INTRODUCTION

Many electricity distribution companies are installing or have already installed a GIS both as an asset database and as a tool for supporting engineering and other applications. The first part of this paper reviews the current situation using experience gained over several years in installing a program to estimate network reliability indices at United Utilities and other UK distribution companies. The availability of GIS data, providing much more detail of circuit components such as joints, offers the potential to explore more complex models of the network. In the case of network reliability, this should assist in providing a better understanding of the mechanisms of failure and lead to improved models to estimate future performance. These in turn should assist in making more informed investment decisions.

BACKGROUND

Historically, most electricity distribution companies have relied upon several different computer systems to support their business. Systems were designed to support particular applications. At United Utilities engineering analysis of the EHV (132kV and 33kV) system uses a specialised power system analysis program which provides a schematic representation of the network. A second power system analysis program is used for the MV network (11kV and 6.6kV). This provides two views, full geographical, and geo-schematic; in the latter only key nodes, such as substations and tees, are given a grid reference, the network being drawn as straight lines between nodes (although the route length is retained). The MV database does not include the position of all circuit breakers, and devices such as switches and fuses are sometimes placed at tees so that electrical connectivity must be inferred or checked against paper records. The database contains loads but does not include customer numbers. Both the EHV and MV systems have been used for over 20 years and were designed to run on early workstations as joints, and 2.2m services. The CRMS will remain the master database for a long period. The master diagrams for HV circuits giving the position of open points are recorded on paper in schematic form. Mains (LV) diagrams are recorded on paper in geographic form.

Various asset files are stored on computer systems, including the Plant file which also contains the customer numbers supplied from each transformer. Details of faults are recorded on a separate database, NaFIRS, to which an additional field providing geographic coordinates has been added. In addition, many engineers keep their own files, often on a spreadsheet, to record data for specialist purposes or where company sources of data are inadequate.

The proliferation of different systems leads to the problems of data duplication and data inconsistency with no automatic updating of secondary records. In many cases the master record is a paper diagram, requiring further manual updating of data for each computer application.

PLAN

The aim at United Utilities is to avoid data duplication, abolish or minimise paper records, provide common systems and framework for applications, and to allow web access for business and technical users. Around 20 asset management systems have already been consolidated into a single Master Asset Management System. Paper diagrams have already been scanned and can be accessed by computer and digitisation is now taking place. United Utilities is a water utility as well as an electricity distribution company and for several years has used a GIS for the water supply business. Whilst traditionally electricity distribution engineering has tended to concentrate on power system analysis, water supply and distribution has been more concerned about the status of the assets and their location in relation to geographical features such as reservoirs, rivers and roads and utilises related information on height, subsoil, drains and drainage, etc., making the introduction of a GIS more evidently beneficial.

The plan is to extend the GIS to cover the electricity distribution business. This will include the location of assets and the circuit route, including all LV network. Data will include switchgear, transformers, towers, poles, more than 4m joints, and 2.2m services. The CRMS will remain the master system for operational information.
OTHER COMPANIES

The situation is similar at several other UK electricity distribution companies where GIS are being installed or have recently been installed. In general, there is a substantial and ongoing investment in GIS in the UK and worldwide. However, this requires considerable investment in software, data conversion, and ongoing costs. The United Utilities contract for the initial supply of the GIS software (matching that already used for the water utility) and associated facilities was £3.8m. plus an ongoing 3 year support contract. The estimated cost for the digitisation of data from paper records is £8m. Total investment on the new systems up to March 2002 is over £10m. with a planned cost to completion, including programme management and business change, of the order of £16m. Further costs arise from the upgrading of the Control Room Management System. Another UK company quoted the cost of its Distribution Asset Management Scheme which includes a GIS plus 14 application packages at £43m, plus an outsourcing contract for £40m for a period of 10 years. In this instance the predicted long-term savings are estimated at £12m. p.a. US sources suggest a minimum outlay of ~$10m.

Where are we now? The placement of contracts for ongoing support indicates a recognition in most cases, that the process of installing a GIS, digitising data and replacing or modifying other systems is likely to be time consuming. Plans for introducing GIS in several UK companies date back to about 1994. The general impression is that the process is proving more difficult and taking considerably longer than expected. This can have major repercussions on the company, as older applications may not be updated (data or facilities), new applications are postponed, and long implementation times mean that company policies and structure can change. In the UK the electricity supply companies have separated from the distribution companies and some distribution companies have merged, one area of potential savings being the adoption of the same or common IT systems. Alternatively, it can mean that one of the companies abandons its planned systems and adapts to those of the other company, leading to a loss of maybe two or more years in the development process. In some instances the companies which have stuck with the same, even if somewhat outdated, systems over many years have fared better than those which have adopted each new flavour of IT system.

EVALUATION

The long-term aim, however, is clear. But is the target of providing master systems on which all, or almost all company applications can be based being met? What happens when a new application arises? What are the problems in implementing an engineering application in the new environment? Trussel [1] outlines the issues involved. The GIS tackles two key issues: The first is the data warehousing of a very large amount of data previously recorded on paper records or in bitmap form. The second is the provision of facilities to display the associated data. The installation of a GIS does not automatically resolve the issue of data integrity and updating, but it should force the designers to tackle these issues directly. Neither does the provision of the graphical facilities automatically provide suitable facilities for the analysis and display of all applications requiring a geographical display. A key issue is access to data. Ideally the GIS will provide wide-ranging facilities both to access data and to implement applications. GIS developers are well aware of these issues [2] and standards are being developed, such as SQL3, to avoid being tied to the scheme of any particular software supplier.

The GROND Network Reliability Program [3] is designed to assist the distribution engineer in carrying out network design and policy studies on the MV network, in particular to assist with assessing the OFGEM performance targets on customer interruptions and customer minutes lost. It requires data on network connectivity, cable type and lengths, switches, substations and open points. Ideally load data are available, so that the loading on alternative circuits can be assessed. An additional module provides an overlay giving the position of faults from the NaFIRS database and analyses their effects in terms of the existing network configuration and protection or as modified by the user. It differs from power system analysis in requiring customer numbers to evaluate the OFGEM Indices. None of this would seem to be particularly demanding in the 21st century. Although some companies have implemented a schematic representation to match their familiar control diagrams, network reliability is best understood when customer locations, distances, and alternative supplies can be intuitively grasped from the diagram. Hence the preferred diagram is geo-schematic [4].
There are problems in basing the application on either the GIS or the CRMS. The CRMS doesn’t include geographic coordinates which are not required for the schematic representation. Hence, there is no sense of distance; cable lengths are not directly included but could be inferred from the impedance between nodes and the unit impedance; customer numbers are not included and there is no sense of location in relation to centres of population, geographically neighbouring supplies, or loads.

However, there are also problems in basing the application directly on the GIS: There is too much detail both in regard to the assets, such as busbar and other items at substations, and similarly too much information about the route of the circuit. It is also difficult to capture the electrical connectivity and functionality.

Implementing GROND over five years in several companies has indicated a number of detailed problems, particularly when drawing data from more than one source:

a) Lack of a unique reference - it is not clear to those inputting data to what extent items comprise the same object.

b) Non-unique and abbreviated names – this is particularly a problem when trying to match historic information with new systems which may have unique names but don’t match names used previously.

c) Overlaid information which can be understood by users on the diagram but which is not attached to items on the diagram.

d) Connectivity – vital for electrical analysis, but not by any means obvious to the person digitising a complex circuit diagram. This can be particularly difficult for the start of circuits from busbars within a substation, where up to 10 or more circuits may start and at the edges of the paper diagrams.

e) Duplicate circuits not being recognised – when two circuits run in the same duct, this is not always recognised in the digitisation. This should be picked up from the connectivity.

f) Historic data, such as fault data, may have no grid reference or incorrect reference.

It is a major task to validate data, particularly those digitised for a GIS. Many discrepancies are difficult to discover without testing against particular applications or situations.

At United Utilities the purposes of interfacing the GROND program to the GIS are threefold: First, to base the analysis on a more consistent and current set of data, removing the need to check against paper diagrams; secondly, to demonstrate the feasibility of using GIS data and to highlight errors or areas of concern in GIS data; and thirdly to carry out studies not previously possible because computerised data have not been available hereto.

**FAULT RATES**

Current modelling techniques used for MV network design and for policy studies analyse the performance of the MV network based on annual fault rates per km of line or cable. They yield results in terms of the estimated Customer Interruptions and Customer Hours Lost. The GROND computer program used by United Utilities allows the user to assign different fault rates to cables and lines. In addition, different types of conductors can be assigned to one of three categories, light, medium, or heavy, intended to represent the type of construction or other factors such as age, condition, or environment. The recommended fault rates to be used in studies are based on the historic rates for the Primary substation over the previous five years. Reports on the analysis and modelling of underground faults at CIRED 2001 and elsewhere indicate that underground faults are not well represented by a simple fault rate per km of cable. One paper [5] shows a graph of the fault rate per km against the length of the cable run. This shows that shorter cable runs have a higher fault rate per km than longer cable runs. The results can be fitted quite well to a model that allows for the effect of the ends. One company has suggested that the underground fault rate depends on the number of joints. This could be because joints themselves have a significant failure rate or because the frequency of joints along a cable is indicative of the likelihood of external interference or of overhead traffic etc. They also suggest that the fault rate depends upon ground type, some soils being more susceptible to drying out, potentially leading to overheating, or to subsidence, leading to movement and damage to cables (and joints). Another model proposed is that the fault rate is a function of the number of faults previously experienced. This may be particularly appropriate in situations where a number of faults have already occurred as it implicitly captures the effect of some of the parameters just mentioned.

The availability of joint data from the GIS along with historic fault data for each circuit enables such hypotheses to be
explored and, if validated, to examine the effect of the derived variations in fault rate on the values of the OFGEM Indices.

The first stage of the study, which was to examine a small amount of network to establish the means of interfacing the program, data checking, and methodology of analysis, did not have sufficient fault data within the sample network area to derive any significant correlations, but has indicated the need for more specific user tools to transfer network and other data. A much larger portion of the digitized network is now available including about 1000km of underground cable with several thousand MV joints. It is intended to report more detailed results at the conference.

LESSONS LEARNED

Large IT systems, in particular a GIS with very large data sets involve very large costs. Benefits are not realised until systems start being used. In many cases there have been large overruns in time and, it must be inferred, in cost. Some lessons can be learned: Systems can be changed or cancelled but data must be re-useable. It is important to be able to access data at all times. Systems need to be tested early on with real applications. As far as possible introduction should be staged with each stage giving practical benefits, i.e. allowing testing of both accuracy and usability with worthwhile applications. Some IT projects would prefer to isolate themselves to avoid distraction and changing objectives. This may be acceptable, provided the period is limited with clear deliverables, but if the period lengthens, then major problems lie ahead. It is preferable to set more limited targets for each stage and keep stages short.

CONCLUSIONS

The advantages of utilising a GIS for electricity distribution have long been recognised and have led to their introduction in a number of companies. There are, however, many pitfalls in the way of a successful implementation. Several such problems have been described in this paper. Probably of most importance is the need to recognise at the start of the planning stage the strategic issues that are involved in introducing any major data system over a long time scale, almost inevitably true for a GIS when extensive digitisation of paper records is required. First and foremost, it is not possible to foresee with any certainty changes which may occur in company structure, policy, or required applications over the period of implementation and over the much longer period beyond, during which the company plans to reap the benefits of the large investment in money and resources. The implications are that the ability to accommodate changes must be built into the initial plan. In particular, it must be possible to recover and utilise data from all systems and allow new applications to be added on top of the planned systems. Whilst in some cases, this may be by full integration using the interface and facilities provided by the GIS, often this may not provide an appropriate solution, and certainly not a quick solution, especially when the GIS is still under development. The view that the data ‘belongs’ to the GIS is fallacious. The data are company data and should be capable of being used for any approved company application.

The GIS at United Utilities enables data on assets, such as joints, to be available for network analysis. At this stage insufficient data are available to draw significant statistical results on the relation between fault rates and joints or line length. It is intended to report the results at the conference. The initial conclusion is that access to the GIS and its associated data will enable a much wider range of issues to be studied than hereto.

REFERENCES