Using Dynamic Real-Time Substation Information to Reinvent Asset Management

David J. Dolezilek
Schweitzer Engineering Laboratories, Inc.

Lee Margaret Ayers
OSI Software, Inc.

Presented at the
18th International Conference and Exhibition on Electricity Distribution
Turin, Italy
June 6–9, 2005

Previously presented at the
IEEE/PES Transmission and Distribution Conference and Exposition, October 2001

Previously published in the
proceedings of the IEEE PES Summer Meeting, July 2001

Originally presented at the
3rd Annual Western Power Delivery Automation Conference, April 2001

USING DYNAMIC REAL-TIME SUBSTATION INFORMATION TO REINVENT ASSET MANAGEMENT

David J. Dolezilek
Schweitzer Engineering Laboratories, Inc.
Pullman, WA USA

Lee Margaret Ayers
OSI Software, Inc.
Issaquah, WA USA

ABSTRACT

Existing applications do not satisfy Asset Management. Geospatial Information Systems (GIS), in part, perform static inventory management of power delivery assets, i.e., location of the asset and nameplate data but not dynamic performance or availability. Maintenance Management systems retain the history of maintenance tasks performed on equipment and predict when new tasks should be performed but do not understand return on investment (ROI) to plan replacement. Work Management Systems help schedule resources to perform maintenance, replacement, or operational tasks only after they have been identified elsewhere. So in essence, true Asset Management is overlooked. The success of these applications should rely heavily on timely and accurate data. Real-time and historical operating data are essential for identifying and improving dynamic performance optimization, for outage management and avoidance, and for planning obsolescence and expansion. This paper addresses overlooked asset management needs of determining and improving the health, reliability, ROI, and performance of apparatus and systems, and hopes to provide a better understanding of how to consider benefits or losses the utility experiences.

INTRODUCTION

The business of electric power delivery has changed. Utilities need to remain lean and profitable while pushing equipment to its limits. This is the new model. In a deregulated environment, the traditional model for equipment maintenance is emphasized and the obvious drawbacks in what the industry loosely refers to as Asset Management become apparent. According to studies done by the Edison Electric Institute (EEI), deregulation (in all industries) also fosters newer technologies that, in many instances, make the replacement of older equipment a profitable choice [1]. Economic opportunities will not be realized without innovative concepts for understanding assets or innovative technology to support automation.

The purpose of this paper is to review the misuse of the term Asset Management, define a new way to think about the problem, and present an architecture that will support a solution. At the very least, Asset Management should encompass and consider the following areas:

- Utilities now recognize that the power system and Instrument & Control (I&C) system assets, such as cables, transformers, breakers, and control systems require more visibility. These assets need to be instrumented, monitored, maintained, and eventually replaced. They need to be managed both physically and fiscally.
- Construction and instrumentation projects for new and existing assets need to provide a measurable return on investment (ROI). Historically, there has been no data to prove projected benefits. In the future, projects will be evaluated on the true value they provide. Each successful project must improve the bottom line with a positive ROI. Soft benefits, such as higher reliability and improved performance, must be assigned a dollar value.

Evaluation will include life cycle cost of the asset, management of the asset, and analysis of the derived value over time.

- Integrated collection, analysis and communication of Asset Management data maximizes power system availability, reduces the quantity and duration of customer outages, reduces maintenance costs, enhances power system performance, optimizes maintenance tasks, and extends the life of power system equipment. In many instances, these data are already measured or stored for other purposes and can simply be reused.

- Access to the real-time and historical data from I&C Systems cannot be overemphasized. Without data, evaluation and optimization of equipment can only remain an educated guess and inaccurate numbers will continue to obscure the bottom line.

WHAT ASSET MANAGEMENT IS NOT

Before we can reinvent Asset Management, we must first review technologies that purport to provide this function. Many applications model portions of the asset, but this is not true management of the asset. Following is a list of applications and a description of their association to Asset Management:

- Maintenance Management Systems (MMS)–Currently, the MMS comes closest to asset management capabilities. Utilities expect to use MMS, if linked with reliability-centered maintenance (RCM) algorithms or applications, to move from reactive to preventive maintenance. The few MMSs with RCM capability may predict when a particular piece of equipment should be maintained, but they do not determine the health of the asset. The unavailable health data is necessary to prioritize work that the MMS schedules for multiple apparatus.

- Work Management Systems (WMS)–The WMS is basically designed to automate a form-intensive process for scheduling and managing work. Through WMS automation, facilities are better maintained and tracked.

- Automated Mapping and Facilities Management/Geographic Information Systems (AM/FM/GIS)–The AM/FM/GIS contains static spatial, physical, and nameplate data for some assets, more like an inventory function. It does not include and cannot acquire or store dynamic operational data pertaining to the asset. The implication that facilities management occurs within this technology is misleading; the applications tend to focus on automating the work order process rather than on management of the asset.

- Design Tools–Design tools provide connectivity models, apparatus and component selection, and diagrams of existing and planned structures. Transmission Design is an example. These applications allow engineers to create and evaluate designs. Intelligent design tools automatically create optimal designs and provide studies of designs, or engineering evaluations. Some models may be linked with operating data, but the result is used simply to determine if the system is well designed, or within system limits.

OTHER TECHNOLOGIES THAT IMPACT ASSET MANAGEMENT

Beyond the applications described above, there are a multitude of technologies that provide key information about the asset but are often overlooked. These technologies are essential to the creation of a true asset management system. Many of these technologies are incompatible with one another and each has its own database.

- Revenue Metering–Time-of-use metering, time-of-use pricing
- Demand Side Management–Demand, load optimization parameters
- Energy Management Systems–Dynamic snapshot, trending, and projection for load management
- Supervisory Control and Data Acquisition (SCADA)–Dynamic snapshot for control and monitoring
- Equipment Monitoring–Diagnostics, measured operating conditions (i.e., temperatures), and condition evaluation
- Substation Automation–Technology in the substation performing monitoring, analysis, and control of devices and apparatus that have been manually operated in the past
- Distribution Automation–Technology in the substation and on the pole-top performing monitoring, analysis, and control of devices and apparatus that have been manually operated in the past. Also, advances in communication have permitted the automation of fault location, isolation, sectionalization, and restoration.

INTRODUCTION TO ASSET MANAGEMENT PARAMETERS

The concepts of health, availability/reliability, and performance (HARP) are familiar terms within today's utility. Many companies strive to achieve reduced expenses, 100 percent reliability, increased performance, and through RCM practices, better system health. When applied, RCM practices move the utility from reactive to preventative maintenance and, with better data collection, from preventative to predictive maintenance. Reduced expenses, improved performance, improved reliability, or improved health each individually promise reduced costs and increased customer satisfaction. However, we must not overlook the dynamic and economic impact of one on the other, and thereby undercapitalize on short- and long-term profit opportunity.

Traditional maintenance and operation methods attempt 100 percent improvement to all of the HARP variables. Most often, one group within the utility tries to increase reliability, another is attempting to increase performance, and yet another group monitors health, while all three try to reduce expenses. But if we take all variables into account, we might determine that the utility would be better served by leaving a piece of apparatus operating at 80 percent health rather than 100 percent. It is probable that in many situations it is acceptable to overload a transformer to satisfy a customer even though we will accelerate loss of life (LOL) of transformer insulation. The projected revenue and availability may justify the overloading of the transformer if the cost of reduced health is known. System health would be reduced, but profit or availability, if justifying the additional cost, dictate that we push past the limits.

Definition of Terms

Realizing that the terms we use in this paper may be used in another manner elsewhere, we have included definitions for the sake of discussion. This is not to preclude (or argue) different definitions of terms used elsewhere. We define HARP variables as:

Health: Health is the measure of the fitness of an apparatus to perform its intended function. A simple analogy would be the measure of the engine temperature and battery voltage within an automobile. For example, attributes of a transformer would include dissolved gas content of the cooling oil, device and environmental temperature, and LOL of insulation. Each of these can be monitored against a benchmark value to create instantaneous alarming of an unhealthy event and also recorded, accumulated, and analyzed over time to indicate an unhealthy trend. Knowledge of expected values and trends for a healthy device and measured values and trends from installed devices allows comparison and calculation of the degradation of in-service devices as they age. This comparison allows us to predict instantaneous and accumulated loss of health as a percentage of total health. The innovative addition to this process is that with appropriate information, apparatus health becomes a variable than can be manipulated to improve ROI.

Availability/Reliability: A failure exists any time that the power system is unable to perform its intended purpose, which is to generate revenue by constantly providing quality power to consumers. Such failures include power system apparatus or I&C system component hardware failures, loss of calibration, and unwanted reactions to environmental extremes. Reliability is the measure of the percentage of time, out of the required 24 hours a day, seven days a week, that the power system or apparatus is available to perform its intended function. A simple analogy would be the percentage of time your automobile is with you and not with your mechanic for repairs. Using reliability information, we can change procedures and designs to create more-available systems and predict the expense of dealing with unscheduled repairs. Knowledge of availability of apparatus and devices helps prioritize maintenance and replacement schedules to optimize use of resources. Availability becomes another variable to be manipulated in order to improve revenue, customer satisfaction, and eventually ROI. Reliability is expressed as a percentage of the total possible availability.

Performance: Performance of a system or device is the comparison of its actual operation to ideal operating parameters. A simple analogy is the ability of your automobile to accelerate as needed and to get predicted fuel mileage. Performance is a value that represents the effectiveness of the power system or an apparatus in service. Effectiveness can also be manipulated to improve revenue, customer satisfaction, and eventually ROI. Actual performance is expressed as a percentage of optimal performance.

In our proposed model for Asset Management, HARP values are integrally linked to one another. Change the value of one, and the others may fall or rise. Economic and derived terms that we need to further expand the proposed Asset Management model include:

Net Installed Value (NIV): NIV (by our definition) is the present value of an in-service asset. NIV is the aggregate of expenses and the HARP variables. These variables have to be weighted accordingly and are site specific. Each site will have different economic drivers that will impact the optimum setting for the interrelated variables. Some utilities will be more profit focused than others whose rates are still controlled by a Department of Public Utility Control (DPUC) and this will in turn impact the HARP settings. Actual NIV is expressed as a percentage of the optimal. Predicted NIV is the predicted result of manipulating the HARP variables while understanding their effect on one another. A simple analogy is that you can reduce the availability of your automobile by leaving it with your mechanic for repairs. The repairs may be inexpensive and improve the health and performance of the vehicle, thus improving the overall NIV in spite of reduced availability. The goal is to achieve maximum NIV, which may mean equipment health is at 95 percent, availability/reliability is at 99.999 percent, and performance is at 70 percent.

Net Revenue (NR): Net Revenue is defined as the total customer billings minus annual expenses (scheduled and unscheduled). Future considerations related to Net Revenue include intangible costs, such as cost to customer, customer satisfaction, and litigation. Many utilities have not calculated these intangible costs, but those who do can factor them in.

Net Potential Revenue (NPR): Potential revenue is the sum of a number of variables:

A. Unserved–is the loss in profit due to an outage, and/or real load that could be served if a breaker, transformer, or wire is under capacity. Since the new operating model is to push equipment to its limits, there will be more and more unserved load. In this case, Potential Revenue is determined using historical data to predict the demand of a piece of equipment had it been 100 percent available.

B. Growth–is future or planned unused capacity. It might be more cost effective in the long term to invest in new equipment or overload existing equipment than to minimize cost and underserve present and future demand.

C. Reduced Operations & Maintenance (O&M) Cost–is the potential to reduce costs (thereby increasing revenue) through automation, or by replacing obsolete equipment with newer, more efficient equipment, or by modifying maintenance practices. Typically O&M costs are predicted, but with real-time and historical operating data these costs can be measured and dramatically improved.

Looking at overall HARP NIV for an existing breaker versus the HARP NIV of a new breaker with the fiscal economic backdrop of Net Revenue and Net Potential Revenue, the result of the evaluation might be:

$$(\text{NIV Existing Breaker} + (\text{NPR} - \text{NR})) < (\text{NIV New Breaker} + (\text{NPR} - \text{NR}))$$

Taken a step further (in what we would consider true Asset Management form), we can now take the NIV/Revenue model and compare existing breaker parameters for the entire territory in order to prioritize obsolescence. We would use NIV, NR, and NPR to compare replacing an asset with one of the same or higher rating to serve more load. After evaluating 1000 circuit breakers, in a true Asset Management scenario, we may also determine that it makes economic sense to obsolete 100 of them. Then, using real-time and historical operating data, we prioritize the replacement of the 100 breakers based on highest delta between (NIV–NR) and (NIV–NPR) and, in turn, get the best value for our money.

With the combination of an Asset Management model and philosophy, and technology to support information creation and collection, we now provide data, rather than intuition, to the modeling and decision-making process and we achieve many benefits.

- Dynamically monitor asset ROI–Understand expense allocations, identify and replace obsolete equipment, strategize effective use of resources and financial capital

- Increase device and system productivity–Monitor and react to dynamic device data, use historical and dynamic system data to predict and react to events

- Monitor and understand apparatus health–Use “healthiest” breaker to avoid outages, optimize maintenance schedules, alter procedures

- Schedule periodic equipment exercise to avoid and/or determine failure–Exercise breaker if unused in last six months, clear transformer fan cages

INFORMATION TECHNOLOGY DESIGN

The Problem

True Asset Management relies heavily on operating data from many separate systems to inform the application of the value of a specific piece of equipment. Most of the data available in these systems is unavailable to applications within the corporation. With this the case, true Asset Management cannot be achieved.

The concept of acquiring Asset Management data from new sources, such as equipment monitoring and substation automation, via the SCADA communications path does not make sense. SCADA is a critical application with specific data needs and using SCADA as a data server would impact performance of the SCADA system ability to respond to critical events. The paper "Substation Integration–A Design for the Enterprise," more fully discusses the problems of using SCADA as an intermediary application for nonessential field data [2].

Most utilities implement automation technologies to achieve specific individual goals without regard to the value that the data these technologies produce would have for other corporate data users. Once the new equipment is put in place, the information is often locked behind a proprietary database with no standard access. If access to the data is available, it is in a limited form and is not easily manipulated by the user. Further discussion on the problems of data management can be found in the article, "Managing Your Data–From the Field to the Desktop [3]."

In short, the problem is that no application exists that is capable of acquiring and storing Asset Management data, let alone analyzing it. As an example, consider a transformer asset and its elements including tank, windings, bushings, heat exchanger, pump, fan, and LTC. Necessary attributes exist in the SCADA, revenue metering, GIS, MMS, and design tool systems at the enterprise as well as within protective relay, controller, automation, LTC, dissolved gas monitor, temperature monitor, weather monitor, and metering IEDs in the substation. A brief review of data within these sources was too lengthy to be included within this paper and reveals a minimum of 250 attributes, with many more in the future as we advance monitoring. Of these 250 attributes available, only ten; three phase current and voltage, watts, vars, and status, are sent to SCADA. This leaves 240 attributes, essential to Asset Management and other applications, that traditionally go uncollected and are not stored. This example sites one piece of apparatus; imagine what this means for all other installed equipment.

One insightful comment by an engineer frustrated with traditional methods: "If we already spend $16 to sensor each value, why not spend a buck apiece to store and analyze them?"

Clearly there is considerable discrepancy between the data that today's automation systems produce, what SCADA needs, and what data are readily available to other enterprise applications. The problem of accessing multiple individual operations-oriented databases such as substation automation, equipment monitoring, maintenance management and work management systems, and the limited information captured by SCADA suggests we discover a solution for moving data more directly to the enterprise so that other applications, such as Asset Management, can use it.

The Physical Model

The best model will be utility independent and will allow the user flexibility to build asset scenarios. If the AM/FM/GIS supports connectivity, then the attribute model from this system may be used as a subset. If there are formal Outage Management Systems or Engineering

Application systems, these systems may provide another appropriate attribute model subset that is needed to support analysis of the asset. Effective Asset Management may not require a database that contains every asset attribute, but may best be a composite of multiple applications and databases contributing to the model. The goal is to avoid building another island of automation, but instead to leverage new technologies allowing applications to share information and modern concepts provided through N Tier Architecture [4].

If your organization does not have adequate models of the asset, much can still be accomplished through queries of historical data for specific pieces of equipment. In the example of the 1000 breaker evaluation, no preconceived model was needed. A simple query was built against the real-time and historical data stored in the real-time historian.

The Real-Time Historian

Competitive industries that want to maintain their edge use real-time and historical operating data to push their processes to the maximum. The real-time historian is data storage of time-series data (timestamp plus a value for all data produced by field devices), open data access to the archive in a variety of standard formats, internet and desktop view/access to these data, and an information technology (IT) infrastructure for collecting and moving these data. The historian is a temporal database, as opposed to a transactions-oriented (relational) database. The latter design conflicts with the massive volumes of temporal data produced by field devices. Please see recommended reading on substation integration and managing your data for more details on historian technology [5, 6].

Real-time historian is a key technology for Asset management, because it stores and compresses all the operating data necessary for analysis, and the architecture of the historian supports operational analysis, unlike other databases that are general purpose.

The I&C System

Many IEDs are dedicated to monitoring and recording equipment health data such as dissolved gas content, device and environmental temperature, and device operation statistics. Other IEDs, with the primary purpose of performing metering and protection, also create and provide valuable equipment health data. Concurrent power system parameters also need to be collected to provide the context for interpreting device and system diagnostics.

When integrated together, IEDs become a powerful, economical, and streamlined I&C system, capable of supporting all aspects of electric power protection, automation, control, monitoring, and analysis. The monitoring and analysis features of the system produce many kinds of data including: instrumented metering, change-of-state, derived, self-test diagnostic, equipment monitoring, control, supervisory, automation, historical, and settings. A communications processor acting as the substation controller can collect data from many different types of IEDs from many different vendors and, in turn, provide that data to many different enterprise applications. Figure 1 illustrates a communications processor in the substation acting as a client/server creating a substation-wide database. This data can then be locally processed and/or sent to the appropriate enterprise applications. Direct communication between the communications processor and enterprise applications is possible, and the design supports sending data to the historian and the historian, in turn, forwarding data to other enterprise applications.

Another trend that will play an increasingly important role is intelligent data analysis within the IED, as close to the asset as possible. This permits concentration of data to smaller groups of processed information that require less bandwidth to transmit and less memory to store. Also, most importantly, intelligent processing at the IED near the asset permits much faster automatic proactive and reactive measures.

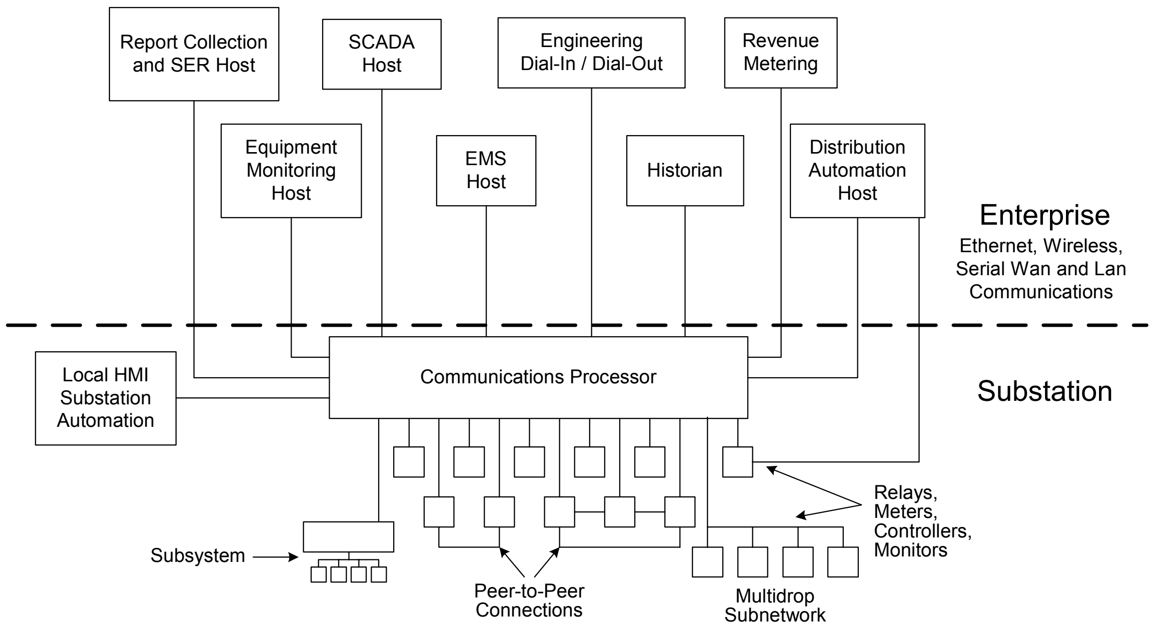

Figure 1 Communications Paths for Dynamic Substation Data

The paper "Understanding, Predicting, and Enhancing The Power System Through Equipment Monitoring and Analysis" discusses the elements of state-of-the-art communications designs to create, collect, and react to equipment health information [7].

In brief, a robust substation controller acting as a data client/server sends data to enterprise applications including the real-time historian. Combining the substation data server and the historian technologies solve the problem of multiple servers and multiple clients that are normally paralyzed when the data are provided by a single-host application, such as SCADA. This solution also adds the ability to manage, process, and store a variety of data types from a variety of sources.

The Solution

True Asset Management needs to determine*, and improve*, the health, performance, reliability, and ROI, of all power, control, and monitoring system components. In order to do this, it is essential that, at a reduced cost, we enhance and integrate automatic data collection and decision making.

It can be seen that the true innovative advancement with respect to Asset Management is the availability of appropriate real-time data from I&C Systems. This adds the dynamic asset performance dimension to what was previously location, inventory, and repair schedule management. One analogy is that without real-time data, you know when you purchased your automobile, what kind of engine it has, and when you are scheduled for an oil change, but you do not know its gas mileage or engine temperature or whether you should instead use another vehicle for a particular task.

PERFORMING ASSET MANAGEMENT

Industry is ever changing, so applications need to stay flexible, and the goal is to use data from available sources, and not to create a new island of automation. Build on what exists and leverage open technologies for your application environment. Not only do we not want to create a new large application with a database capable of holding every asset attribute value, we do not even want access to every asset attribute value. These attributes are all necessary and contribute to the control and operation of the apparatus but Asset Management relies on the preprocessing of attributes to provide information. Asset Management relies simply on understanding and analyzing the relationship between revenue, expenses, health, reliability, and performance. In short, Asset Management consists of managing, understanding, and manipulating the NIV of assets. Figure 2 illustrates a logical view of measured values of the parameters; the knobs represent manipulation of these parameters to improve NIV.

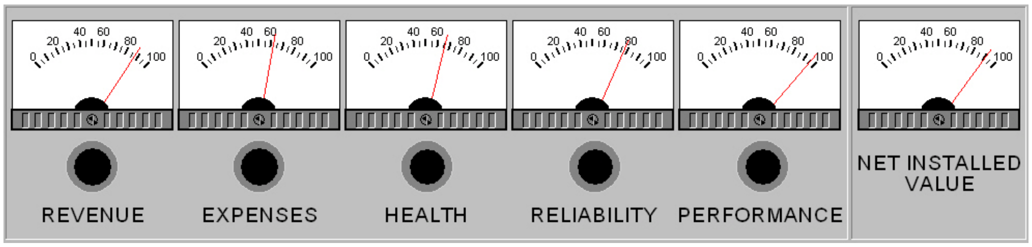

Figure 2 Logical Representation of Managing HARP Variables to Maximize Net Installed Value

CURRENT AND FUTURE OPPORTUNITIES

The presented solution in Figure 1 shows a direct link between the I&C System and the real-time historian. This works right out of the box. However, if application integration is also a concern for your utility, you may want to consider the Electric Power Research Institute (EPRI) initiatives to support a Common Information Model (CIM). CIM provides a model of the electrical system resource. A common data definition for shared attributes takes the proprietary nature out of data and opens all systems to one another. If your utility is moving in this direction, building an Asset Model using a CIM reference model will be very powerful and can be used across the enterprise via integration frameworks such as the utility information bus (UIB). CIM is easily incorporated into the historian/I&C solution.

In addition to CIM, EPRI has worked with utilities and vendors to establish standards of communication between applications using existing industry standards for guidance. CIM as a reference model, implemented within the historian, will allow higher level modeling of the asset.

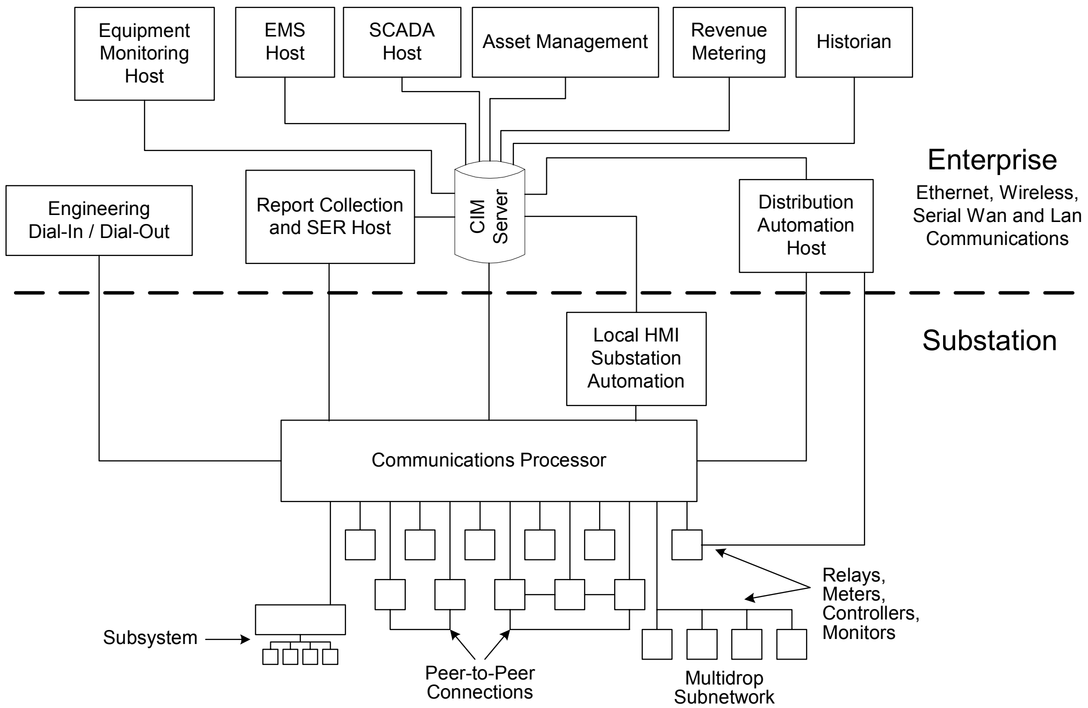

Figure 3 Future Possibilities for Communicating Data Between the Substation and Enterprise Applications

CONCLUSIONS

In order to enhance the performance of existing systems and new designs, electric utilities must fully understand the current state of the power system as well as predict future capabilities and system expansion to increase reliability and performance. Increased global competition, deregulation, availability demands, and pricing pressures are forcing the electric utility industry to reduce operation costs while increasing reliability. Utilities often need to push equipment to higher loading levels to meet demands.

The main goal in true Asset Management is to move from the traditional role of trying to achieve 100 percent individual improvement of health, or of availability/reliability, or of performance, and move toward a model that considers all three variables along with appropriate economic drivers. The proposed application will not create a massive database; rather, it will leverage existing databases, including the real-time historian, and readily available communications processor technology to collect and integrate decision-making information. The I&C System can support direct access and links to the historian and other enterprise applications and will no longer be underused. Asset models may be as sophisticated or as simple as you like.

REFERENCES

[1] Power Engineering Update, "Deregulation Spurs Debate on Asset Depreciation," Volume 104, Issue 7, July 2000.

[2] Ayers, L. "Substation Integration–A Design for the Enterprise," Conference Proceedings DA/DSM Asia, September 1998.

[3] Ayers, L. "Managing Your Data–From the Field to the Desktop," Conference Proceedings DA/DSM Europe, October 1999.

[4] Kennedy, J.P., "Building an Industrial Desktop," Chemical Engineering: Feature Report, January 1996.

[5] Ayers, L. "Substation Integration–A Design for the Enterprise," Conference Proceedings DA/DSM Asia, September 1998.

[6] Ayers, L. "Managing Your Data–From the Field to the Desktop," Conference Proceedings DA/DSM Europe, October 1999.

[7] Dolezilek, D. "Understanding, Predicting, and Enhancing the Power System Through Equipment Monitoring and Analysis," Conference Proceedings Second Annual WPDAC, Spokane, WA, April 5, 2000.

BIOGRAPHIES

David J. Dolezilek received his BSEE from Montana State University in 1987. In addition to independent control system project consulting, he worked for the State of California, Department of Water Resources, and the Montana Power Company before joining Schweitzer Engineering Laboratories, Inc. in 1996 as a system integration project engineer. In 1997 Dolezilek became the Director of Sales for the United States and Canada, then moved on to serve as the Engineering Manager of Research and Development in SEL's Automation and Communications Engineering group. In 2000, Dolezilek was promoted to Automation Technology Manager to research and design automated systems. He continues to research and write technical papers about innovative design and implementation affecting our industry, as well as participate in working groups and technical committees. He is a member of the IEEE, the IEEE Reliability Society, and the International Electrotechnical Commission (IEC) Technical Committee 57 tasked with global standardization of communication networks and systems in substations.

Lee Margaret Ayers is a T&D Systems Architect with OSI Software, Inc. With working knowledge and experience in SCADA and a strong background in historian and AM/FM/GIS technologies, Ms. Ayers acts as an educator, systems consultant, designer, and industry expert for utilities and a variety of SCADA, DA, AMR and AM/FM/GIS vendors desiring to link real-time data to their applications and throughout the corporation.

Previously presented at the IEEE/PES Transmission and
Distribution Conference and Exposition

20010307 • TP6117-01