SUBSTATION MAINTENANCE OPTIMIZATION

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The Dayton Power and Light Company is an investor owned company with over 475,000 electric customers, served by approximately 1,800 miles of transmission lines and over 180 substations.

Prior to 1982, we had a centralized Substation Maintenance and Construction Group that had a time-based maintenance program that resulted in excellent system reliability. During the late 1970's and early 1980's, our service area experienced a severe recession that resulted in a near stoppage of new construction in our area. Consequently, in 1982, we had a work force reduction and decentralized substation maintenance to be the responsibility of our individual service centers. During the decentralization of substation maintenance, emphasis was not placed on performing substation maintenance; however, no adverse consequences were immediately visible.

The winter of 1988 resulted in an identifiable reduction of system reliability when several breakers failed to operate during extreme weather conditions. As a result of those system problems, a centralized group was formed and a time-based maintenance program was implemented for substation equipment. The time-based schedule was adhered to without fail and soon the system reliability was restored.

Dayton Power and Light surveys our customers to monitor how well our customers think we are performing. The 1995 surveys indicated that our "Satisfaction Index" was at an all time high. The customer satisfaction is an important factor in the decision making at Dayton Power and Light. Dayton Power and Light, like all utilities, is being pressured by the unknown of the unregulated industry. One of Dayton Power and Light's objectives to meet the resulting competition is to reduce O&M cost while maintaining or improving electric system reliability.

During mid 1995 there was some thoughts that we were performing more maintenance than necessary on our transmission and substation equipment.

The Dayton Power and Light Substation Maintenance and Construction Group formed a project team in late 1995 to review maintenance practices used for transmission and distribution substation equipment. The objective of the project was to maintain or improve system reliability while reducing O&M cost 40% by the year 2001.

The project team interviewed five major engineering firms. We provided each firm with our objective and asked them to respond by telling us how they would help us meet our objective.

Technical Diagnostic Services (TDS) of Dallas, Texas was selected to conduct a Maintenance Program Assessment of the Dayton Power and Light Company substation maintenance practices. The agreed to approach was very simple. We would strive to perform only maintenance that is required, only when it is required resulting in a totally productive maintenance program. The assessment reviewed maintenance concepts used at Dayton Power and Light and compared them to concepts used at other utilities and concepts used in other industries.

As a result of the assessment, a "Maintenance Optimization Program" (MOP) was defined and a pilot project was started in February, 1996. The MOP is a condition Based Maintenance Program which monitors the condition of equipment and identifies the optimum time to perform maintenance. The program utilizes field testing and inspection programs as well as a computerized "equipment assessment system" that provides on-line, real-time monitoring of sensors on equipment, evaluates the data and produces recommendations to perform maintenance tasks. The computerized system interfaces to a Computerized Maintenance Management System (CMMS) that generates a work order to perform the task. Both of these systems were installed on a local area computer network and integrated with each other as well as our System Control and Data Acquisition (SCADA) System.

The "Equipment Assessment Sys

- Real-time display of sensors
- Continuous performance assessment
- Trend data collection
- Expert diagnostic analysis
  - Preserves knowledge base
- Maintenance recommendations
- Data for computerized work orders
- Risk analysis

The CMMS provides or performs

- Issues work orders to document work
- Maintains history per device in labor hours, parts and work completed
- Provides a system to schedule personnel
- Manages backlog of repair, preventive maintenance and testing work
- Provides data base to help manage assets
- Consolidates preventive maintenance and testing, work generation, tracking and feedback
- Facilitates identification of high cost devices
- Reinforces work practices

Equipment Links, Inc. (EQL) was brought on board to complement TDS and the Dayton Power and Light team for the implementation of a "Proof of Concept" pilot project. This resulted in a very dynamic project team that completed the pilot project in less than six months.

The team adopted a Reliability Centered Maintenance (RCM) concept defined as "Performing maintenance necessary to preserve the functional design of the equipment." This RCM concept started with asking some basic questions such as:

- What does the equipment do?
- What functional failures occur?
- What are the likely consequences of these failures?
- What can be done to prevent these functional failures?

The team focused on what they identified as the "Low Hanging Fruit". What they meant by that is to focus on areas that will result in the maximum dollars saved and will preserve or improve

reliability. We immediately implemented changes in our time-based maintenance practices that started to reduce our O&M cost.

Additionally, Dayton Power and Light had a five year time based maintenance projection in place that quickly identified transformer load tap changer and oil circuit breakers as the highest cost maintenance items. When we looked at our system in whole, we found our 345/138kV to 69kV transformers were also a vital part of our system reliability. The existing five year projection also provided a benchmark to track actual savings achieved in the MOP.

Sensors have been installed to monitor:

- Dissolved Gas in Oil
  We use the Hydran transformer incipient fault monitor on our 345 to 138kV and our 138 to 69kV transformers due to their critical nature to our system. Additionally, we have installed dissolved gas in oil monitors on transformers in our power plant switchyards.

- Load Tap Changer
  The 'TDM" monitors were installed on substation transformers with load tap changers. The TDM monitors the temperature of transformer tank and compares it to the temperature of the load tap changer.

- Fault Current
  The "Optimizer" monitors instantaneous phase current of breakers during a fault. We have installed them on transmission class oil circuit breakers.

- Nitrogen Cylinder Pressure
  Pressure transducers are installed on the nitrogen cylinders that provide a positive pressure blanket on substation transformers.

The data from these sensors combined with the normal data collected by our SCADA System is transmitted through SCADA to our MOP diagnostic software. SCADA data is then combined with the MOP sensor data and processed through logic trees. Maintenance advisories are generated when exceptions are identified by the logic trees.

The benefits of expert diagnostics include:

- Adds discipline to the RCM process
- Captures knowledge of most skilled staff
- Makes knowledge available to everyone
- Ensures consistency
- Provides process for improvement

The diagnostic maintenance advisories are passed to the computerized maintenance management system (CMMS) that generates a work order and documents completed work. The data maintained in the CMMS provides the basis for probabilistic engineering evaluations to predict both maintenance requirements and potential for failure of individual devices.

An early success in the program was preventing a catastrophic failure of a 200 MVA 138/69kV transformer. A routine oil dissolved gas analysis indicated a small gas build-up in the

transformer. This transformer was selected to be part of our pilot "Proof-of-concept" Program. Less than three months into the program, this transformer experienced a rapid build-up of combustible gas and was taken out of service without an adverse effect on our system. Reliability was maintained through early knowledge of potential equipment failure – the transformer failure case was not determined by field test.

The transformer was sent to a manufacturer, dismantled and the source of the developing fault was found near the bottom of this transformer.

Upper management support of our program has been excellent. One key factor in maintaining this support is keeping communications open by consistently documenting results and sending them to upper management.

In conclusion, I would like to review lessons learned in our project.

- Key to good results is an excellent RCM strategy
- Buy-in is critical
- Buy the right software
- Implement strategies immediately
- Don't force-feed computer literacy – evolve by curiosity
- Keep diagnostics "simple"
- Focus more attention on data transfer

Dayton Power and Light is ready to move to the next generation of the MOP by participating in the development of new diagnostic software, the addition of new sensors and the development of an engineering and operations module utilizing the same computer server and communication network.

I would like to leave you with a quote from a recent publication "The difference between great ideas that work and great ideas that don't work out is in the implementation. The only way to make great ideas come into the real world is with teams of professionals who do more than the bare minimum."