from the effort that Open System Foundation (OSF) has put to this topic, where the Distributed Computing Environment (OSF/DCE) is one of the most important ones.

On the hardware side, the evolution towards more powerful computers with lower price has made it easy to install more computer resources. By the development of standardized and fast inter–computer communication media (LANs and WANs) new computers can easily be interconnected.

On the software side, communication standards have made it easier for computers of different manufacturing to communicate with each other. Further enhancement in this area makes it easier for different applications to exchange data on a higher level, but the levels provided today are sufficient for a distributed software platform

For a system designed for centralized power network control, a global, but not centralized, real–time database is essential in order to perform power system supervision and optimization. It must be possible to distribute this database over the computer network, yet not denying any user access to the data.

Inter–process communication must be transparent, either the user program executes in a local server or remote in the communication network.

The S.P.I.D.E.R. concept fulfils these criteria, providing a truly distributed computing environment. Applications can be added or moved between servers under control of the system manager.

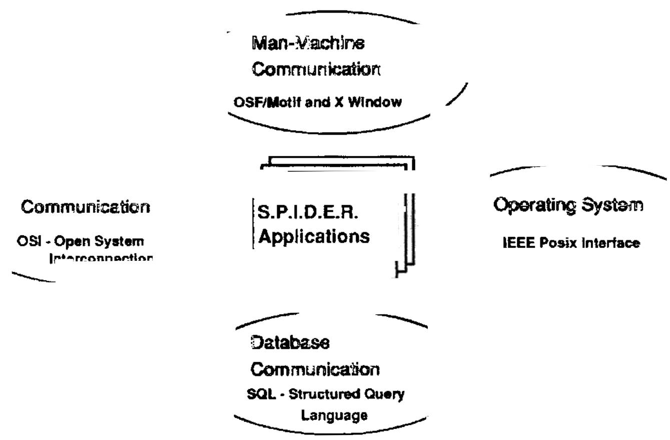

Fig. 4 Directions of international standardization

Technology and standards

To fulfil the open system criteria the product design strategy for S.P.I.D.E.R. is based on the following:

- Adherence to international and industry standards, which are appropriate and relevant for network control applications.
- A portable software design, which allows for an efficient migration path when the technology advances.

The international standardization in the field of open systems has taken a substantial step forward during the last few years. By using the relevant standards for network control systems in the design of S.P.I.D.E.R. a great flexibility and reliability is achieved in the selection and design of hardware and software products. Figure 4 indicates the standardization being important for the design of network control systems:

- The use of IEEE Posix (Portable Operating System Interface specification) as a base provides the user with a flexibility for selecting his operating system, although the OSF's Unix (OSF/1) is the preferred base for S.P.I.D.E.R.

The ISO/OSI reference model specifies a layer structure where each layer has its standard specification. Lower levels naturally conform to various CCITT recommendations and the communication concepts allow the use of both private or public, local or wide area networks. The S.P.I.D.E.R. concept favours the protocols that are recommended as a standard or being a de facto industry standard.
The OSF efforts comprise operating systems (OSF/1), a distributed computing environment (OSF/DCE) as well as the man–machine interface (OSF/Motif). The environment for man–machine–communication in S.P.I.D.E.R. bases the implementation on OSF/Motif. Motif specifies the development of a graphical user interface built on top of the X–Window system.

– The design of database management is the crucial and determining factor for functional performance and flexibility of upgrading. ABB has designed S.P.I.D.E.R. so that the Avanti DBMS is used for the real–time environment while the Oracle DBMS is used for data engineering. Both database systems offer an SQL–interface (Structured Query Language) which is the means for internal and external database communication.

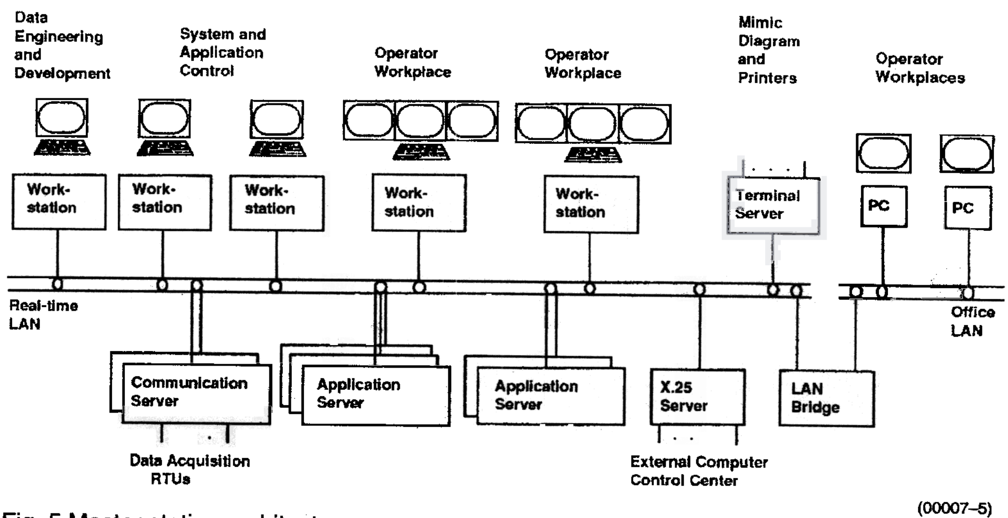

Fig. 5 Master station architecture

Hardware architecture

Real–time LAN and Servers

The hardware architecture of a S.P.I.D.E.R. master station is built around a local area network, LAN, according to the IEEE 802.3 specification. The LAN is called the real–time LAN. This LAN can be either single or redundant.

The computing environment consists of a number of servers. These are operated independent of each other, connected by means of open system communication facilities. The concept of independent servers gives the possibility to allocate one or more software applications to the servers and to increase the flexibility of the configuration. Various servers are connected to the LAN:

– The number of workstations in each installation is determined by the operational organization as well as by the system development strategy of the power company. Each workstation is connected to the real–time LAN.
– The communication servers provide the interface to data acquisition. The number of communication servers is determined by the needs for data acquisition. A communication server can be implemented by single or redundant processor configurations.
– Application servers perform functions without direct communication except via the LAN. Each application server can be built up by single or redundant computers. The number of servers that are needed depends on the total functionality, performance and availability requirements imposed with this.

Process WAN and Communication Servers

The RTUs are distributed over large geographical areas and placed in power stations and transformer substations. In modern substations, on high voltage as well as on medium voltage, computer systems for substation control are installed. Substation Control Systems (SCS) as well as Hydro Power Control Systems (HPC) are integrated in the S.P.I.D.E.R. concept as parts of the standard solution.

The communication network is configured with point–to–point links, multi–drop (party–line) or series/stars structures. Also common, is the loop configuration which offers an increased availability of communication. The communication between the master station and the RTUs/SCSs is performed over many types of media, like power line carrier, radio link, microwave link etc.

In S.P.I.D.E.R. the communication protocol between the master station and the RTUs is RP 570. This protocol is based on the international standard interface specification IEC TC 57, which specifies data exchange over medium speed communication channels with reference to the ISO/OSI model. In the near future higher speed communication lines come into use. The S.P.I.D.E.R. concept is prepared also for this development.

Hardware architecture (cont'd)

Other types of RTUs or already installed data acquisition terminals which do not implement the RP 570 protocol are easily integrated in a S.P.I.D.E.R. environment.

Office LAN and PC–connections
The interfacing of an Office LAN with interconnected PC–computers (or another external office computer) is most efficiently done by including bridges between the Real–time LAN and the Office LAN.

This solution gives good integrated design while isolating the LANs from each other with regard to "local" traffic. The bridge operates as an address filter in both LAN–directions, which gives a minimum impact on system performance from one computer to the other, and vice versa.

The S.P.I.D.E.R. system offers services for applications in the PC–computers to retreive and store information from the real time as well as the time tagged database. In this way a connection between real–time applications and off–line applications is easily established.

External WAN and Control Centres
The interconnection to external computers or other control centres is done by means of servers and an appropriate communication protocol. The protocol design is based on the ISO/OSI–layer structure which eases the implementation of various protocols.

Whenever two ore more S.P.I.D.E.R. system based control centres are interconnected, the ELCOM protocol is recommended. It is based on the OSI model and utilizes standard ISO protocols for reliable communication over local and wide area networks.

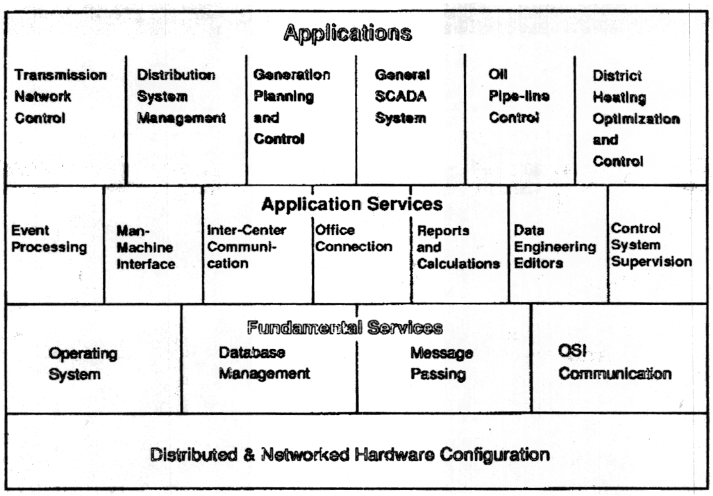

Fig. 6 Software structure (00007–6)

Software architecture

Common Environment
The S.P.I.D.E.R. software comprises a set of modular and decoupled packages. Combined together these packages are tailored to suit each specific application. By using the layered software structure and internal interface specifications a great variety of applications can be implemented on top of the basic system. The majority of the software packages use the same database management system, the same interface to the alarm handling system, a common man–machine interface etc.

With its capabilities of functional distribution in a distributed environment, the S.P.I.D.E.R. software offers the advantages of an integrated network control system. The common software environment enables a concentration or distribution of the total software into the available servers, depending on system size and performance and availability needs.

Modularity and flexibility
All of the software packages of S.P.I.D.E.R. offer a comprehensive set of functionality, although in many installations only a limited set is needed. The approach of "tailored standardization" is the principle for bringing down system cost, increasing system performance and reliability as well as maintaining software quality through a well–proven design and finally making system development and implementation more secure.

There are two design objectives involved to achieve this:

– Modular structure. The whole software concept is subdivided into function modules (packages). Some of the modules are obvious, e.g. load forecasting, knowledge–based alarm processing, contingency analysis. Some modules might be more intimately related to other modules. Therefore a careful system design is needed in order not to jeopardize system performance.

– Parameter control. Each individual function module is designed to offer a specified flexibility. This flexibility is controlled by parameters stored in the database. The parameters are easily changed as a part of the data engineering procedures or on–line in the real–time operational system. In this way the functionality of the standard packages is changed and adapted to special needs, without reprogramming.

Portable Design

All S.P.I.D.E.R. packages use standardized interfaces to the fundamental system services. These interfaces are provided by the Avanti database system, the S.P.I.D.E.R. Message Passing System and the S.P.I.D.E.R. Real–time Environment.

This means, that the software packages are independent of the underlying operating system. The services are using the IEEE/Posix 1003 interface specification. This interface is supported by operating systems from many vendors. This means that S.P.I.D.E.R. software can be executed on many operating systems and hardware platforms making it a truly portable software system.

The choice can be made for an actual implementation depending on power utility preferences and the best price–performance for the particular installation. Today the most favorable platform of computer technology is the RISC architecture.

Software Integration and Distribution

S.P.I.D.E.R. provides the design for distributing functions among the servers on the LAN based on the following:

- Standardized Operating System Interface
- Distributed Database Management
- Network Transparent Inter–process communication
- Use of the Local Area Network communication
- Use of standard High Level Languages

Since all these design factors are met, functions can be distributed on a process by process level. However, some functions are more suitable for distribution than others. It is a matter of tuning the overall system performance and observing the resulting need for data communication over the LAN.

The characteristics of S.P.I.D.E.R. make it possible to allocate functions to servers depending on user requirements. In this distribution, only the interdependence between modules limit the possibilities, in terms of common parts of the overall data structures and their needed access frequencies. Basically, the system performance requirements are the ones bringing constraints to the functional distribution.

Database management

Data storage and data communication are two key factors when designing a distributed network control system. The database represents not only the model of the monitored network but also comprises a vast amount of information for the variety of application programs implemented in each control system.

The features of database management therefore determine on one side the overall functional performance and on the other hand the flexibility for functional development and control system expansion.

Real–time operation requires fast data access. On the other hand advanced application programs need advanced search paths through the process model. Data Engineering needs interactive and easy–to–use window and form handling interfaces related to the structure of the process. Simulation programs need slices of the real–time situation for further analysis and optimization. Therefore parallel databases must also exist concurrently.

The need for exchanging/transfering data between databases has increased. This can of course be done by means of regular data communication procedures. However, the SQL, Structured Query Language, has evolved as the general and de facto standard means for database communication. It exists in both interactive and embedded versions.

S.P.I.D.E.R. takes advantage of a set of databases, to meet these, in a way, contradictory requirements:

- The Avanti DBMS is a distributed, real–time database, specially designed for real–time applications. It is used in many installations all over the world and combines fast top level access of hierarchical data structures with general purpose search calls.

  Avanti also provides a standardized way to access data by offering an SQL–interface. It hides the physical storage structures completely from the user who only sees a logical view of the database.

- The Oracle DBMS is a relational database, especially designed for general purpose applications. It is used all over the world and has become a de facto standard in its area of application. Oracle combines a flexible data structuring and data storing with an interface to a form handling system.

  Oracle also provides an SQL–interface for database communication.

Message passing

S.P.I.D.E.R. incorporates a Message Passing System that is the used method of communication between S.P.I.D.E.R. programs. The Message Passing System utilizes a sender – receiver concept (client – server).

The sender process sends a message containing a data buffer to a specific receiver process. If the receiver is active, the message will be put in the queue and fetched by the receiver in the right order. If the receiver is not active, it will be awakened or created by the message system, transparent to the sender. A message can of course be empty, which is the easiest way of only starting a process, without parameters.

The message system can handle both asynchronous and synchronous messages. Asynchronous mode means that the sender will continue its execution directly after sending the message while synchronous mode means that the sender will hold its execution until the receiver has executed and acknowledged the message. A return buffer can be used together with the acknowledge.
All message passing is transparent over the computer network. This means that the sender and receiver can be located in different servers. The locations are transparent to the sender and receiver.

A redundancy and security system is built into the message passing system.

Application services

In addition to the fundamental distributed services, S.P.I.D.E.R. provides a set of application services. They constitute software resources available for any application program on a higher functional and integration level than the basic resources.

Each application service has a specification of its own interface towards its users/clients (i.e. the application programs). This interface is an entry through the message passing system. It also implies that the application services are available throughout the distributed network and its servers.

The application service interfaces provide the means to connect a variety of applications to the S.P.I.D.E.R. system.

Typically, the application will use the process interface service for retrieving and updating process data, the event processing service for alerting the operator about special application events and the man–machine interface service for interacting with the operators.

The man–machine interaction may alternatively be implemented through a dedicated window, using the X–Window services, or by means of standardized dialogues and presentation windows, using the S.P.I.D.E.R. man–machine interface service.

Conclusion

By implementing the concept of open systems into S.P.I.D.E.R., ABB offers its customers not only an excellent state–of–the–art network control system but also a framework and foundation on which an integrated company information management system can be built.

This is true for communicating with other centralized computer systems as well as integration of computers for local control in power substations and transformer substations. The integration gives rapid access to all the information stored in various computers so that monitoring may be enhanced, and operation and its planning may be optimized.

Additionally, the S.P.I.D.E.R. concept offers extensive and state–of–the–art functionality to help operators control and monitor all aspects of electrical networks. This spans the entire network, streching from power generation through interconnected transmission grids to distribution networks.

The use of international standards and principles for a portable software implementation of S.P.I.D.E.R. assure an extended control system life time, increase system reliability and finally offer flexibility for functional development and power system expansion in that technological advances may be incorporated, when needed.

References

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