Implementing a World Class, On-Line Expert Diagnostic System
Integrating SCADA, Diagnostics and CMMS

Mr. Desi G. Dundics, P.E., President, Equipment Links, Inc.

Mr. Barry Arp, Manager, SMT, Tennessee Valley Authority

Overview and Vision

Increasing competition and evolving deregulation is rapidly transforming the utility industry. Cost competitiveness is a key determinant for survival. To maintain market-share and to remain competitive, utility organizations are investigating ways to redefine their equipment related operations and maintenance practices. These practices must consider not only ways to reduce the costs of operating and maintaining their equipment but must do so by simultaneously improving their reliability and performance.

Barriers to achieving these objectives are both technological and organizational.

> Technological limitations are evident in the application of computer systems, limitations in the scope and usability of software, inability to effectively communicate between systems, and limitations in applying these technologies across a wide "enterprises" approach.
>
> Organizational limitations reduce the effectiveness of organizational performance.

The technological obstacles are rapidly being overcome through the availability of powerful, inexpensive, and integrated computers, software, expert systems and other technology. The challenge lies in cost effectively applying this rapidly developing technology to the needs of the industry and applying it today with a vision of the future. The second obstacle is formidable because it will require many painful changes affecting the culture of the organization.

Tennessee Valley Authority (Transmission Operations and Maintenance Group) embarked on a mission to implement a project jointly with their Technology Advancement Group to achieve the above vision. Early results of this project have been outstanding. This paper and presentation describe the steps taken to plan, prepare, and implement this program.

Basic Requirements Needing Solutions

We were looking for better ways to manage the maintenance of our equipment, specifically in the Transmission Operations & Maintenance Group. This equipment consisted primarily of transformers, breakers, and related substation equipment.

By no means did we feel that our practices were poor or less than standard. In fact, we actively participate in continuous improvement programs, and our practices probably lead the industry. Nevertheless, we wanted to do better.

The specific areas that we wanted to address with this program were:

- Make real-time equipment performance information readily available to those responsible for making maintenance decisions on their own desktop PC.
- Implement a system of "expert diagnostics" that would automatically apply routine and consistent performance analysis, allowing personnel to concentrate on the important issues and not get consumed in the normal.
- Integrate our solution to optimize the process. Our maintenance strategy had already evolved into using the basics of RCM. The execution of our strategy was already being performed in a common CMMS. We were already using a number of "predictive" diagnostic tools and monitoring technologies. Each of these areas were being treated as stand-alone tasks, and there were tremendous gains to be achieved if we could integrate each of these areas into one "total solution."

We set out on a goal to define the total solution we were trying to achieve and to implement a lead project targeting known problem transformers and breakers. The time schedule to demonstrate complete functionality was one year from the point of approval of this entire program.

Basic Steps of The Program

1. Perform a Programmatic-Level Reliability, Availability, and Maintainability (RAM) Assessment of maintenance operations. One result of the RAM Assessment was to define a plan to implement a pilot project.

2. Pilot Project – Data Acquisition. Acquire real-time data from the critical equipment.

3. Pilot Project – Graphical User Interface. Install and implement a robust, low-cost PC based application for display and basic data processing.

4. Pilot Project – Expert Diagnostic Development. Build expert rules that can be applied to the pilot equipment for diagnostic processing.

Step 1 <u>Programmatic-Level Reliability, Availability, and Maintainability (RAM) Assessment.</u>

The RAM assessment was designed to gather the required information to make engineering and business decisions regarding the allocation of maintenance dollars. The RAM assessment included seven key areas.

- Collection and review of reference documents
- Interviews with various TVA personnel
- Visits to various service centers and substations
- Maintenance tasks, frequencies, and duration assessment and comparison to others
- Testing frequency assessment and comparison to others
- Data collection and utilization assessment
- Organization and employee skills assessment

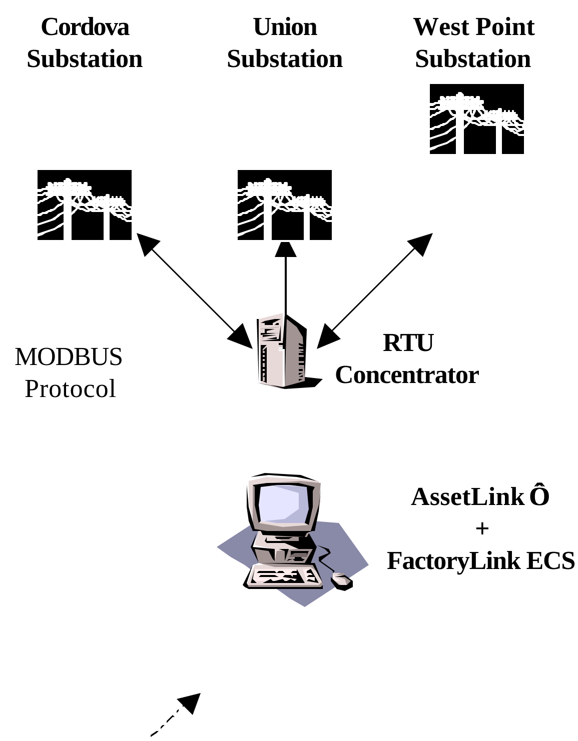
The RAM assessment was extremely extensive, and was performed by Technical Diagnostic Services, Inc., with involvement from Equipment Links, Inc. Significant potential savings were identified in the resultant assessment report. Other, harder to quantify benefits were even more significant. These benefits include increased efficiencies, reduction of forced outages, and increased reliability and customer satisfaction.
One key recommendation of the assessment was the identification of three critical substations to be included in a pilot project for technology advancement. This project would involve the acquisition of various data from transformers and breakers. It requires the installation of new instrumentation and in one case multiple installations of competitive vendor instrumentation for benefit analysis.

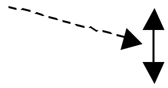
Step 2 <u>Pilot Project – Data Acquisition</u>

While TVA has extensive experience installing remote instrumentation and communicating with that instrumentation, making that information available in the form of a wide area SCADA system, and available to multiple managers and engineers was exciting.

The challenge was to implement an architecture that could be proven on this small pilot system with only three substations but would not be cost prohibitive when expanded to other locations.

The standard mode of TVA communication has been with the MODBUS protocol, making use of the Landis & Gyr Concentrator TG5700 to poll the individual substation RTUs. "Middle-ware" software or hardware solutions to transfer this information from the TG5700 to a PC running Windows was bulky and expensive. We were able to completely eliminate this middle step by careful selection of the development tools for our program. FactoryLink ECS from USDATA running the AssetLink™ application was determined to satisfy our every requirement, including cost. A layout of the final architecture is shown below:





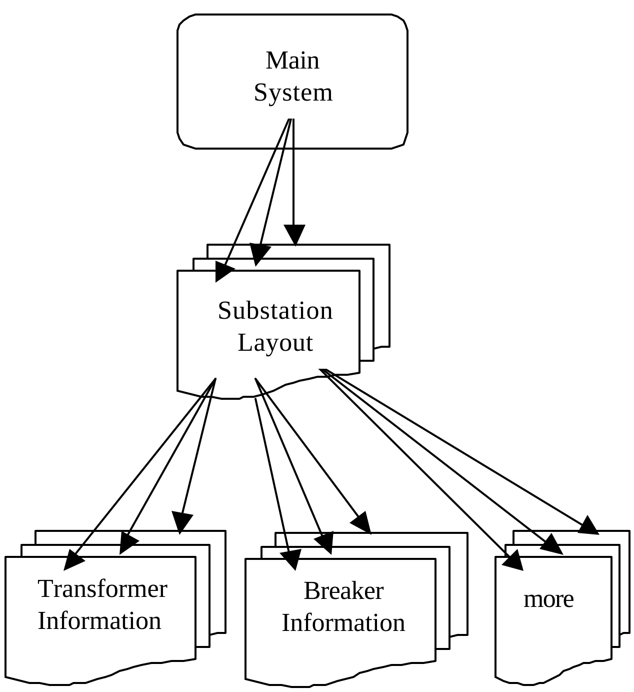
Step 3 Pilot Project – Graphical User Interface

In our preliminary investigation, many told us that what we were looking for in terms of a graphical user interface didn't exist. There were three basic requirements:

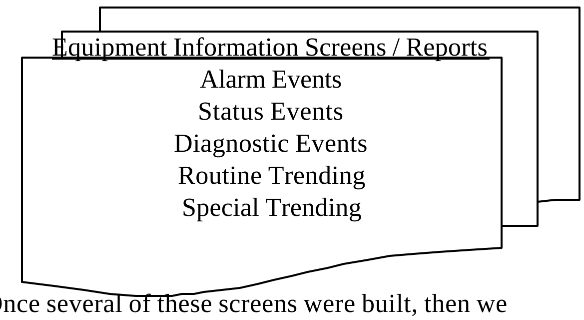
- The display had to be graphical and object oriented; and of course, it had to display data real-time.
- Any data that needed to be stored must be kept in TVA's standard database, meet ODBC compliance, be compliant with OPC, and preferably be compliant with MIMOSA. Again, of course, it had to be easily accessible by anyone in the system.
- The development tools had to be easy enough to use so that TVA personnel could perform all adjustments and enhancements with little or no vendor involvement.

We proceeded on the project with AssetLink™ SMD, a version of AssetLink™ tailored specifically for substation automation.

The resultant application was basically a drill-down, point and click system that ran as a WebClient on a Windows 95 workstation. The drill-down architecture followed the following pattern:



Each screen consisted of graphical objects representing items of equipment. To look at any item of equipment in more detail, the user simply pointed and clicked on the desired object. In this way the user could drill-down to any level of detail desired. The lowest level of detail for any equipment included:



Once several of these screens were built, then we identified a pattern of the placement and functionality of these objects, and were able to build a generic "template" for all future screens. The template approach allowed us to build new substation screens in a matter of hours.

In addition to the display functionality, each component needed an alarm and diagnostic checking associated with it. Getting back to the "total solution" aspect of our project, the goal was to have this system perform all of the routine performance checking, and then alert engineers when their attention is required.

Much of our alarming and diagnostics is not complicated, but there is a lot of it. Building rules for a single transformer, for instance, is a reasonable effort, and we were able to get a number of engineers involved in that process. Entering those rules for thousands of transformers could be extremely time consuming. In addition, if later it was determined that the rules needed to be adjusted, then making the adjustments for thousands of components would be cost prohibitive. The system we implemented uses the approach of a "model builder," whereby an unlimited number of components can reference the same model for alarm processing. In this way, enhancements could be made to the model and any change would be incorporated immediately to any component that used that model for its processing style.

Because making model improvements were so easy, we immediately recognized that configuration management was going to be a real issue in our program. The organization was restructured to ensure that changes and change requests followed strict formal guidelines and approvals. This restructuring is still in its infant stage, but we believe that it will alleviate tremendous potential for confusion down the road.

Step 4 Pilot Project – Expert Diagnostic Development

Transformer Diagnostic Rules

Following an in-depth RCM and failure mode and effects analysis of transformers, it was determined that there are two primary and two secondary failures that the pilot needed to address.

Primary Failures:
- Insulation Breakdown / Internal Problems
- Load Tap Changer Problems

Secondary Failures
- Cooling System Problems
- Instrumentation Failure

Internal problems and insulation breakdown often manifests itself as a build-up of combustible gases within the transformer. Various gases are prevalent as a result of different problems, and usually an analysis of the oil contained in the transformer will indicate that a problem is occurring. Taking unnecessary oil samples on transformers can become expensive, and we are always running a risk if a problem occurs immediately after a regular sample is taken because it may be many months before another sample shows that there is a problem. On-line gas monitors were installed on the critical transformers in our pilot. The gas monitor is most sensitive to hydrogen and percentages of other gases and does not break it down into individual elements. We believe that this total combustible gas value will immediately indicate that a problem is surfacing, and then a more extensive oil analysis will be requested to show a specific problem. This approach was selected over more expensive instruments that would evaluate several gases on-line. By getting gas concentration on a real-time basis, we were also able to calculate rates of change. The rule for gas buildup was to alert whenever:

- Gas would build up to predetermined levels for maintenance, warning and emergency levels
- There is an excessive change in gas concentration over a short period of time (i.e., 15 minutes)
- There is an excessive change in gas concentration over a longer period of time (i.e., 6 hours)

The Load Tap Changer in a transformer is typically a multi-position contact device that is used to regulate voltage under various load conditions. Carbon buildup on the contacts and other contact related problems will cause heating, which causes a localized rise in the oil temperature. A device was installed to continuously monitor both the main compartment oil temperature and the oil within the load tap changer compartment. The rule for load tap changer problems was to alert whenever:

- The difference between the LTC oil temperature and main oil temperature would deviate outside normal limits

Transformers have fans and coolers to cool the oil as loading increases and causes oil temperature to increase above a specified limit.. High levels of loading can be sustained for short periods of time but can significantly degrade useful life of the transformer if elevated temperatures are maintained for extended periods of time. Oil cooling systems can be either forced oil circulation through the transformer or forced oil/air circulation. If main oil temperature fails to drop below predetermined levels when cooling is activated, then a rule can be implemented to alert whenever:

- appropriate cooling system has failed to activate, or
- cooling system has degraded to the point where it is no longer sufficient to cool the transformer load, or
- transformer is experiencing excessive load

Not surprising, any new technology and instrumentation will come with failure and maintenance problems of their own. This system has implemented “smart” instrument techniques that will alert the operator whenever data is outside of normal for the current conditions. This is valid for the combustible gas instrument as well as the temperature monitoring instrumentation.

Breaker Diagnostic Rules

Unfortunately, the advanced breaker monitoring instrumentation that was selected for this project was not released by the manufacturer in time for inclusion in this report. The instrument was to continuously store breaker related information in a Microsoft Access database. The AssetLink™ system would read the breaker database at frequent intervals (every minute) and perform normal display, alarm and diagnostic checking consistent with the entire system.

Integration with the Computerized Maintenance Management System (CMMS)

TVA (Transmission/Power Supply Group) has selected PSDI's MAXIMO for their computerized maintenance management system. In keeping with the total solution concept of equipment management, the future vision for this program is to interface diagnostic advisories from the AssetLink™ system directly with MAXIMO. At this time, it is not desired to have the system interface automatically to generate work orders. Instead, this interface would allow the maintenance planner to follow a two-step approach:

- Planner would be able to regularly access a special file of information deposited by AssetLink™ to indicate any new equipment problems that need to be addressed by the maintenance staff.

- Planner would then generate a work order in MAXIMO based on the information in AssetLink™. Even though this step is designed to be manually initiated, much of the data that would go into the work order would be made available by AssetLink™, so there would be little need for additional data entry.

In addition to the CMMS planner being able to access information from the diagnostic system, the diagnostic system would also have the capability to retrieve maintenance history directly from MAXIMO. In this way, the engineer will be able to have at his/her fingertips everything about the equipment being inspected without having to run different software applications. Directly from AssetLink™, the engineer will be able to

- View the defined maintenance strategy associated with each component,

- View detailed current and past performance of each component,

- View documented maintenance history of each component, as well as active work in progress.

This interface with the CMMS is currently under development, and the migration path is to have this functionality available within the next six months.

Summary

TVA is positioning itself strategically in preparation for deregulation of the utilities with the use of advanced technology tools and improved processes. On-line monitoring, with integrated diagnostics and condition based strategies will be the key to optimizing equipment performance and reliability. These practices, applied consistently, will give the leaders a clear advantage and world-class respect.

Biography

Barry Arp is Manager of Substation Maintenance and Test in the Transmission Operations and Maintenance Group at the Tennessee Valley Authority. He has over 26 years experience in the area of transmission maintenance, including relay, breakers, transformers, and other related power equipment. He is presently functioning as project manager for condition assessment in TVA's transmission organization.

Biography

Desi Dundics is President of Equipment Links, Inc., a leading integration and consulting company in the field of asset management and condition assessment. He has over 23 years experience in the nuclear, utility, and general industry with particular emphasis in the areas of equipment reliability and plant operations. A US Naval Academy graduate, he qualified as Chief Engineer for Navy Nuclear Propulsion Plants, managed on-site startup and operations contracts while with NUS Corporation, and was an Instrumentation and Controls Engineers with Gilbert Commonwealth Associates.

He may be contacted at telephone (702) 454-1939, fax (702) 454-6676, or at ddundics@equipment-links.com