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NEW TELECONTROL SYSTEM ARCHITECTURE : OPEN SYSTEMS

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1 Introduction

1.1 Current Situation

The power utilities are undergoing significant changes including deregulation, increased competi-tions, take-overs, mergers and down sizing. Top utility management is emphasizing innovative approaches to better planning and operations.
As power utilities transform into the 90's, the business of operating a power system has become very complex and is changing rapidly. Environmental concerns are leading to emissions trading and operating constraints. Independent power producers have entered the market, creating more complex, competitive dispatch requirements. Power systems are being stressed today as never before, due to long distance transfers and the decline in new constructions of base load generation and transmission facilities. The utility needs have also changed dramatically, with the need for optimization schemes, advanced security applications and artificial intelligence. It is essential that the Telecontrol System Architecture continues to be dynamic and evolve as the needs of the utility change. A flexible architecture is a competitive advantage for a utility.

Most of today's Telecontrol System Architectures consist of a number of systems (hardware/software) which are organized in an hierarchical structure. In general, there are 3 levels:
- The substation/generating station level is equipped with microprocessor based RTU's.
- The area/region level is equipped with computer based SCADA/EMS.
- The national level is equipped with computer based EMS.

The communication between the systems of various levels has been realized via a telecommunication network based upon point-to-point connections. In more recent years Regional/National communications have made more use of bridged wide area networks.

Computer technology has changed dramatically in the last 5 years. Prices of hardware are still decreasing each year while the performance is still increasing. This is the case for both CPUs processing power and also for memory.

Recent developments such as optical storage, parallel processing etc. are available for a reasonable price. The end user will have more and more computer power at his or her desk (PC's, workstations).
In addition, in the last 5 years the computer vendors are moving to software standards especially in the areas of communications, operating systems, data bases etc. This provides the end user with the possibility to integrate various software packages from different vendors on one hardware platform.
These two trends, decreasing hardware prices and software standardization, provide the possibility of an architecture which is flexible and dynamic.

The computer industry is rapidly moving to Open System Architecture following pressure from customers in many industries wishing to protect their investment in both computer hardware and software when they want to expand or upgrade their systems. The utility industry has little choice but to follow this trend and properly managed should benefit from it.

1.2 Report Objective

The objective of this report is to discuss some of the issues surrounding a new Telecontrol System Architecture for the SCADA/EMS based upon the computer technology now available. This new Telecontrol System Architecture is called the Open System Architecture.
The Open System Architecture, described in this report, is a general architecture that will fit on the various hierarchical levels.

Open System Architecture can address utility needs more quickly, at lower cost, while providing protection of investments and flexibility for the future. After Open System Architecture Systems are installed utilities will tend to upgrade incrementally rather than completely replace their SCADA/EMS.

This report addresses the following questions:
- What is an Open System Architecture ?
- What changes in power utility industry are affecting control centre design ?
- How can an existing SCADA/EMS be upgraded to an Open System Architecture ?
- What factors are important to open SCADA/EMS designs ?

1.3 Report Scope

This report will concentrate on a new Telecontrol System Architecture for the SCADA/EMS which are used at the area or national level.

The architecture of the 70's and 80's consisted of tightly bundled proprietary hardware and software. Maintenance and expansion are very complex and very costly. Until recently, the only practical way to add several additional applications to an existing SCADA-/EMS was to install a complete new system. However, changes in computer hardware and software technologies are now making it worthwile to investigate the upgrade of an existing SCADA/EMS. The new generation of SCADA/EMS that is being designed will make upgrading even simpler. This report describes in detail the major hurdles in upgrading an existing SCADA/EMS, and outlines how the different subsystems can be upgraded with third-party products. In doing so the section clarifies the requirements of the new SCADA/-EMS that are designed for their total flexibility to upgrade.

There are many advantages to Open System Architecture but it's use also causes some concerns. This report indicates a number of concerns especially in the area of the organization serving the SCADA/EMS and also in the area of the Open System Architecture itself.

2 Traditional Telecontrol System Architecture

2.1 Introduction

The early computerized SCADA/AGC systems of the 60's made it possible to migrate many off-line analyses functions to the on-line mode. Since on-line analysis usually requires more computation in less time, the rapid growth of computer power with respect to cost has played a major role in making this possible. The on-line analysis of power system security, which required fast network solutions, became common in the 70's. Also at this time, the scheduling applications like unit commitment were made available directly to the operator so that changes in the power system could be quickly incorporated to update the commitment schedules. These enhanced systems came to be known as Energy Management Systems (EMS). In the last decade, this explosion of analysis applications has continued while, at the same time, the changes in computer hardware technology have had a profound impact on the configuration and software environment of the SCADA/EMS.

2.2 Configuration

Hardwired measurement devices and controllers disappeared when digital computers were introduced, except for a brief period when they were sometimes used for backup. These computers are connected to RTU's through communication channels:microwave links, fibre opties, power line carriers, cables .... mainly owned by the power utility.

An RTU, which today is microprocessor based, is placed at each substation and generating station to gather all the measurements and process state changes at that station and to execute the control commands sent from the SCADA/EMS at the control centre.

The control centre computer configuration is driven by the need for reliability to assure that critical applications of the SCADA/EMS are not disrupted. Reliability was usually achieved by providing a dual redundant computer configuration in which the primary computers normally carried out the applications while the secondary computers were on (hot) standby. This was achieved by checkpointing the data in the secondary whenever it was updated in the primary. A bumpless failover to the secondary was possible if the primary went down. Quite often, several computers were needed to run the control centre applications.

For example, it was common to run the SCADA-AGC applications on a real-time oriented mainframe while the network security and scheduling applications were run on a number crunching computer. Each such primary computer required a backup. A typical SCADA/EMS configuration that exists today is shown in Figure 1.

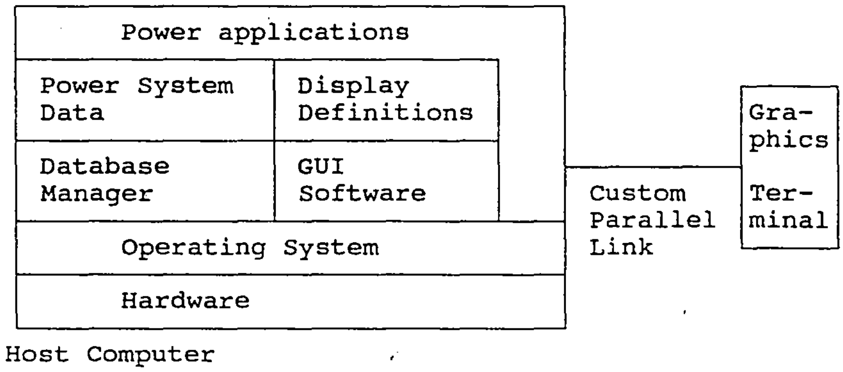

Figure 1: Typical SCADA/EMS layered software convention

The applications for power system operations, shown in Figure 1, have traditionally been very closed and proprietary. Changes in one area tend to have a ripple effect on many other parts of the system. Characteristics of the traditional Telecontrol System Architecture are as follows:

* The application software has been protected by copyright and trade secret covenants. It was exclusively available for a single SCADA/EMS vendor to distribute and add value.
* The applications ran only on expensive mainframe and minicomputer hardware.
* In some cases the applications ran on highly customized non-standard operating systems.
* The user interface hardware was expensive and highly specialized to the power utility industry. Customized interfaces to the host computers were needed.
* The user interface software was proprietary and exclusive to a single SCADA/EMS vendor.
* The data bases were proprietary, exclusive to a single SCADA/EMS vendor and used non-standard data formats.
* Upgrades and add-ons that involved significant changes to the installed system had to made by the original vendor or an inhouse team. Often, the power utility bore the full cost for such changes.
* There was no regard for use of hardware/software standards.

Most of the 70's and 80's traditional architecture consisted of tightly-bundled proprietary hardware and software. Many used proprietary operating systems, communication protocols, and user interfaces. Their proprietary nature restricted access by third parties to design software and interface specifications.

3 New Telecontrol System Architecture: Open System Architecture

3.1 Introduction

Many of the medium to large power utilities replaced their first generation SCADA/AGC systems with second generation SCADA/EMS during the 80's. During the 90's, we can expect to see continued pressure on power utilities to reduce capital and operating expenditures. As a result more and more power utilities are likely to implement incremental upgrades rather than full scale SCADA/EMS replacements. However a cost/benefit analysis between these two options is stil necessary.

The following statement from the Southern Electric System EMS specification typifies the modern requirements of utilities for Open System Architecture: "One of the most important design guidelines for achieving a flexible, long-lived system is the incorporation of products, devices and systems based upon published and industry standards and the avoidance of vendor proprietary solutions. The more widely accepted a product, device, or system is, the more opportunities exist for competitive pricing, second-sourcing, and market-driven rather than vendor driven product evolution."

This section describes how power utilities can develop an Open System Architecture for their SCADA/EMS. The section identifies barriers to openness that continue to exist today and outlines what is required to overcome those barriers.

3.2 Personal Computer Analogy

IBM-compatible personal computers provide an analogy to an Open System Architecture. Vendors are able to develop hardware that is compatible with the IBM PC and software that can run on the IBM PC for several reasons.

First, an underlying architecture is openly published, and operating system software is available at nominal cost to all suppliers.
Second, standards exist for suppliers, and a system can be assembled from standard components. In addition, the investment in software and hardware development is protected.

As a result, a large installed base of hardware exists, further encouraging the development of new products, and there are multiple sources for virtually all components and systems.

Realistically, SCADA/EMS will not approach the level of openness in the PC industry. However, valuable lessons learned in this industry can be applied to the development of an Open System Architecture for SCADA/EMS.

3.3 An Open System Architecture SCADA/EMS

An overview of an Open System Architecture for SCADA/EMS is shown in Figure 2.

The architecture divides into the following subsystems:

* Server hardware and operating system.
* Operator console/workstation hardware and operating system.
* Database manager.
* Power system data.
* User interface software (GUI software).
* Display definitions.
* Power application programs.
* Standardized communications between systems.

The target for an Open System Architecture has the following features:

* An underlying architecture wich is openly published.
* Operating system software which is available at a nominal cost to all players without discrimination.
* Standards which exist for suppliers to build components and subsystems.
* A system which can be assembled from standard components.
* Protection of the investment of users in hardware and software
* A large installed base which encourages the development of new products.
* Multiple sources for virtually all components and systems.
* Easily assembling and expanding the system.

The advantages to realizing truly Open System Architectures include:

* The utility will not be restricted in the sources that it can consider for future upgrades, enhancements and additions to its power applications programs.
* Third parties will be motivated to develop enhancements as commercial products so that the power utility will not have to cover the full costs of these enhancements.

* Hardware and software designs will become decoupled, allowing each power utility and system vendor to have the freedom to independently choose the best hardware, operating system, user interface, data base manager, and application programs. This introduce the concept of economically adding enhancements via third parties and therefore a truly competitive situation for the supply of new hardware and software.
* The power applications will be dynamic, able to change with the introduction of new technology, yet flexible in order to meet the rigorous operator requirements for an on-line real time system.

Compared to the closed proprietary solutions of the 80's, the Open System Architecture has a looser coupling between the subsystems. The subsystem interfaces are based upon published standards. Any one or several of the subsystems in Figure 2 can be upgraded or replaced at any time without a significant impact on the other subsystems. This architecture provides power utilities with the maximum amount of flexibility on how the software can be upgraded and enhanced. The reasons for selecting the standards shown in Figure 2 are described below:

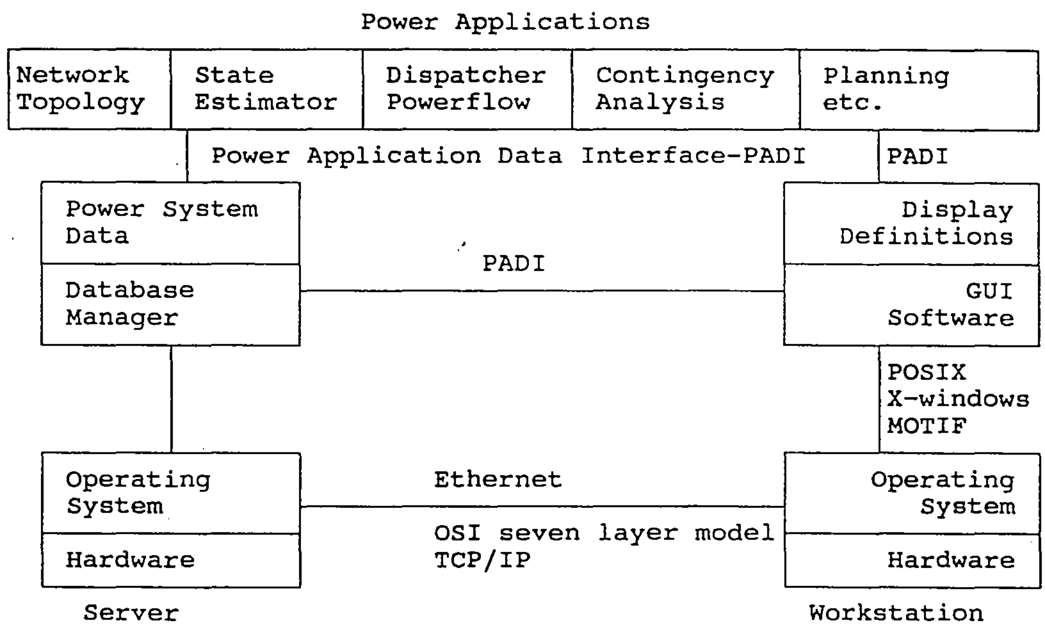

Figure 2: Open System Architecture

* POSIX stands for Portable Operating System Interface Standard. It describes how application programs interface with the operating system. It was developed as a standard by the IEEE.

By standardizing on a POSIX compliant operating system the applications will be capable of being moved from one vendors machine to another, if required, with less modification/customisation than without POSIX compliance. The performance range can vary from PC's costing several thousands of dollars to computer servers with more than 100 MIPs of power.
Some versions of UNIX are POSIXcompliant. UNIX is supported by at least four of the major SCADA/EMS vendors. The remaining vendors are expected to support this operating system. The POSIX standard therefore ensures that any application program will run on the computers that are now being delivered by all the major SCADA/EMS vendors.

* By using X Windows the power applications can use any one of numerous industry standard workstations for the graphical user interface. X Windows provides a protocol for exchanging graphics information between a network of multi-vendor workstations and servers. All major workstation vendors now support X Windows. X Windows is also supported by all the major SCADA/EMS vendors.

* MOTIF provides a standard window management environment for users to interact with the applications. MOTIF provides standards for how windows, scroll bars, menus and icons look and feel. Its appearance is very similar to Microsoft Windows. Using MOTIF helps ensure that the user interface is consistent across applications and hardware platforms. This same look and feel can apply even when different vendors provide the applications. MOTIF is available on all major brands of workstations.

* Ethernet 802.6, TCP/IP and OSI seven layer model are by far the most popular standards for interfacing workstations and servers in the SCADA/EMS environment. Most workstations include an Ethernet interface port and software as standard features. TCP/IP comes bundled with the UNIX operating system and is available on VMS systems.

Until now, the Power Application Data Interface (PADI) have been highly proprietary to the SCADA/EMS vendors. Each vendor has used non-standard data formats and unique data bases and libraries, even though they all basically represent the same power system information. Standardization of a PADI is still far away.

Another important area is the use of PC's in an Open System Architecture. It is worthwile to investigate the use of spreadsheets and other PC-functions in relation to the Open System Architecture. Aspects which should be considered are system security and transfer of data.

3.4 Barriers to an Open System Architecture

3.4.1 **Power Application Data Interface**

The POSIX, Ethernet, OSI seven layer model and MOTIF standards are general computer industry standards that are being widely specified by utilities and implemented by SCADA/EMS vendors.

However, the Power Application Data Interfaces (PADI) have been highly proprietary to the SCADA/EMS vendors. Each vendor has used non-standard data formats and unique data bases and libraries, even though they all basically represent the same power system information. Therefore it is virtually impossible to mix and match applications and support tools from different vendors. For example:

* Applications from one vendor cannot share data with applications from another vendor.

* Databases from one vendors system cannot be ported to another vendors system.

* The graphical user interface software from one vendor cannot work with the applications from another vendor.

3.4.2 **Existing Proprietary Terms and Conditions**

The SCADA/EMS vendor documentation and code are typically covered by a proprietary clause such as:

> "XYZ corporation proprietary and trade-secret information. Do not copy or disclose to third parties without written permission of an officer of XYZ corporation".

Quite commonly, the vendor-customer contract will include a clause which allows the customer to disclose proprietary information to consultants solely for the purpose of making custom software modifications. In this case the consultant must sign a non-disclosure agreement declaring that the information received will be used only for the stated purpose. Use of the information to build a product for sale to other customers would be a violation of the non-disclosure agreement. The SCADA/EMS vendor could file an injunction against the consultant if the consultant were to use the information in a way that was prohibited by the non-disclosure agreement.

This essentially prohibits any third party from developing complementary products or enhancements to the SCADA/EMS vendors application software. Although interface requirements can be disclosed by a power utility for its own benefit for the incorperation of programs developed by third parties, it is very restrictive for the general development of new applications.

Until SCADA/EMS vendors change these proprietary and trade secret terms, their systems will remain very closed at the application software level. This level is critical in that it determines the functionality seen by the user. Interfaces to databases must become standardized and they must become public information. Pressure for change to defined interface standards must come from customers, including power utilities. The application software itself should remain proprietary to protect vendors and third party's developments.

Many existing systems will be equipped with RTU's having proprietary protocols varying from simple bit serial protocols to sophisticated byte protocols. A truly Open System Architecture should be able to communicate with RTU's from a number of vendors in an identical manner. In the short term it is possible to provide protocol emulation software to interface to existing equipment but these interface designs should be conceived to provide an easy transfer to the evolving standards (e.g. IEC 870-5-X and IEC 870-6-y). Similarly new RTU's should support or be capable of upgrade to these same standards. RTU's meeting all OSI-levels of IEC 870-5 are now available on the market. Verification regarding the functionality and openness is still necessary.

3.4.3 Graphical User Interface

The widespread availability and acceptance of workstations for graphical user interface (GUI) devices has eliminated much of the special purpose equipments required in the past. X Windows can support operation of the GUI in a network environment. A user at a single workstation can window into multiple systems and applications on the network. MOTIF provides a standard for a common look and feel across applications.

Despite the use of X Windows and MOTIF, applications from different suppliers will not interface to a single GUI because of the following non-standard practices:

* Each SCADA/EMS vendor has its own data base structures. The GUI software packages offered by the vendors are most often closely coupled to these.

* Each SCADA/EMS vendor has its own full graphics display editor. The formats for defining displays are inconsistent.

* There is no easy way to export/import diagrams from one vendor's system to another.

The GUI can be functionally separated into one-line displays and into tabular displays.
The one-line displays are typically built by the power utility and are customized for each system. Several thousands of staff hours of effort may be required to build displays for all of the relevant substations and transmission lines. Power utilities want to build these displays once and do not want to build them over repeatedly as they integrate new applications on multiple platforms.
A standard set of tabular displays is provided with the application by the vendor. Few custom changes are usually made for each power utility. Most of the tabular displays tend to be used by engineers and programmers.

There are no standard display format definitions for one-line diagrams. A large system may have two thousand displays. Based upon this, it is acceptable if each application has its own closely integrated set of tabular displays. However, once the one-line diagrams are built, it should be possible to use them with multiple vendor applications across multiple servers and workstations.

One approach is to adapt a single user interface package that can run across multiple platforms. This requires that it be used by all application developers.

Another approach is to maintain the one-line diagrams in one environment and translate them to the other environments. However, such translations tend to take a long time. The need to perform local updates in the different environments often arises and the coordination of these can be difficult.

One other option is to greatly reduce the amount of effort required to maintain the one-line diagrams by automatically generating them from the data base definitions and generic rules on layout, e.g. busbars are horizontal, lines are vertical, high voltage equipment at the top, etc. In the long run, this may be the best solution for supporting multiple vendor applications across multiple vendor platforms. This will overcome the problem of verification of data and displays.

4 Criteria for evaluating an Open System Architecture

4.1 Introduction

With the Open System Architecture a wide range of configuration and upgrade options will be possible. It is anticipated that multiple sources will be available for all components in the architecture. Some of the new opportunities available will include:

* The servers computers will be selectable from any one of the vendors that support POSIX.

* The workstations will be selectable from any one of the vendors that supports POSIX, X Windows and MOTIF. Currently this includes most major vendors.

* The power application programs can be interfaced to a variety of data base packages including ones that are openly available. They need not be tied to any single SCADA/EMS vendor's proprietary data base. The PADI standard should not impose any restriction on whether the data base is relational, object oriented or flat file. It may be a hybrid system involving a relational data base for static data and flat file data base for real time dynamic data.

* The power application programs can be integrated with multiple user interface packages including ones that are openly available as commercial products. They will not be tied exclusively to any single SCADA/EMS vendors user interface package. Because the Power Application Data Interface will be openly published, SCADA/EMS vendors will be able to integrate their user interface packages with the power applications.

* The sources for the power applications can include all parties that have access to the PADI definition which will be openly published.

When a power utility implements a new SCADA/EMS with an open architecture or starts a phased upgrade project of an existing SCADA/EMS with a traditional architecture, there are key issues which we expect to address. These include:

* How can new applications be integrated so that they work smoothly with existing applications and minimize disruption to users ?
* How can the customer retain the freedom to select the best combination of hardware and software at different phases of the upgrade ?

* How can the increase in system complexity and maintenance overhead due to multi-vendor solutions be minimized ?

* How can customers protect their investments in hardware and software in the face of rapid technological changes ?

* How do we ensure that the new system can be upgraded indefinitely so that a forklift replacement is never required ?

Criteria for addressing these issues are covered in the following sections.

4.2 System Level

An Open System Architecture will have the following system level characteristics:

* Distributed configuration
  The overall configuration will be based upon a distributed computing model of Application nodes, Data Acquisition and Control (DAC) nodes and GUI workstations. These will be loosely coupled via standard and/or openly published interfaces (reference section 3.7 about standardization of PADI).

* Interoperation
  The SCADA/EMS will interoperate with other computing systems within the utility.

* Standard Operating Systems
  The EMS will build on standard, unmodified, upgradeable operating systems that comply with the POSIX standard. Users will be able to move applications to new hardware and operating system platforms.

* Standard Communication Protocols
  The major subsystems will communicate with telecommunication industry standard protocols. Interfaces between subsystems will be available to third parties.

* Flexible Database
  The database will be open, and the data dictionary will be published. The capability will exist to import/export the power system model database between vendor systems and third-party software applications.

* Standard User Interface
  The user interface will be based upon standard workstations that comply with POSIX, X Windows and Motif and the OSI seven layer model for both local and wide area communication. This will ensure that the workstation can window into multiple computers from different vendors, with the applications from different vendors having the same look and feel.

* Modular Compatible Application Software
  Application software will be modular and will be based on published data structures or data base interfaces. Third parties will be able to offer new applications that function with the existing applications.

The computer hardware and software vendors have responded to their customer demands and have done much to improve how their systems interoperate. SCADA/EMS suppliers are taking advantage of these developments and are now providing systems that are more open in the hardware, the operating systems and the communication levels. However, much more progress can still be made in areas that are specific to Energy Management Systems. These include SCADA/EMS user interfaces, databases and application software.

4.3 Hardware

During the 80's much of the EMS hardware was highly customized, especially in the areas of GUI, SCADA front ends and CPU links. Hardware was generally purchased from the SCADA/EMS supplier as a bundled part of the system. With Open System Architecture significant changes are occurring:

* Hardware is being unbundled from the system purchase. With transportable software SCADA/EMS suppliers will support multiple hardware platforms. Customers will be able to independently select the hardware platform and still receive competitive SCADA/EMS bids.

* With the use of standard computers and interfaces the need to stage the complete system at the suppliers factory early in the project is eliminated. Customers want to buy the hardware later in the project and have this directly shipped to their site. Of course, with an incremental upgrade, the system may always be on site.

  However testing at the factory (especially performance) will be needed. This will be partly possible on the supplier hardware which is compatible with the customer hardware and also partly by simulation.

* Instead of buying the hardware capacity for a ten year lifetime, utilities are recognizing that they may upgrade hardware more frequently and take advantage of on-going improvements in price and performance.

Some key questions to address the openness of the hardware are:

* What customized hardware interfaces are used ?

* Can hardware be purchased independent from the SCADA/EMS vendor ?

* Does the SCADA/EMS vendor unbundle the hardware ? Can the customer buy hardware directly from the indent computer vendor ?

* Is there a broad family of software compatible CPUs ?

* Are there multiple manufacturers of software compatible hardware?

* How to test system response and performance for some predicted load that will be handled by a future additional processor?

4.4 Operating Systems

In the traditional architectures the operating systems were often customized or had limited commercial acceptance. Because the operating systems were non-standard and were not upgraded these systems could not take advantage of new hardware. As a result of the industry's past problems with operating system obsolescence more and more power utilities are requesting compliance with the POSIX standard.

The software environment of a computer usually refers to the operating system, but in a SCADA/EMS the applications also depend on a common real time data base manager and a graphical user interface. Operating systems used to be completely dependent on the choice of hardware as each computer manufacturer had developed their own. The move now is towards a IEEE POSIX standard, quite often utilizing some version of UNIX, and so the choice of hardware is essentially independent of the operating system.

Key questions to address the openness of the operating system are:

* Is the operating system POSIX compliant ?
* Is a standard operating system used ?
* To what extent does the SCADA/EMS software use services that are specific to the computer vendor ?
* Can the operating system run on different hardware platforms ?
* What is the procedure for upgrading to new operating system releases ? What are the measures to ensure upward and forward compatibility?

4.5 Database

In the traditional architecture, the database interfaces have been highly proprietary to the SCADA/EMS vendors. Each vendor has used non-standard data formats, unique data bases and libraries, even though they all basically represent the same information.

Power utilities spend a large amount of effort assembling and maintaining the data needed for a SCADA-/EMS. In the future, in order to support centralized and non-redundant maintenance of data bases, power utilities and suppliers need to agree a common import/export format for data.
The power system models and their parameters are generally well known. Therefore there is not much cause for keeping this information proprietary.

Some level of standardization is also being forced in the area of data base managers (DBM). For example, many generic DBMs are now commercially available with various features and their interface is being standardized by using a standard query language (SQL).

Commercially available DBMs are usually too slow for the real time requirements of the control centre. Thus DBMs for SCADA/EMS are still unique to each control centre vendor.

Quite often, the maintenance of the non-real time data base can be more easily done on a commercially available relational or object-oriented DBM and so a combination of such a relational or object-oriented DBM and a special real-time DBM is used. Real-time data is also exported to the relational DBM for more general access by application programs.

Some key questions to determine if the data base is open are:

* Are the formats for importing/exporting SCADA/EMS data published ?
* Is the SCADA/EMS data dictionary published ?
* What third party database software is used ?
* Can new releases of third party database software be integrated independent of the SCADA/EMS supplier?
* Is the SCADA/EMS database software managed as a product set ? Or is it customized for each project ?
* Is the SCADA/EMS database software available for third parties ?
* What are the response times and expandability of the real-time database?

4.6 Graphical User Interface

Greater quantities of data are being made available to the dispatchers but this data is not often presented in fully integrated form. Some control centres tend to be a stack of Video Displays Units (VDUs) surrounding the dispatcher.

Three levels of GUI integration are desired across multivendor systems:
* Common GUI hardware
* Common GUI look and feel
* Common one-line display definitions

The use of workstations with X-Windows can provide a solution to stem the proliferation of dedicated terminals. From a single multi-head workstation that is connected to a LAN, the operator can window into a variety of systems including:

* The existing SCADA/EMS using character graphics emulators and gateways.
* New application processors using full graphic displays.
* PC applications using DOS emulators or co-processors.
* Pool computers using VT style terminal emulators.
* Corporate computers using terminal emulators.

It is important that the user interface is consistent across applications and hardware platforms from different vendors.
Consistency of how applications appear within the windows must be accomplished by the SCADA/EMS vendors.
Now as suppliers and customers experiment with new types of applications for full graphics there is a much greater amount of diversity. Full graphics display guidelines are needed to counteract this divergence.

There is also a need for SCADA/EMS vendors to productize and unbundle their full graphics packages so that other application developers can use them. These packages should be loosely coupled to the SCADA/EMS vendors proprietary data base through a published interface. This will provide power utilities with the ability to use a single GUI and a single set of one-line displays across multiple vendor applications.

Some key questions to evaluate the openness of the GUI are:

* Is the GUI based upon industry standard workstations ?
* Are X-Windows and MOTIF supported ?
* Are Ethernet TCP/IP or OSI standards supported ?
* Is the protocol for GUI to server communication published ?
* Are emulators available to window into the existing SCADA/EMS ?
* Can the GUI system import display definitions from multiple sources ? E.g. other SCADA/EMS vendor systems ?
* Can the GUI system export display definitions for use by other systems ?
* Is the GUI software tightly coupled to a proprietary database ?
* Can the SCADA/EMS vendor GUI package be unbundled and purchased as a separate product to support third party applications ?
* Can displays, built with the GUI package, be viewed on networks of PC's ?

4.7 Data Acquisition and Control (DAC) Subsystem

In the traditional architecture RTU's provided the only source of field data for use by the SCADA/EMS. Now there is an increasing diversity in the sources of field data which the SCADA/EMS must acquire. Examples include relay target and fault data from solid state relays, digital fault recorder data and load metering data.

In addition there is a need for field data to be communicated to more than one master station. This is especially true to support emergency backup control centres.

Ethernet is now widely used as the media for communicating between application processors and SCADA front end subsystems.

Just as the protocols of the RTU manufactures have become generally available, it would be very useful for the protocols for communicating with DAC nodes also to be standardized and published.

Some key questions to address the openness of the DAC subsystem are:

* Does it use Ethernet and a standard protocol such as TCP/IP ?
* Is the protocol for data exchange between the server and the DAC node published ?
* Can the DAC node communicate with multiple servers ?
* Can the DAC node operate over a wide area network remote to the master station ?
* Does it handle a wide range of RTU protocols ?
* Can it handle data from other sources e.g. solid state relays ?
* Does it handle the communication protocol ELCOM90 ?

4.8 Application Programs

The application software can be divided into SCADA, Generation, Network Security and Operator Training Simulator Subsystems. The data exchange between these subsystems can be defined so that it becomes possible to implement multi-vendor solutions for the different subsystems.

Ideally, power utilities would also like to mix and match individual applications within these subsystems. The main obstacle is that the internal database structures have been proprietary.

The Electric Power Research Institute (EPRI) has completed projects for Operator Training Simulator and Network Security Enhancement. These packages are based upon comprehensive power system data structures. As the number of companies utilising the data structures for these programs increase there is the possibility that these data structures will become defacto standards. Also the standardization work of IEC in the area of application programs is important.

In many systems the applications have been customized significantly and are very satisfactory from a functional viewpoint. The problem may be that the underlying hardware, operating system, database and GUI layers are obsolete. In these cases the utility needs can be best met by porting the applications to a new platform.

Some key questions to determine if the application programs are open are:

* Can the application software run on different operating systems ?
* Are there multiple sources for customized application software ?
* Are there multiple suppliers for applications that use the same GUI and database ?
* Can standard application software be integrated ?
* Is the data dictionary for the application program database published ?
* Can applications on the existing SCADA/EMS be ported and integrated with the vendor's applications on a new platform ?
* Are the applications only uses those features that are POSIX compliant or also uses special features that provide the required speed of performance ?

4.9 System Integration

More and more, power utilities are buying a SCADA/EMS with the realization that some time in the future a significant amount of new hardware and software may have to be integrated without involving the original system supplier.

A new need is arising for system integrators to take responsibility for the integration and operation of multi-vendor subsystems and their interfaces.

Some questions on the openness of the system integrator are:

* Is the system integrator willing to support a range of hardware platforms ?
* Does the system integrator have experience in implementing phased upgrade projects ?
* Does the system integrator support and warrant the system when third party components and programs are included ?
* Does the system integrator unbundle his software e.g. GUI, data base, applications, etc., and supply these as standard products for third parties to use ?
* Does the system integrator use strategic partnerships to help customers get the best solutions on the market at the best price ?
* Are necessary software tools available to add new application servers, to define the databases on these servers, and to implement the software processes to run on these servers ?
* Does the system integrator have an organization in place that supports a regular inplementation of new releases of OEM and third-party software ?
* Will supplier of any hardware or software package provide full details of all its interfaces to other subsystems ?

5 Upgrading of a SCADA/EMS

5.1 Introduction

The major impediment to upgrading existing SCADA/EMS is the design philosophy itself, which was limited by the available computer technology. Upgrading, as used in this section, means the ability to enhance the functionality by replacing portions of the SCADA/EMS by either the original vendor or with third party products. Most of the existing designs are mainframe based with a primary-backup failover system rather than a purely distributed design. The data base (DB) and graphical user interface (GUI), which constitute the operational environment, had to be specifically designed to the operating system of the mainframes used. The applications (SCADA, Generation Network Security and Operator Training Simulator Subsystems) sit on top of this hierarchy whose three other levels in descending order are DB/GUI, operating system and hardware. Upgrading the applications was always the easiest although the development environment was not particularly friendly. Upgrading the DB/GUI level is more difficult and normally not cost effective for one utility to undertake, but is now possible.

The proliferation of personal computers and workstations in the engineering workplace have brought inexpensive and user-friendly software environments with powerful DB and GUI capabilities. In addition, the capability to network computers of different kinds is now here.
Thus extra workstations can now be interconnected to an existing SCADA/EMS and new applications can be developed on these newer, more user-friendly computers. Of course, the old DB/GUI are not compatible and remapping of the data and slightly different graphics have to be accepted. It is, however, possible to upgrade at the DB/GUI level by, for example, adding a relational database that makes system data maintenance simpler while generating the same real time data base. The old GUI can also be upgraded separately by replacing the old consoles with UNIX/X workstation front-ends.

The new Open System Architecture, however, is bringing a revolutionary change at all levels. The hardware configuration is a distributed one, with increased standardization enabling the mixture of different computers. The IEEE POSIX standard is being accepted as the way to interconnect different hardware and operating systems.

Workstations with RISC processors using an UNIX type operating system are the main workhorses. The X/Open standards are becoming the main application interface with X-windows providing the main user interface usually with some program like Motif enhancing the aesthetics. The Open Systems Foundation (OSF) is trying to provide these standardized software environments and they will be adopted as quickly as they are published. The impact on upgrading of existing SCADA/EMS is obvious and dramatic since additions and modifications can then be made at all four levels.

In the next section the configuration of the existing SCADA/EMS is described and contrasted with the new Open System Architecture. In the following sections a phased upgrading of an existing SCADA/EMS to the new configuration is described. A logical sequence of upgrading the GUI, power applications, SCADA and DB is followed but these subsystems can be upgraded independently in a different sequence.

5.2 EMS configuration

5.2.1 Hardware configuration

A typical SCADA/EMS configuration that exists today is shown in Figure 3. The hardware consists of a dual redundant computer configuration (primary, secondary). The primary computer performs all the functions while the secondary is on (hot) standby.
The RTU's are connected to this configuration via special front-ends (device interfaces). Finally special front-ends were used to connect the consoles and other terminals.

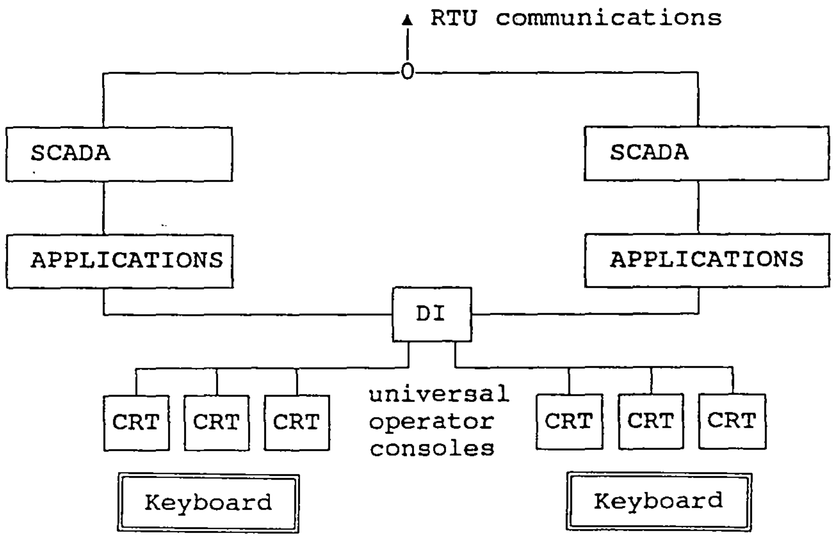

Figure 3. Traditional telecontrol architecture

As the cost-performance ratio of computers has gone down, the functions performed by the computers have mushroomed and distributed processing has become quite common. If all the computers used are the same not every one requires a backup; instead a cluster with only one or two standby computers can provide the reliability needed.

The trend today is the use of distributed processing achieved by a local area network of modern workstations with a standardized software environment (see section 3). A simple example is shown in Figure 4. Even when different computers are used the standardized concept of backup, that is copies of the updated data base and the application, are kept in more than one place so that no function can be lost because of a failure.

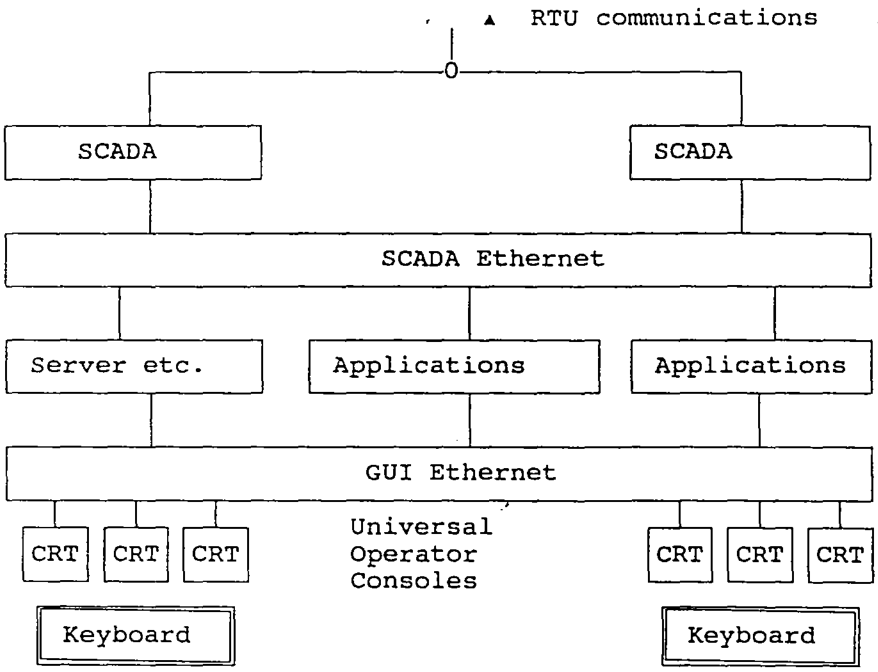

Figure 4. New telecontrol system architecture

Very high reliability can also be obtained by the use of fault tolerant computers. Such computers are appropriate for the most critical applications and could be incorporated into the distributed network configuration. This also reduces the need for proprietary checkpoint/failover software.

The move from hardwired SCADA to digital EMS also changed the user interface from meters and control panels to Video Display Units (VDUs). The better resolution VDUs of today can provide full graphics whose ultimate use is still being explored. The zooming and panning capability can provide a system map that can duplicate all the functions of the wall mapboard at the operator console.

5.2.2 Utility Information Systems

A side effect of this Open System Architecture is that the SCADA/EMS will no longer be an isolated system. The trend is towards coupling the related functions like distribution control, load management, and substation automation to the SCADA/EMS. This sort of coupling will also change the functionality of the SCADA/EMS. For example, the introduction of Substation Automation Systems (SAS) will change the classical concept of RTU's connected to the SCADA/EMS via point-to-point connections. As SAS provides local SCADA capabilities the trend will be towards "harmonization" of services provided by the SAS in the substation and the centralized SCADA/EMS. The approach would be to transport process data in object oriented data structures either spontaneously or on demand.
As some of the SCADA functionality (e.g. limit checking) is done locally, data at the SCADA/EMS could be updated at a much slower rate than today. On the other hand the amount of data that can be made available is much larger than usually collected with RTU's. Files with trend data and time stamped data can more efficiently be maintained in the SAS and be sent to the SCADA/EMS either periodically or on request.

This sort of harmonization of different control functions can be looked upon as a hierarchy of computer systems coordinating the overall control. It can also be looked upon as a network of information systems in which each system gathers a designated set of information while all can use the information as needed. This network can be more than just the sum of the different control functions. For example, all the historical data stored by the SCADA/EMS could be made available to the planning and design engineers simply by connecting the planning computer system and the design computer systems with the SCADA/EMS through some wide area network. Thus the SCADA/EMS will become a part of the utility wide information system even while retaining its special mission of real time control.

5.3 Graphical User Interface

The graphical user interface (GUI) existing system was custom built and unique to that particular vendor, the computer and its operating system, and the graphics hardware. In contrast, the new graphical user interfaces are built on X/Open standards and can run on any standard workstation.

Upgrading the man-machine interface usually implies going to this new type of GUI so that the old applications as well as any new applications can be easily interfaced to it. To accomplish this upgrade a gateway is needed from the existing computers to the new workstations that run the new GUI and serve as the graphics controllers. The old operator VDUs can then be retired. This new configuration is shown in Figure 5.

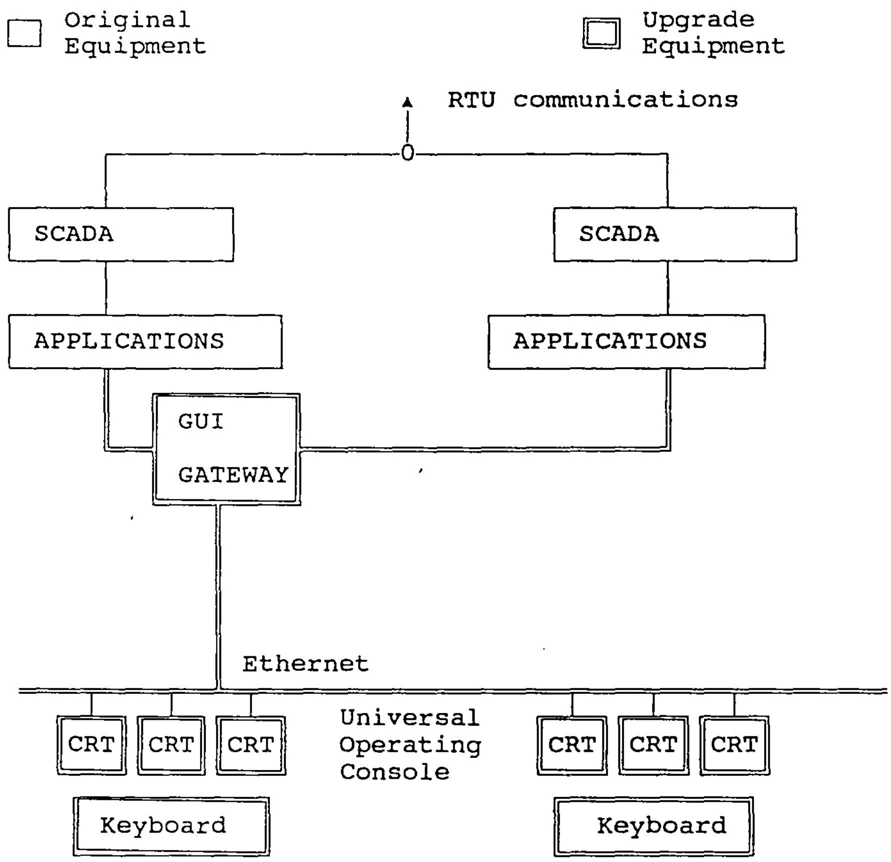

Figure 5. Upgrading GUI

5.4 Applications

The upgrading of applications can take many forms. Existing applications may be put on new hardware or replaced to obtain better performance. New applications may be added on existing or new servers to obtain expanded functionality.

Until recently, the only avenue was to modify or add applications within the existing system. This precluded the replacement by or the addition of any third party applications. This is now changing because new computers can be added by networking to the existing ones. However, if new applications on new platforms are networked with the existing system (through a database gateway), the GUI and DB for the new applications would reside on the new platforms and be different from the existing one.

Since a different GUI is usually unacceptable to the operator, it is expected that upgrading of the applications will usually follow the upgrading of the GUI. Such a new configuration is shown in Figure 6.

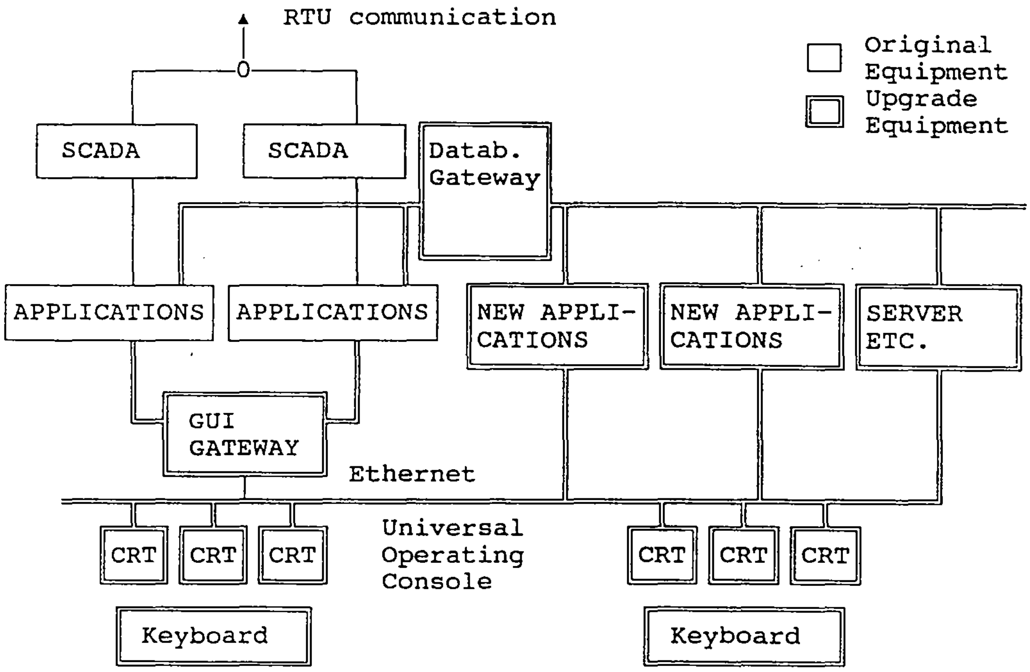

Figure 6. Upgrading GUI and Application

In this figure, it can be seen how easily the new applications can interface to the upgraded GUI through the GUI ethernet. Since the new applications are assumed to be running under X/Open standards the new GUI can directly interact with its data base, thus bypassing the old existing data base in the old hardware.

5.4.1 **SCADA**

In cases where the existing system does not have the expansion capacity for extra RTU's and/or communication channels a SCADA/EMS server node can be added to handle these. The networked SCADA server can allow other systems beside the SCADA/EMS to access the RTU's. The other systems could be a distribution management system or an alternate energy control centre. The SCADA server nodes can be used to handle communications with smart devices like that of a substation automation system.

The look-and-feel for the SCADA server can be usually made to closely mimic the GUI for the existing SCADA. As a minimum, the alarms for the two systems should be combined. In a more closely integrated system, the substation one-lines will reside within a common software package. Figure 7 shows an upgraded configuration with these new SCADA servers. It is also obvious from this figure that a complete cutover from the old system to the new system will result in a completely new Open System Architecture similar to that depicted in Figure 4.

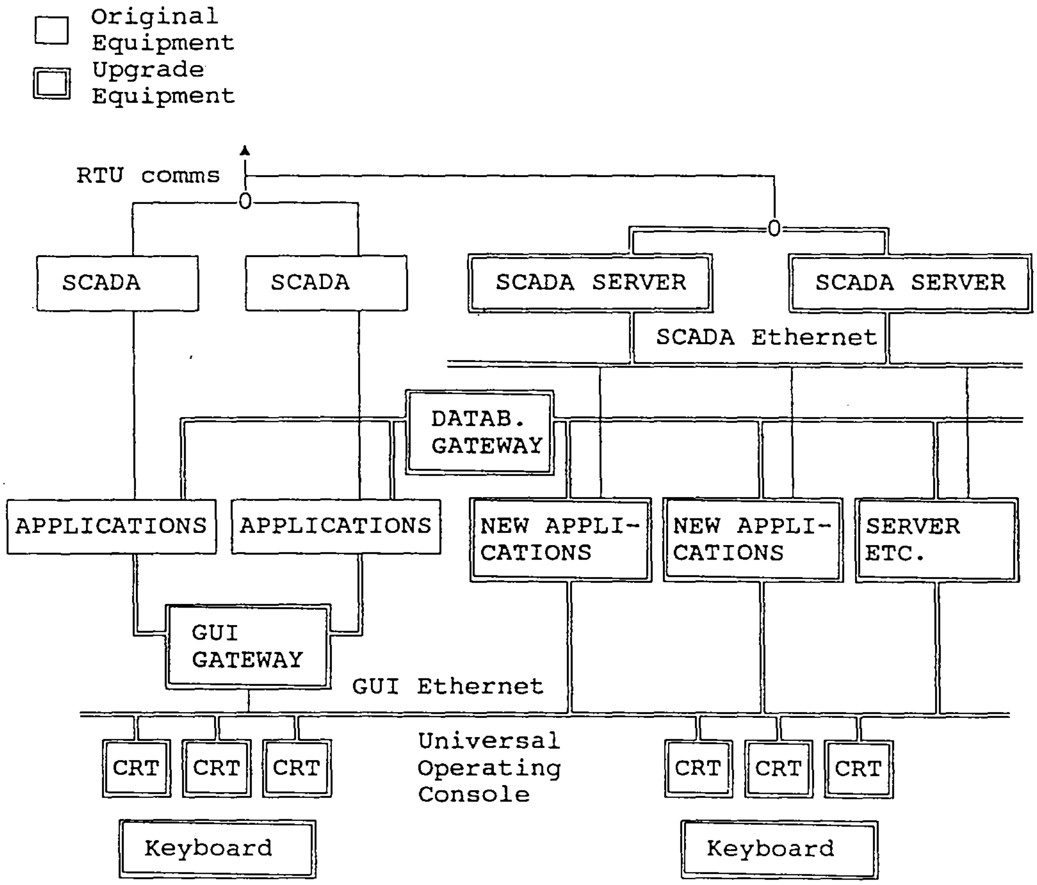

Figure 7. Upgrading GUI, Applications and SCADA

Figures 5, 6 and 7 show a sequential upgrading of GUI, applications and SCADA but these modules and the data base manager can be upgraded independently in any sequence. The point is that an evolutionary strategy can be followed to achieve an Open System Architecture and a complete turnkey replacement is no longer the only alternative.

5.4.2 **Data Base Management**

In existing SCADA/EMS, the data base manager (DBM) is usually proprietary to the SCADA/EMS vendor and the data base structure was designed for the speed required in such real time control environments. In the new systems, the DBM is usually a third party relational data base manager (RDBM). The data is classified in an object oriented way and most of it is stored in a relational structure. Access to data is through Standardized Query Language (SQL). However, this access is slow and, at this time, the real time portion of the data base is structured and accessed the old way, but is created by the RDBM.

The RDBM is very effectively used in two areas: data base maintenance and historical information management. Database maintenance is one of the most labour intensive and error prone tasks. Standard tools can be used for data entry, data validation and report generation. An SQL interface is used to populate (update) the real-time data base. Historical information management capability provides collection (SQL interface), processing, presentation and reporting of SCADA/EMS information recorded over periods of time. This information is available for operations personnel as well as, through wide area networks, other utility personnel outside the control room.

The main motivation to update the data base manager in an existing system is to make data maintenance more efficient. Of course, the addition of new applications would also be helped if the upgraded database could handle them.
Given that the existing real time data base structure and access is critical to the performance of the existing system, it is best to leave that in place. However, the data entry, data validation, and population of the existing data base can be shifted to a third party RDBM. Such an RDBM would simplify the data maintenance function by utilizing the relational structure (although it would not be object oriented). Moreover, the RDBM can be used to create any new data structures needed for any additional functions.

Databases for an Open System Architecture are only partially standardized. The allocation of the real-time part of the database in relation to the update possibilities and the transparency to the applications differ from vendor to vendor. Based upon the concept of an Open System Architecture the RDBM could be a problem.

5.5 Procurements

The implementation of an Open System Architecture upgrade requires a departure from the traditional approach used by utilities to procure SCADA/EMS projects. There is no place for the traditional specifications document which addresses the replacement of a system. An open system procurement model would state the rules by which the power utility, the main or primary vendor, the consultant and third party suppliers would operate and price their services and/or products. At this time, it is utopian to believe that at each step of the evolutionary process different SCADA/EMS vendors and third party suppliers will participate. For the foreseeable future, power utilities will migrate their systems with the main players defined.

Special purpose or custom gateways to existing closed systems are used to interface to the Open System Architecture. Efforts must be made in the design of the evolutionary process to ensure that this migration is largely transparent to operators.
The implementation of a universal GUI which enables a single operator station to display information from all deployed systems becomes an essential requirement.

An evolutionary upgrade implies that the system is never at a SCADA/EMS vendor factory, but only at the power utility control centre. This can be put to good advantage by prototyping new developments and testing them in a live environment, thus obtaining operator feedback at early stages of the process. The power utility is an active participant in this continuous development under an open systems evolution, which is a radical departure from the traditional practice whereby the power utility is largely in a project management role until the replacement arrives, is installed, tested and then handed over. This new approach is nowadays possible. However the cost/benefit analysis will be different for each power utility.

6 Concerns with Open System Architecture

6.1 Introduction

The computer industry is rapidly moving to Open System Architecture and the power utility industry has little choice but to follow.

There are many advantages to Open System Architecture but their use also causes some concerns. The advantages far outweigh the disadvantages but the concerns need to be addressed.

6.2 Organization

Changes may need to be made to the present organizations serving the Energy Management Systems.

The standards that are being implemented on Open System Architecture are evolving rapidly. It is by no means certain that the standards in use today will be those of choice in even the near future. There will be a need to have people on staff or have a close relationship with consultants who understand these standards and can choose, or move to the optimum one for that particular power utility.

There will need to be a very tight ongoing relationship between the power utility, standard making bodies, hardware and software manufacturers and the vendors who integrate these hardware and software components along with their own software into an Energy Management System.

Since these standards are now being implemented on an international level, participation and awareness must be at the international level. Initially, this will probably need to be through international standardization bodies like ISO and IEC and also through other international organizations like CIGRE, IEEE, OSI and IEC. Users groups could be formed to serve as the focus for these activities.

The power utility organization will need to be staffed adequately to manage hardware and software revisions down to the release and version level. It will be mandatory that all changes are made and kept current because all new hardware and software that may be added will be based on the latest standard. This is a radical departure from the previous closed system architecture where the systems were usually frozen at the time of factory acceptance testing.

The SCADA/EMS systems offered today are partly based on proprietary products. Examples of proprietary products are: the real-time database, the communication protocol between DAC servers and application servers, etc. Therefore a long term relationship with the EMS vendor will be necessary and advantageous. This means that servers and software can be added when required and proprietary products can be replaced by standard products when available and required.

There was little need to incur the expense and risk of installing each new release and version because the original SCADA/EMS vendor supported all releases and the original application software worked on the orginal operating system software that came with the system.

This will make a big impact on the power utility support staff size and the way they operate. Installing the revisions will not be an option. In some cases, the software vendors only support the latest two or three releases of the software. The power utility must either size their staff to do it or issue maintenance contracts to make certain that it is done.

With Open System Architecture, in-house development of software will be restricted to application level software. The base software will either be a commercially available package or one that is closely coupled to a software standard and updated frequently.

One of the problems associated with having to upgrade and use the latest release or version of the software is that other software developers may be required to use the new release before it is stable. This causes support problems and delay in finding problems because it is difficult to determine which level of software is causing the problem. It may also cause a lenghtly down time (possibly hours) to down load all of the software to all of the servers - especially remote servers and GUIs.

Moving from the very closed systems is challenging and generally requires significant cost and effort. Furthermore, the cost and level of expertise required to maintain Open System Architecture is perhaps ten times that of traditional SCADA/EMS, according to one SCADA/EMS vendor who has looked extensively at the standards and the issues. In a rapidly changing power utility industry the benefits related to inter operability, flexibility etc. outweight the disadvantages of the cost and effort.

It will be necessary to have people available who understand each of the software standards and the way the applications link to those standards. A great debate will be whether to have these people on staff or whether to have a service contract or contracts to perform these services.

The issues of number of staff persons, training, promotion potential, and availability of in-house people versus reliability, cost and availability of contract services will be the subject of many studies. Hardware maintenance will be completely different from the past because of very large scale integration. Board swapping and exchange will be more common.

The commercially available standard software packages are more costly to place in an energy management system than vendor internally developed packages. When procuring a new SCADA/EMS, a careful analysis needs to be made to rationalize the lower initial cost of a vendor internally developed package over the long term cost or savings of using industry standard software packages. However the cost of standards will be lower over the longterm because, as standards are used by more and more customers, the cost of development to the vendor can be spread over the larger volume of sales.

Wide Area Network, Local Area Networks and Open System Architecture in use in both Energy Management and Electronic Data Processing computer systems will make it technically easy to connect and/or merge the two systems. Security of information and organizational considerations will determine whether and/or how these connections will be made and how information will be shared. Task Forces in both IEEE and CIGRE are beginning to discuss these issues.

6.3 Architecture

The first Open System Architectures differ from vendor to vendor in the way they have implemented their concept of open systems. Some of the issues that need to be examined in selecting a system are listed below.

Open System Architectures were not designed specifically for mission critical systems. Today, some of the systems are not very fault tolerant. These systems must be examined and the issues addressed. Some power utilities are even considering purchasing a back up control centre with a completely different platform to get away from the problem of common failures - even though this means more complex training and spare parts problems.

The distributed data base will need to be maintained and it is critical to examine the technique. Can it be done in one location and down loaded across the system - even to remote locations - or will it have to be updated in each unit. Data security issues must be considered when the data base is down loaded over communication channels.

Several concepts are emerging on configuration management. These should be examined to see if they meet the power utilities operating requirements and how these may work with future software standards.

There is a need to examine the tools needed to maintain the hardware and software. Careful consideration must also be given to the tools available to test and monitor the system for a variety of performance conditions.
Data security is a very important issue that needs to be addressed. The use of standard protocols, hierarchical systems, Local Area Networks, Wide Area Network, remote workstations, remote PC's, distributed data bases, and interconnection with power plants and Electronic Data Processing department computers have increased the chances to compromise the data. There is a critical need to examine the data security techniques proposed by each vendor for each of the above operating conditions.

7 Summary

The availability of standards are the critical success factor for an Open System Architecture

An Open System Architecture depends upon having the standards inplace so developers can build products that inter-operate (work together).

The key to inter-operation for electric power applications is:
* A standard power application data interface
* A standard graphical user interface.

With this approach, virtually all of the Open System barriers that were described can be removed. Power utilities, as buyers of software and services, can require in their specifications that the vendors be compliant with a standard power application data interface and a standard graphical user interface.

EPRI may also have a role in supporting a standard power application data interface. The Power System Planning and Operations Program of the Electrical Systems Division is working with a focus group to investigate the problem. The group is evaluating the feasibility of using the EPRI Operator Training Simulator databases as a framework upon which to build guidelines for a standard power application data interface.

With a SCADA/EMS based upon the Open System Architecture upgrading of the System will be an ongoing activity with the opportunity to protect the investment in both computer hardware and software.

During the late 80's, open systems have had a major impact on the computer industry. During the 90's, we expect to see their effects have a marked impact on the SCADA/EMS industry.

The most profound effect of open systems will be that power utilities will implement phased upgrade projects instead of complete system replacements. The trend for this is well underway. In 1990, there were more than 35 active SCADA/EMS upgrade projects in the U.S. and Canada.

When purchasing an entire SCADA/EMS from one vendor, customers should specify and manage the project to retain the option for multi-vendor support after delivery. When upgrading an existing system, customers should purchase off-the-shelf products that meet the open systems criteria. Customers should require the suppliers to disclose interfaces, but not the internals, of software subsystems.

The industry will benefit from user participation in defining functional requirements for necessary standards. Bodies such as the IEEE, OSI and IEC are likely to contribute to the formation of such standards via a consensus building process. However, defacto standards are likely to occur as a result of one or more vendors deciding that it is strategically important to have their technology used widely in the marketplace and making it openly available.

As the hardware continues to improve rapidly, the ability to take advantage of this will be constrained by the availability of software. The major benefit of open systems is that they provide the power industry with the opportunity to minimize redundant and labour intensive software efforts and to achieve a quantum improvement in overall effectiveness.

The Open System Architecture needs another approach from the power utility organization servicing the SCADA/EMS.

It will be necessary to constantly update the EMS with the latest releases and versions of system and base application software as they are made available by the vendors.
This will be necessary so that new applications, designed on the new releases, will work when installed. In addition, some vendors only support the previous two releases of software. Servicing of SCADA/EMS by the power utility itself, larger and more sophisticated maintenance staff will be required than with the older systems. One EMS vendor who has studied the standards and the issues, stated that the cost and level of sophistication could be ten times that of the traditional SCADA systems.

While the computer industry is rapidly moving to Open System Architecture and the power utility industry has little choice but to follow, strong words of caution need to be given.

Open System Architecture rely heavily on hardware and software standards. System level software standards are evolving and are becoming available but there is not a perfect set of standards for SCADA/EMS at this time. In addition, application level standards and graphical display standards are just beginning to be defined. All of these factors will complicate the future upgradability and interoperability of the EMS until designs stabilize.

In most cases an evolutionary upgrading of the existing SCADA/EMS is now feasible at reasonable cost.

Finally this report explores the gap between the existing Telecontrol System Architecture and the telecontrol architecture which is an open architecture with distributed functions. Many of the existing SCADA/EMS are too new to justify replacement and will have to serve their operators for many years.
However, the technology of the new SCADA/EMS designs itself suggests that an evolutionary upgrading of the existing SCADA/EMS is feasible at reasonable cost.

The present SCADA/EMS configurations are first compared to the new designs. Then, the report shows how the GUI, applications, SCADA and data base management can be upgraded in phases. If all of these upgrades are done the transition from the old system to the new open design is complete.

The basis for this upgrading is the capability to network various hardware platforms through standard networking protocols and operating systems. This allows the swapping of the old GUI with X/Open based GUI and the addition of an RDBM to maintain data. The addition of new applications on new servers, and the cutover to new SCADA servers completes the transition.

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9 ACKNOWLEDGEMENT

The computer industry is rapidly moving to open architecture systems and the utility industry has little choice but to go along. There is a need to get information on the concepts of open architecture systems to CIGRE members as quickly as possible.

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10 ABBREVIATIONS LIST

AGC	:	Automatic Generation Control
AT&T	:	Company which developed UNIX
CPU	:	Central Processing Unit
DAC	:	Data Acquisition and Control
DB	:	Database
DBM	:	Data Base Manager
DEC	:	Computer Company
DI	:	Device Interface
EMS	:	Energy Management System
EPRI	:	Electric Power Research Institute
GUI	:	Graphical User Interface
HP	:	Computer Company
IBM	:	Computer Company
IEEE	:	Institute of Electrical and Electronic Engineers
OSI	:	International Organization for standardization
LAN	:	Local Area Network
MIPS	:	Millions of instructions per second (unit for computing power)
MOTIF	:	Standard window management environment for users to interact with applications
NOVELL	:	Name of a Local Area Network
OOP	:	Object Oriented Programming
OSF	:	Open Systems Foundation
PADI	:	Power Application Data Interface
PC	:	Personal Computer
POSIX	:	Portable Operating System Interface Standard
RDBM	:	Relational Data Base Manager
RISC	:	Reduced Instruction Set for Computing
RTU	:	Remote Terminal Unit
SAS	:	Substation Automation Systems
SCADA	:	Supervisory Control and Data Acquisition
SUN	:	Computer Company
SQL	:	Standard Query Language
TCP/IP	:	Transmission Control Protocol/Internet Protocol
UNIX	:	Standard operating system for Open Systems
VAX	:	Computer type from DEC
VDU	:	Visual Display Unit
VMS	:	Virtual Management System
X-WINDOWS	:	Computer supplier group, working with specifications for presentation of information

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