Substation Management for Distribution Utilities

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Introduction

This paper presents a number of case studies dealing with the implementation of Substation Management in three utilities, each with differing strategies and levels of development for control and communications. A view is presented that Substation Management can play a strategic role in integrating and managing distribution assets within a multi-vendor environment.

The three utilities have widely varying requirements and control strategies, but share a common goal of many utilities today i.e to provide a multi-vendor *open* control infrastructure, where industry and *de jure* standards provide a common platform for integrating the utility's different levels of information management.

A specific focus on Substation Management describes how the goals of the three utilities were achieved in this area.

Utility Background

Utility 1.

Utility 1 is a large, mainly urban distribution authority experiencing strong growth in demand and customer numbers. During the early 1980s, the utility was being placed under ever increasing pressure to improve its performance due to higher expectations, tighter budgets and limitations on tariffs. Goals were set in place to improve efficiency and reduce operating costs.

One way to achieve both targets was to “push the system harder”, and SCADA was seen as a possible tool in the quest.

At that time, most SCADA systems were comprised of a large central Master station in a control centre, communicating with low-intelligence remote telemetry units (RTUs) at the substation. The utility faced a major barrier in that this scheme required a major outlay of capital in computing equipment and RTUs at one time, and was deemed to be unacceptable. Furthermore, the use of unintelligent RTUs was seen as a major waste of equipment, since much could be achieved using localised control of the substation.

The utility decided upon a strategy of installing intelligent control units within each substation that could operate with the need for a master station, and could provide control and monitoring of functions normally performed by relays or Programmable Logic Controllers (PLCs). These units could be installed and once a suitable number of systems were in place, the master station could be deployed with immediate operating benefits.

Utility 2

Utility 2 is a generation and transmission authority that is undergoing restructuring in various ways, such as transfer of some assets to other authorities, and transfer of control for other assets between departments.

The utility has a master station already installed, but is experiencing limitations due to database restrictions and performance problems. The utility had the requirement to provide different control interfaces to different groups with the utility, such as allowing a switchyard substation to contain a local operator interface for field staff, but to also provide a separate interface to a power generation operator, with tailoring of the interface to each different group.

The utility has a number of substation management systems installed, and therefore had some experience and expectation of the different generations of equipment available. A key goal was to provide seamless integration of the substation management with the existing control infrastructure.

Future plans include eventual decommissioning of the existing master station and installation of a new latest generation master station. Any substation management system would have to take this into account in providing a flexible and open communications strategy so that much closer integration between the master station and substation management could be achieved.

Utility 3

Utility three in this case study was a semi-rural authority that was desiring to automate larger substations in an effort to improve efficiency and reduce operating costs. An existing master station is in place, and one option for the authority was to attempt to install substation management systems and integrate the system with the existing master station. Another option was to parallel the existing master station with a smaller master station dedicated to those substations with substation management, and eventually extend the newer master station to subsume the functions of the older master station.

Cost was a key factor, so that the system could be installed with full functionality at the substation management level, but that the large cost of a fully functional master station could be deferred.

Substation management was also seen as a way of providing automation within the substation, so that better use could be made of the distribution network.

Common Goals

Even though the three utilities were quite different in terms of size and requirements, some common goals emerged such as a desire to use Substation Management not only to provide some intelligence at the substation for replacing existing older facilities, but as a major section of an integrated control and monitoring strategy. This strategy encompassed distribution automation, enterprise-wide communications facilities to allow sharing of data and resources, customer load management etc.

To this end, it was clear that a substation management system that could meet these expectations successfully should have a number of key attributes and goals, such as:

- Reliability, considered both in terms of the inherent nature of the architecture (i.e distributed, redundant, duplicated, no single point of failure etc.), and of the known track record of the particular implementation of the architecture.
- Cost effectiveness, so that deployment of Substation Management can take place at all levels of the distribution network.
- Flexible communications, so that the Substation Management system can interoperate with a wide range of other items or systems, such as intelligent plant equipment, remote field devices (sectionalisers, reclosers etc.), other substations, different vendor RTUs and master stations etc.
- Scalable, so that large substations, or clusters or substations in a localised area (such as a central business district) can be managed as easily as a distribution substation.
- Extendable application foundation, so that the user could develop new algorithms or applications as required.
- Highly configurable, so that the user can tailor the Substation Management system to their own local situation, and also adapt the system to a wide range of operational conditions and requirements.
- Easily maintained, so that as plant equipment is changed or upgraded, the Substation Management system can be readily reconfigured to reflect the changes.
- Easily installed; since a substantial cost of Substation Management is the physical marshalling of cabling, providing a method of easy installation can reduce significantly the cost (and man hours) involved in the installation of the Substation Management system.
- Integration with an enterprise wide Information Technology strategy, that may involve GIS, AM/FM, SCADA, Energy Management etc.

Architecture of a Substation Management System

Megadata's approach to providing a open solution for substation management that would meet the diverse needs of the various utilities focussed on three key elements of the Substation Management system.

Hardware Architecture

Figure1 shows a typical substation management system. A central unit (which may be duplicated) performs the bulk of the processing, and Distributed Intelligence Units (DIUs) perform local data acquisition and Local Control Routines.

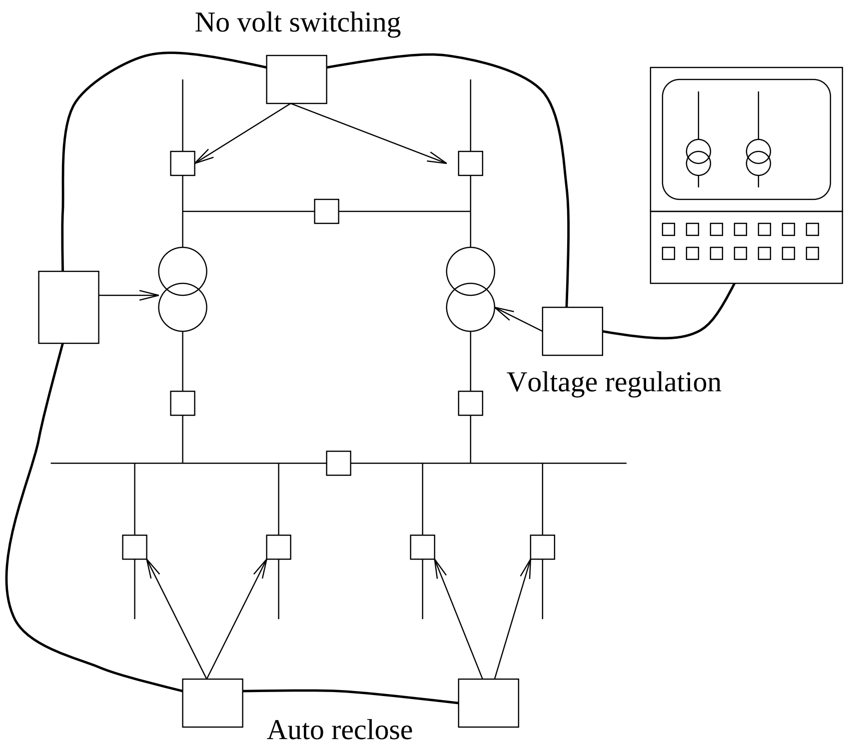

FIGURE 1. **Distributed Substation Management System**

Each node is a full peer on the network, and the database is truly distributed; nodes can access peer data across the network, and interact with other nodes, without requiring the services of a centralised unit.

The fully distributed nature of this architecture allows the system to be reliable in the face of node failure, and also to scale to different sizes of installation easily. Plant upgrades are easy, since the telemetry and control can be placed physically close to the equipment. The MMI is typically another node on the LAN, but with extra database and facilities for displaying mimic diagrams.

In terms of functionality and reliability, this architecture is the most cost effective, since a high degree of control may be obtained, there is no single point of failure, and the user has the advantages of the distributed telemetry (i.e no central marshalling of cabling).

Since the cost of an intelligent controller is not orders of magnitude more than a dumb acquisition node (mainly due to the decreasing cost of electronic hardware), and the capability of these units is becoming increasingly sophisticated, placing localised processing on these nodes is becoming common. This trend is continuing, even getting to the point where plant equipment suppliers will be placing controllers with standard interfaces into their equipment, allowing direct interconnection with the Substation Management system.

Software Architecture

Rather than deliver a *fait accompli* of Substation Management applications, Megadata chose to develop an application framework centering around some key elements that allowed the customer to develop their own sophisticated applications. These key elements are:

- **Distributed Object Database.**

  Sophisticated applications by their nature deal with complex data models, and any Substation Management system allowing these applications to operate must have as a foundation a database subsystem that allows these complex models to be developed, built, and distributed throughout the Substation Management system. Rather than attempting to describe the telemetered data in a fixed and flat database schema using simple analogue or digital points, Megadata's SMS database uses an object orientated approach, where each plant equipment type can be represented as a different class, and each instance of a class (termed an object) can represent a real world object such as a circuit breaker, transformer etc.

  These database objects can be connected together into a hierarchy that describes the relationship of each object to others (such as high voltage CB connected to a particular transformer). This allows the user to build and configure the Substation Management using familiar types of data, rather than attempting to relate these real world objects to some fixed representation using digital and analogue data.

  These hierarchies of data objects can be distributed to different nodes upon the network, and application programs are written that can access the objects transparently across the network e.g. if one node wishes to determine the state of a particular transformer (which is being telemetered via a different node), the client node will automatically discover the node 'owning' the transformer and access the data in the transformer object directly. At no time does the client node need to look at any of the underlying data structure of the transformer object such as the raw telemetry points, CB statuses etc., it can just access the transformer record which contains the processed data for that transformer object.

  New classes and objects are easily created, configured and downloaded to the Substation Management system as new applications are developed that require more sophisticated data manipulation. Substation Management schemes that do not provide this level of object orientated database processing and distribution will not be a good foundation for the development of future applications.

- **Open Communications.**

  From the experience of installing Substation Management into three different utilities, it was clear that a flexible networking and communications architecture was required to meet the needs of the future. Such requirements were seen such as interconnection of remote Distributed Intelligence Units (DIUs) using serial lines, Ethernet, 802.4 Token Bus operating over twisted pair or carrier band, connection of distribution reclosers etc. Future communication options included substation-to-substation interconnection using ISDN, switched telephone network dial up for remote MMI and download, and interconnection with off-the-shelf communication products such as routers, terminal servers etc.

  To provide for such a sophisticated range of communication options, and yet not to develop a proprietary solution, an open communications standard was required.

  The Internet Protocol suite (TCP/IP) is used as the main communications networking protocol with SMS, and has proved to be a major factor in the flexibility of the communications options available. Industry standard protocols such as SNMP, TELNET, TFTP, the X Window system etc. are all available for use.

  Interoperability is becoming important in all levels of the control infrastructure, so that the Substation Management can be an integral part of the enterprise wide communications system. The use of proprietary protocols is a major drawback to any substation management system, as it locks the user out of many choices of equipment and services, and should be avoided if possible.

- **Local Control Routines.**

  Customers wishing to develop sophisticated applications need to be able to develop, test and install LCRs easily in an Substation Management system. The LCR subsystem must be robust, and integrated with the rest of the distributed object database. The LCRs must also be highly configurable and allow complex data manipulation to be performed. PLC or ladder logic style control routines were found to be too low level and cumbersome to allow complex applications such as were being developed by the utilities. The LCRs must also be parameter driven, so that only one master copy of the LCR is maintained and downloaded, but that many instances of the LCR can run, each with different parameters.

  Early versions of LCRs used the C programming language, but C is not a robust language in this environment, and the learning curve for C is quite high for most control engineers. Debugging compiled languages in the substation environment is also problematical.

  The use of Megadata’s Sequential Control Language (SCL) allows engineers to develop a customized LCRs quickly and with confidence. SCL was found to be much more robust and easy to debug than C LCRs; control algorithms expressed in SCL tend to be much shorter and easier to maintain and read than ladder logic or C.

  The control language is also extendable so that new unthought of applications can be accommodated as and when they are developed.

The overall approach for Megadata’s SMS has been to deliver a system that allows the customer to reach the full potential for Substation Management, without the customer having to deal with limited application support.

Examples of such applications are customer load control handling, where a DIU directly interfaces to frequency injection equipment, and the load control is thus made part of the overall Substation Management system.

Results

Megadata Substation Management systems have been (or are being) installed in all three utility's substations. Utility 1 has some 70 distribution and transmission substations being controlled. Utility 2 is in the process of installing a number of substation management systems into transmission substations, and Utility 3 is also installing substation management in 10 substations, as well as smaller telemetry units in a much larger range of sites.

Each utility has benefitted from Substation Management in concrete ways, such as reducing operating costs, obtaining better information for controlling the network, and running the network at a more optimal level.

One example of a Substation Management application is being operated by Utility 1, which has a number of zone substations in a central business district; due to the high density of the area, it is nearly impossible to expand the system by adding new substations, or even sub-transmission feeders. One way to reduce the necessity to increase the plant in such an area is to make greater use of reserve equipment at any one location e.g to share a standby transformer between two or even three zones.

The Substation Management Systems within this area are all interconnected via a Wide Area Network, and in the event of a failure of one piece of plant, the network is reorganised so that the load may be picked up by the remaining system.

This method of network reorganisation may also be used to defer the installation of reserve equipment when catering for increased load, thus saving considerable capital outlay.

Substation Management systems are also being used as the gateway to Distribution Automation, where a number of utilities are using Substation Management Systems as masters for a large number of reclosers and sectionalisers. This allows DA to be introduced at a lower level, and provides for a much cheaper form of deployment, without affecting existing master station conditions.

The cost of Substation Management is considerably lower than replacement of existing master station facilities. Utility 2 is experiencing immediate cost/benefits as a result of installing Substation Management, since the Substation Management System can act as a RTU to the existing master station (thereby avoiding the need for a new master station or a protocol converter). Moreover, since the Substation Management system has powerful communications and networking functionality, full remote operation of the Substation Management system may be achieved via a dial up modem; complete MMI and operator interface functions can be achieved remotely, as well as remote login, database examination, history data upload, and new database downloading.

Utility 3 has deferred the cost of a new master station by incorporating Substation Management as a separate control and telemetry system; this allows expansion of the system, and also provides for future replacement of the existing master station in a painless process via a smooth upgrade path.

All three utilities are continuing to explore new applications through Substation Management. It is expected that as new technology is brought to market, the existing system will allow these new technologies to be incorporated seamlessly into the existing control architecture, thus preserving the training, equipment and procedures. This contrasts to other, more proprietary, systems, where the only approach to system expansion or integration is complete replacement.

Conclusion.

Substation Management is increasingly important in today's world, especially as authorities are being asked to provide a reliable and efficient supply of electricity, often with dwindling resources. Nowhere is this more evident than in the particular climatic and geographic situations that Australian authorities endure. Substation Management is a major tool for these authorities to survive into the next millennium.

Utilities are increasingly becoming aware of the cost and value of information, and how important it is to provide a stable and open infrastructure for evolution of their information processing, rather than wholesale replacement of control systems, master stations etc. One key to this evolution is the use of Substation Management as a central data collection and processing point, and it is vital that Substation Management is seen as a strategic benefit to allow utilities to cost-effectively manage this evolution.