EXPERIENCE IN IMPLEMENTING A CONDITION-BASED ASSET MANAGEMENT SYSTEM WITH HAND-HELD ELECTRONIC DATA CAPTURE

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SUMMARY

Eastern Electricity are introducing an Asset Management Process which is based on the inspected condition of distribution network equipment. Key parts of this system are the streamlining of the process of gathering the inspection information and the relation between the observed condition of equipment and its maintenance need. This paper describes the issues which arose during the trial of the system, the steps which were taken to manage the risk of change and the benefits which have been gained from the system.

BACKGROUND

Eastern's network is one of the largest in the United Kingdom. The Network covers East Anglia and reaches westward into Oxfordshire and Buckinghamshire and southwards into London's suburbs - a total area of 20,300 sq. km. supplying electricity to over three million customers.

The Network includes some 61,000 substations connected by 51,000 km of underground cable and 35,000 km of overhead lines distributing, transforming and controlling electricity at 132,000, 33,000, 1 1,000 and 415/240 volts. Together these carry a peak load of over 6,000,000 kilowatts.

As part of its asset management strategy, Eastern Electricity has recognised the value of condition based monitoring. The application of such techniques can provide valuable information on the condition of network assets, leading to the implementation of more focused maintenance and replacement strategies. Sub-station inspection is carried out for a variety of reasons. The frequency of maintenance of equipment requires judgement based on experience of the assets and increasingly, their condition. The aim of Condition-Based asset management is to apply the measures necessary to prevent loss of function in a scheduled manner “just in time”; that is prior to the loss of function (in the P-F interval).

It has been established that large populations of similar plant can be managed by a strategy of invasive inspection and maintenance of a statistically-derived sample, in conjunction with data derived from “forensic” examination of units taken from service randomly, annual non-invasive inspection of the entire population, and other data derived opportunistically. Sub-station inspection is an opportunity to gather information in order to assess the condition of the electrical plant and perhaps perform some maintenance tasks or gather general asset information.

To gain the maximum benefit from undertaking sub-station inspections and condition based monitoring in particular, it is imperative that on-site measurements and assessments are recorded and analysed in a consistent and efficient manner. The efficient acquisition and effective use of data are the biggest challenges contained in the new asset management strategy. The concept is that data flows through a hierarchy of levels to provide relevant information to a number of different users.

Eastern Electricity’s Network Business started work in 1995 to develop an asset management system to facilitate the future management of maintenance principally on the basis of condition data. The continuing development and improvement of this system links the identification of key asset condition indicators, inspection procedures and techniques and data acquisition and analysis. In the course of implementing its asset management strategy, Eastern Electricity has adopted a phased approach to reduce risk and confirm business benefit before committing to major expenditure. This approach includes the selection and trial of products which fulfil the requirements for the system before adoption.

EA Technology have developed a flexible data gathering and decision support system known as InMEX which can be used for any task which involves systematic inspection and action based upon the information gathered. An efficient and cost-effective asset inspection system can readily be achieved using InMEX. Eastern Electricity selected this system for a trial of data gathering for substation inspection because of its flexibility (applications can be produced and changed quickly and easily) and because it is simple and easy to use with a clear and intuitive user interface. EA Technology have also developed the Partial Discharge Monitor (or TEV). This measures the level of partial discharges within switchgear housings and terminations and is an important non-invasive diagnostic technique. The InMEX inspection system interfaces with the TEV condition based

monitoring database to provide on-site indication of potentially unsafe conditions.

THE SUBSTATION INSPECTION SYSTEM

The Substation Inspection System was delivered on a pen based computer in the field. User interaction is by means of menus, buttons, drop-down lists and tick boxes with restricted use of alphanumeric input aided by character recognition. User experience and feedback shows that this way of working requires only a few minutes of learning and then is very easy to use. The pen approach has been found to match the user input requirement in an on-site environment where input is needed whilst standing in front of a piece of equipment.

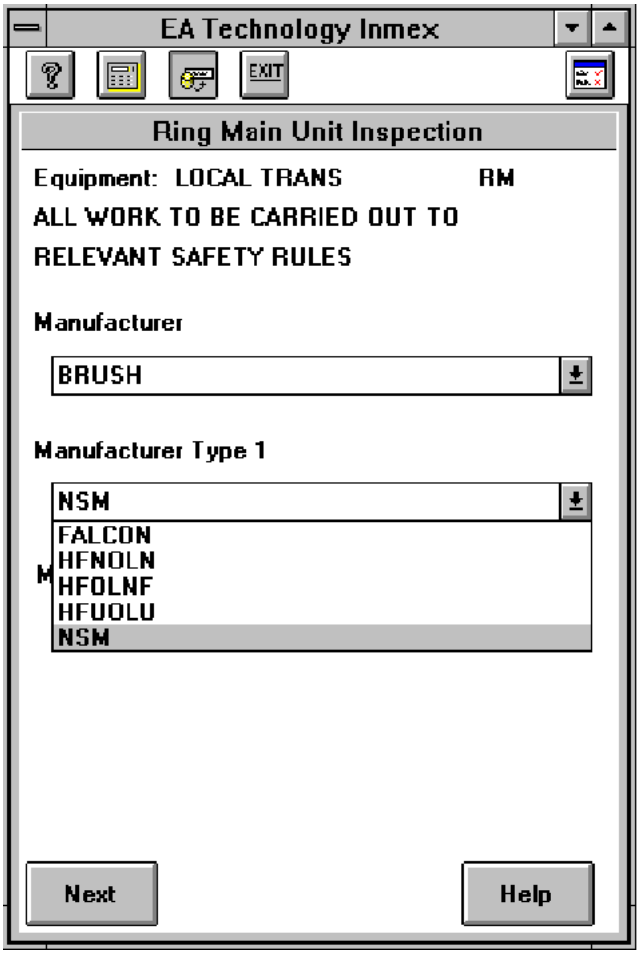

Figure 1: Example screen showing context sensitive drop-down menus.

The following types of plant were supported by the trial system:

- Transformer
- Switch Fuse
- Oil Switch
- Circuit Breaker
- Ring Main Unit
- Extensible Board
- LV Fuse Board

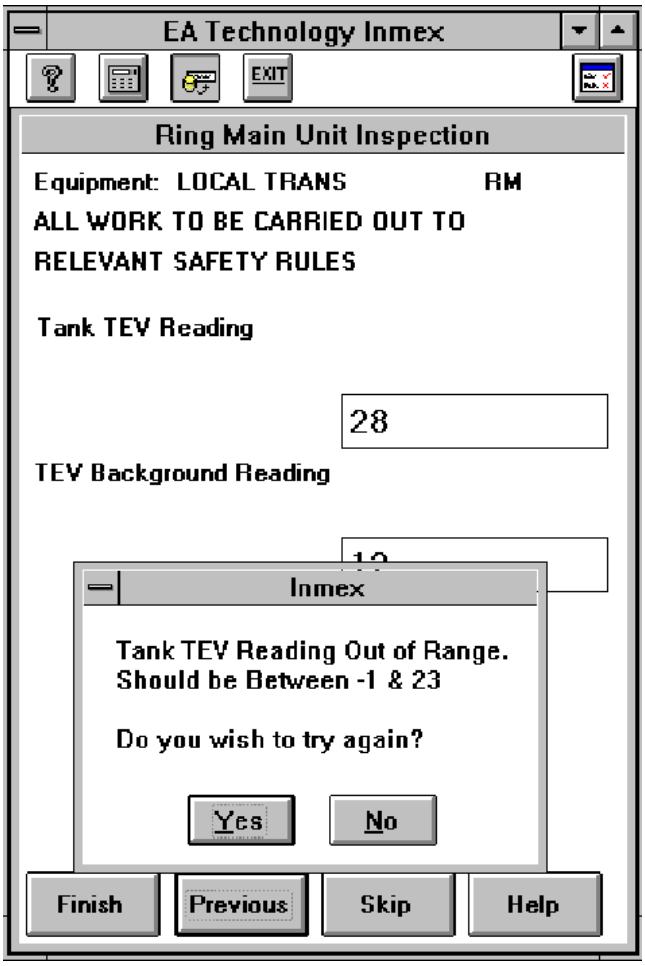

Figure 2: Example screen showing comparison of "actual" with "expected" value

A generic inspection template for each of these types was developed rapidly, using a selection of generic screens and logic. This has been found to lend itself readily to this class of activity. Moreover, because the inspection applications are flexible and easily adaptable they were amended during the trial based on user feedback.
Example screens from the application are shown in figures 1 to 3.

Condition data that was collected included TEV partial discharge measurements and oil levels. These were compared against safe limit values and exceptions flagged up in the field when the measurements were taken.

The system guides users through the inspection activity, stores test results obtained on-site and if required, analyses and suggests the appropriate course of action. Structured access to help documentation guides the user in carrying out the tests. Data is transferred to and from a central database for trend analysis, degradation modelling and the production of management reports and provides a uniform reporting procedure, an audit trail and history for each asset.

For each specific item in the field, where required, the system provides the functionality to compare the condition as measured or observed with a predetermined value or state. This, for example, may be a statistically derived upper limit value based on measurements of a large population of equipment, or may be derived by a model from the relevant data already in the condition database for the plant item concerned, based on age, environment, duty and other identified criteria. As the actual data is entered, the system compares "actual" with "expected". This comparison achieves two principal objectives:

- The entered data is immediately verified at the point of entry and excursions from the expected condition will be immediately queried. Data entry errors can be readily trapped and efficiently corrected.
- Real excursions from the predicted values can be assessed to validate the robustness of the sampling strategy. Additional sampling requirements will be identified if necessary.

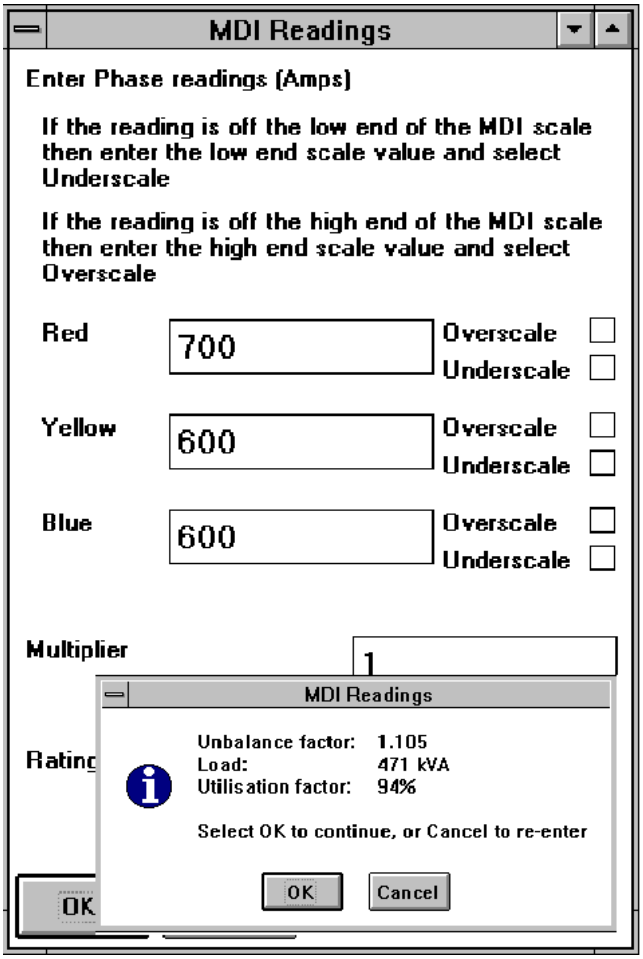

Figure 3: Example Screen showing calculation of derived values from entered data

THE HARDWARE

The requirements for the field machines were that they must support a pen interface for interaction with the software and they must be sufficiently robust for daily use in a Substation environment.

With this in mind, two different units were investigated, the Norand 6350 handheld computer and the Husky FC486 portable notebook computer. The Norand unit has a lower resolution screen and is somewhat smaller and lighter than the Husky. It uses a pressure sensitive screen for recognition of pen actions whereas the Husky uses an active pen. The Husky had a full VGA screen and a full keyboard. The Norand had a 1/2 VGA screen and a limited numerical keyboard, supplemented by a "soft" keyboard. This is an application which ran concurrently with the inspection application and provided an on-screen image of a keyboard. Keys are selected by tapping with the pen and the corresponding character is inserted into the selected input field of the inspection application.

The users preferred the screen contrast and the pen action of the Husky, but preferred the size, weight and casing of the Norand unit. The combination of the "soft" keyboard and the 1/2 VGA screen was not liked because the keyboard obscured some of the inspection application due to the limited screen size and had to be dragged around to fully use the application. The Husky unit proved to be more reliable.

FIELD TRIAL

The field trial concentrated on the data collection of annual non-invasive inspection data for over 800 substations in the Operations units of Rayleigh/ Harold Hill (North London) and Cambridge. The substations which were inspected were chosen on the basis of the annual inspection cycle. There was no manipulation of the selection to represent the constitution of the overall asset population. The purpose of the trial was to gain experience of the practical challenges of implementing computer-based substation inspection and to assess the formulation and evolution of modelling for the full implementation of the Asset Management System Project.

Existing asset register data and limited condition data for the assets in the selected substations were extracted from the mainframe plant database. The central database for the trial was populated with this data. The availability of this data on the field machines provided a useful mechanism for checking the accuracy and completeness of the data held in the central register.

Condition-Based inspection had been carried out on the assets previously using a paper-based system. Therefore some paper records on the condition of the assets at the previous inspection were available. In carrying out the inspections, data on each asset was entered into the system from the paper records, before carrying out the new inspection. Hence the trial allowed the capture

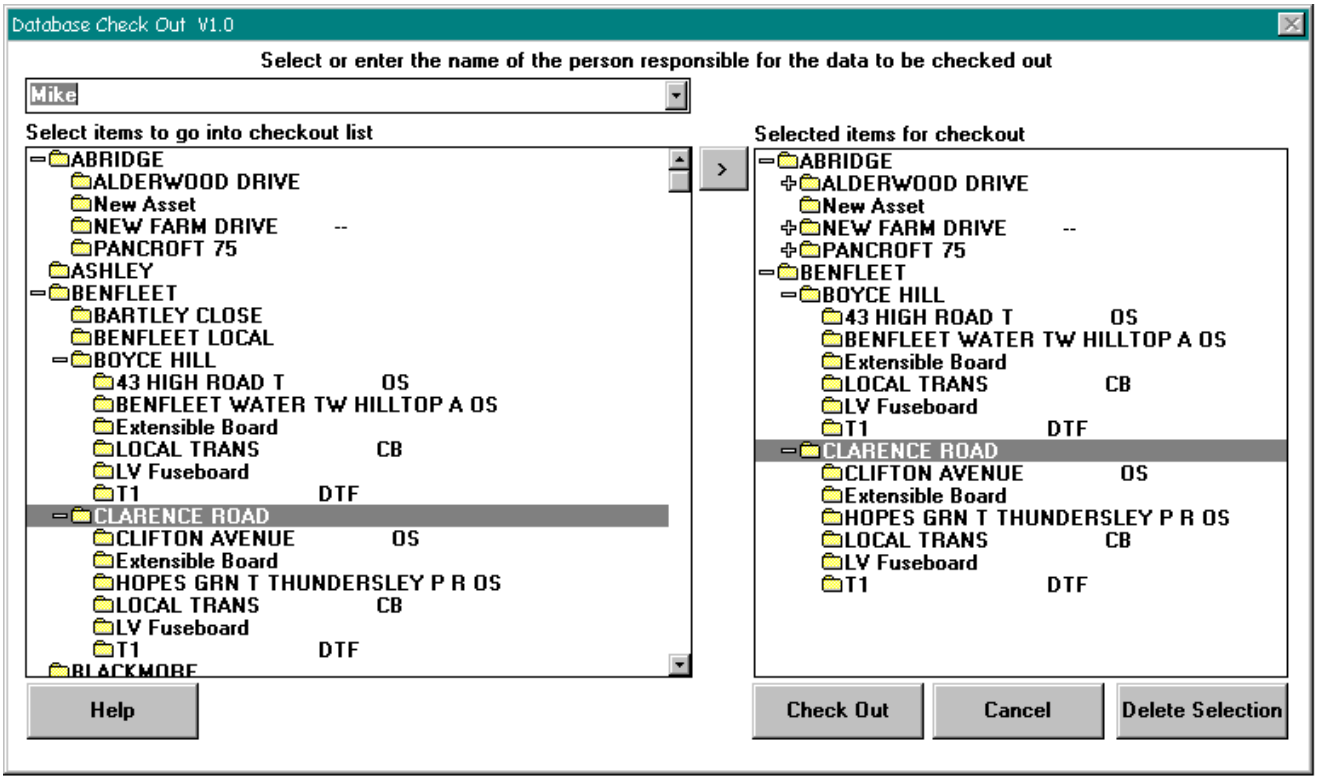

Figure 4: Example Screen of Field Database Management System showing selection of assets

electronically of inspection data from two inspection cycles for the assets selected for the trial.

TRANSFER OF DATA TO AND FROM THE FIELD MACHINES

Data was transferred between the central machine and the field machines by means of PCMCIA memory cards. These can be accessed by the operating system of both the central machine and the portable machines as a hard disc. Consequentially no bespoke communication software was required for transferring data. Instead a card was inserted into the central machine, data was written to and read from the card, the card was then removed and inserted into the selected field machine. It was found that data corruption could occur if the machines were not rebooted prior to insertion and removal of the cards. Provided this procedure was followed the transfer of data by this means was found to be quick and reliable.

The EA Technology Field Database Management System provided a simple user friendly method of allocating work, managing the return of data from the field and upload to the central database. Overlapping sets of work can be allocated and the system manages any data conflicts if for any reason an asset is worked on by more than one person between allocation and return. It provides a full audit trail of all work carried out and records any additions, changes and deletions of assets made in the field. The system can be configured to automatically update the central database with these changes. Alternatively it can be configured to produce an exception report to enable existing data change management procedures to be followed. This system has been in operation in Yorkshire Electricity for nearly three years.

USER EXPERIENCE

Productivity using the system was initially low due to unfamiliarity with hardware & system. As the users gained experience the productivity, in terms of number of substations inspected per day, was as good as, and occasionally better than the current paper-based procedure. Added to this, four times as much condition information was collected in each inspection compared with the current practice. Hence in terms of amount of data collected per day there was a four-fold increase in productivity. This was because data entry was quicker (point rather than write) and some data was already present from previous inspections where relevant. Feedback from the users improved the inspection sequences and this fed back into improved productivity.

The battery life of both units was initially found to be a problem. However, with experience in the management of charging and active manual power management (manual suspension of the machines when not in use, rather than waiting for the automatic power management system to recognise inactivity and suspend the machine) useful

working days in excess of eight hours were achieved from a single charge.

Entering data only once (in the field) rather than entering on paper and then subsequently entering from paper into a central computer system not only saved time but assisted in the acceptance of the system by the users.

Minimal training was found necessary for the trial users and full familiarity with the system was achieved after a few weeks of use. It is felt that this lead time could be shortened by targeted training during the roll out.

Although some revisions and enhancements to the inspection applications were identified, in general the applications were found to be sensible, helpful and promoted efficient and effective inspections. The use of template scripts for the inspection assessment process was found to promote objective assessment and constrain subjective judgement. This in turn assists in the objective comparison of inspections carried out by many different people in a wide range of environments and backgrounds.

THE BENEFITS REALISED BY THE TRIAL

Extensive experience was gained by Eastern into the comparative performance of the hardware. The move to electronic data capture was readily accepted by the trial users. It has been established that a significantly greater amount of data can be gathered on each asset without reducing the number of substations inspected. Data validation when captured meant errors were identified and corrected immediately by the inspector. Data transfer avoided double entry of data into the central database. An increased understanding of plant inspected during the trial has been obtained from analysis of the data collected. It has been firmly established that electronic data capture during substation inspection is practical and supports the requirements of a condition-based asset management system.

THE FUTURE

Based on the experience of the trial, Eastern Electricity is considering the introduction of electronic data gathering on substation assets across all operating units, with further development of the application to other types of assets. Both non-invasive diagnostic inspection and invasive maintenance operations are to be included. The system will have two levels of detail and response: “Beginner” and “Experienced”. These levels are to differ in the number of screens displayed and the speed of response.

Eastern Electricity is embarking on a major programme of work to enhance the capacity and capability of its Networks Management System to meet its challenging business objectives for the future. The Network Asset Register (NAR) will be one of the first of the new systems to be installed and it will be the data hub for all the other systems

The Networks Business has recently implemented the change from time driven asset maintenance to condition based maintenance. The business has two main electronic asset databases for plant and overhead lines and in addition, asset data is kept on paper and on stand-alone PCs. None of these systems adequately support condition-based maintenance in the way which is now required. A new asset database is therefore required to provide a single repository for all Networks assets, including related condition data, so that the full benefits of condition-based maintenance can be realised.

The introduction of the data gathering solution will follow the implementation of the new central Asset Register Database System. This will accommodate static and dynamic data on all of the electrical network assets.

InMEX presently runs on any Microsoft Windows platform excepting Windows CE. A port of InMEX to Windows CE is planned and an early prototype has been produced.

ACKNOWLEDGEMENTS

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