"Application of Low-cost, High-performance, PC-based Mapping Systems in Electricity Utilities"[1]

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Abstract:

This paper outlines the advances made in PC Desktop Mapping Systems that are able to run on the standard of PCs commonly in use in most utilities and have very low costs per user. The paper also instances PC Desktop Mapping applications already being used in a number of electricity utilities and some of the new applications being developed for this environment.

It also discusses the critical issue facing any utility transferring to a mapping systems - establishing the mapping information database. Topics covered include migrating of existing data to a mapping systems, the collection of additional data, and using tools such as Global Positioning Systems and aerial photography to obtain spatial data. The interfacing of PC desktop mapping systems with both corporate databases and other mapping systems is also discussed.

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Introduction

When Desktop Mapping emerged in the late 1980's the AM/FM Geographic Information Systems (GIS) market had already been shaped, and was dominated by, minicomputer and mainframe based systems costing many hundreds of thousands of dollars, only affordable by very large organisations. Since that time some of these systems have migrated to engineering workstations, but have still required computer hardware costing many tens of thousands of dollars per user, and users need relatively high levels of skills to operate and access the systems. Typically, these systems have only a handful of specialist users, generally highly skilled technical personnel such as draftspersons or technical officers, and the systems are usually quarantined in special section of the engineering office.

Recent developments in personal computer (PC) based desktop mapping systems have made it possible to implement extremely cost effective Geographic Information Systems (GIS) for even small to medium sized electricity utilities. Desktop mapping systems now have features closely comparable to those previously only available on high-end engineering workstations or mini computers.

Now Desktop Mapping is the fastest growing segment of the mapping market. Some basic mapping functions have even been included in the latest releases of popular spreadsheet software packages, such as Microsoft Excel and Lotus 123.

Even where high-end AM/FM GIS has been installed, and the high cost per user has previously inhibited making access more widely available in the organisation, these organisations are now deploying PC-based mapping systems as a front-end to those systems as the necessary interfacing software becomes available. Often these new users are provided with customised applications, built with PC desktop mapping software, allowing them to perform very specific functions that need access the GIS corporate database but do so in a very user-friendly way.

Desktop Mapping Functionality

Present versions of PC-based desktop mapping software systems provide an extensive array of features. Typically, a full-featured PC desktop mapping system will include features such as:-

Map Display:

- *Layers* - Support for hundreds of layers with complete control over ordering, visibility (including automatic hide/display according to zoom level)
- *Zoom* - shrink the whole world to the width of the screen or show just a few centimetres of the earth with precision to a few centimetres
- *Projections & coordinate systems* - support for numerous mapping projections and coordinate systems - and for non-earth coordinates
- *Change View* - by zoom, scroll and "drag", view entire map or layer, position selected object in middle of screen, revert to saved view, etc.
- *Display of Raster Images* - and use of raster images as a base map layer

- *On screen measurements*
- *Symbols, regions and lines* - choice of colour or monochrome, shading, fills, line types, etc.
- *Labelling* - automatic or manual control of labelling of objects with choice colours, fonts and text rotation

Data Storage & Analysis:

- *Direct access to industry standard databases and spreadsheets*
- *Import of objects and attributes* from CAD and other GIS systems (through such interchange file formats such as DXF)
- *Remote database access* through client/server links to industry standard databases such as Oracle, Sybase, Informix, DB2, etc. on network servers, mini & mainframe computers, etc.
- *SQL Searching & querying*
- *Geographic Searching* including queries such as : within, contains, intersects, etc.
- *Geocoding of data* to determine positions
- *Thematic shading* of objects
- *In-built graphing and statistical functions*

Reporting:

- *User defined report layouts* including maps

Support for Customised Aplications:

- *Development language* or macro capability to allow building specialised applications automating processes .

Electricity Utility Applications

When a electricity utility commits to a network-wide GIS system they simultaneously commit to making an extremely large investment in GIS data - an investment that will soon come to dwarf the initial costs of the system. How successful any investment in a GIS will be depends on the "leverage" obtained from the data committed to the system. This "leverage" comes from making the data accessible to everyone who has a needs for it for their routine or irregular tasks. This wider access is usually facilitated by applications that allow more general users to draw on, or contribute to, the data while interacting with it in a manner that is appropriate to their level of skills, knowledge and needs.

Mapping is only one part of the return that should accrue from the implementation of a well conceived and executed geographic information system. Many benefits also come from having the mapping representation of the electricity network as the interface through which workers access the information they need in their daily work. This is applies to administrative, sales & marketing and engineering functions.

Electricity utility application in use or under development include:

□ System Mapping

Certainly a major benefit from a GIS comes from the way in which it meets the organisation's mapping needs. Some consultants have estimated that savings from this area alone amount to 40% or more of the total potential benefits. Indeed it is now possible to almost eliminate the reliance by a utility on paper plans.

The advent of portable computers - particularly tablet type units with high resolution screens capable of running graphic user interfaces, such as Pen Windows - and Desktop Mapping software has effectively taken mapping into the field for both data collection (see below) and reference purposes.

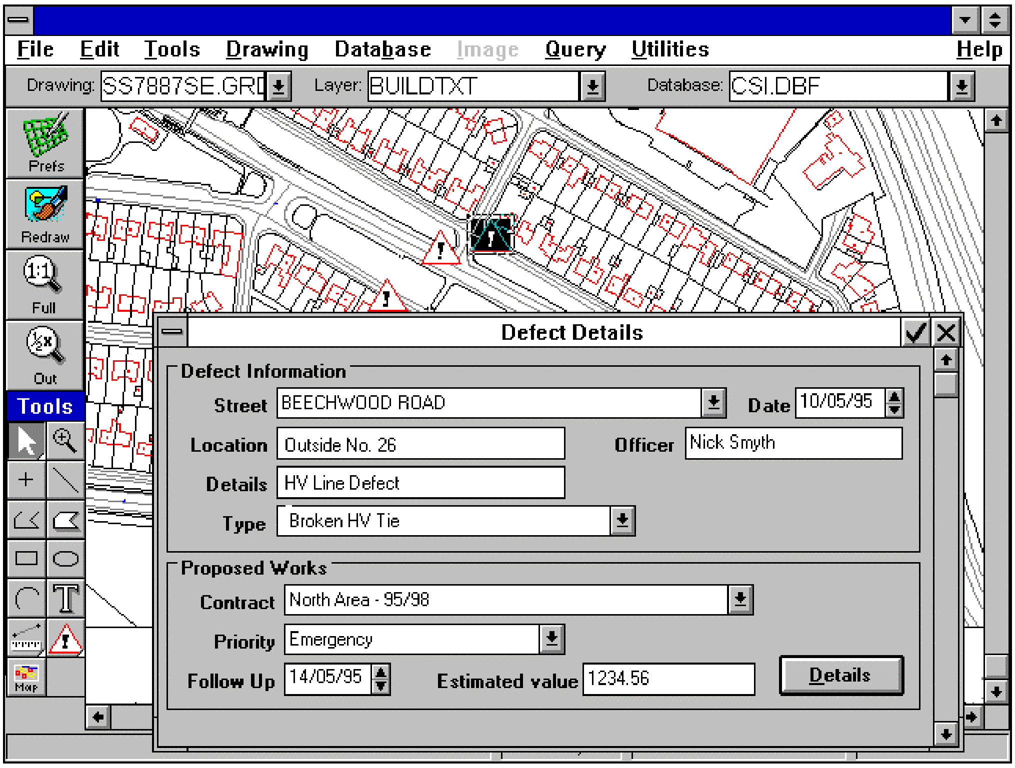

Figure 1. Field Based Data Capture using Mapping Software

□ Network Modeling and Analysis

A mapping representation of the network can be used to store technical details of the network characteristics - voltages, impedances, connectivity, etc., and be used as a source of data for system modelling and analysis - such as *Load Flow Analysis, Fault Calculation, Harmonic Analysis, etc* and, if results can be overlaid onto the network diagram, it also makes a valuable contribution to the interpretation of results of analysis.

There is a strong trend towards representing the network ***geographically*** and storing all the data behind this representation - and, indeed, making it the interface to the entire corporate database through which all users will “drill-down” to whatever the data they need. However, it needs to be remembered that when it comes to interpreting results of network analysis the best view of the network ***is not a geographic view***. When the relationship between parts of the system need to be readily comprehended - as when interpreting analysis results, or when operating the system - the better view of the network is a ***schematic view***.

Ideally, support is needed for both a ***geographic and schematic*** views in the GIS.

Another consideration is the level of detail in the data. If, for example, an aerial line is modelled down to the level of poles or structures and individual spans of conductors - which may be well warranted for many uses - it is not the ideal level of data for system analysis.

If all impedance data and connectivity information is at a individual span level of detail, and this data is to be used for system analysis, there is potentially and extremely large overhead for the analysis software to cope with in terms of the number of nodes and branches to be analysed - perhaps as much 10 or 20 times as much detail as is actually needed for analysis purposes!

What is needed is a more abstracted view of the data that reduces the unnecessary detail when creating study files for analysis.

□ Asset, Contract and Works Order Management

Another GIS application offering major benefits is in the management of a utility’s various assets and the management of work associated with them. This includes work carried out within the utility and, of considerable importance now, the management of work performed by external contractors.

Systems are available that are designed to be able to manage the full life cycle of an enterprises' various assets. Right from the time of their establishment or creation ... through the processes of:

- recording the attributes of the asset
- monitoring and recording their condition,
- collating and issuing instructions for remedial or maintenance work for action by external contractors or workers within the organisation,
- verifying work completion,
- maintaining a full history of the asset and work performed on it,
- reviewing its condition once again

... and right through till the eventual retirement or replacement of the asset. Or any part of that cycle. In this way it helps to maximise the usefulness and life of its assets and to maintain essential records.

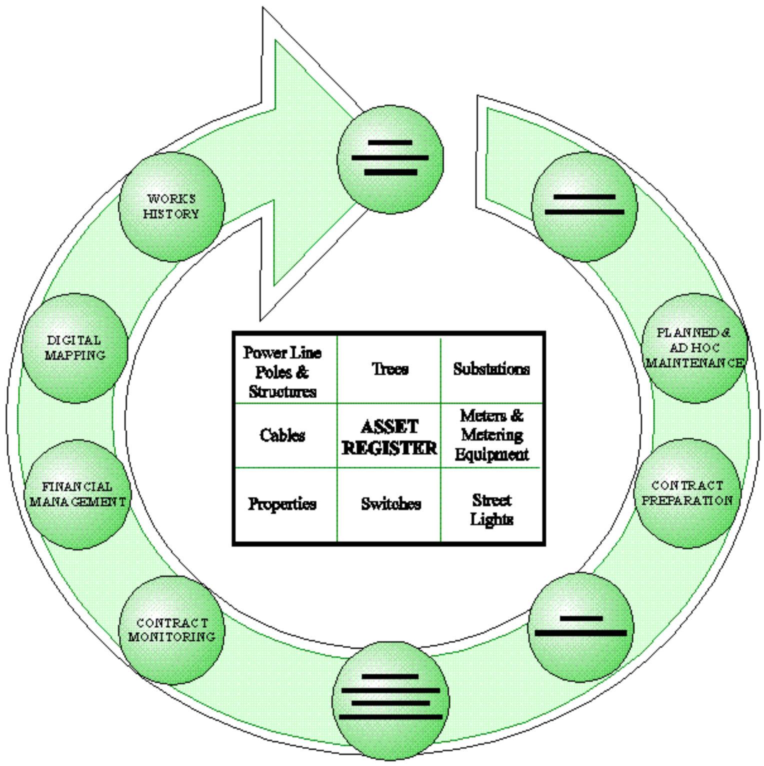

Figure 2. Asset Life-cycle Mangement by "COMPASS"

□ Power Line Route Selection

Mapping is a powerful tool to use in assessing and selecting power line routes.

Over a base map covering the proposed routes it is possible, for example, to add layers for:

- population densities
- land use
- flight paths for airports or agricultural landing grounds
- environmentally sensitive areas - national parks, nature reserves, aboriginal sites, endangered species habitats, etc.
- visually sensitive areas eg. ridges, skylines
- existing routes of power lines, railways, etc.
- difficult construction areas eg. swamp areas

and create “no-go” regions by merging appropriate regions from the above layers, plotting the possible routes and evaluating each one individually.

The evaluation of potential routes can then include buffer distances from the proposed routes to sensitive areas, line route length, accessibility of the line route, etc.

☐ Substation Siting

PC desktop mapping can assist in siting distribution or subtransmission substations.

Aspects taken into account can include the suitable areas available for substation sites, the maximum feeder lengths required to distribute power in an area, the zoning of adjacent areas and anticipated load densities, and the distances to existing high voltage power lines for connection to the network.

☐ Low/Medium Voltage Distribution Design

The design of low/medium voltage distribution design has been integrated with PC based mapping systems. The designer is able to import a subdivision layout from a CAD drawing (by importing a DXF file), digitise from a plan, or draw the feeder in a schematic layout (entering distances in this case rather than having the map system determine the lengths) and calculate voltage drops and loadings.

☐ Trouble Call Monitoring & Outage Notification

If customer phone numbers are linked to distribution substations supplying the customer (or addresses in urban areas), and customer telephone numbers are logged when they call to report faults or supply difficulties coded symbols can be generated on screen showing the affected locations. These data associated with these symbols can also be automatically date & time stamped.

Clustering of similar symbols will indicate the section of the network affected and guide the efficient direction of staff involved in carrying out investigations of supply faults and restorations of supply.

When a disconnected section of the network has restored following a fault, it is a simple matter to make an on-screen selection of a group of customers at the extremity of the restored section of the network accessing their telephone numbers to call them back to confirm that their supply has been successfully restored.

Similarly, when it is necessary to advise certain customers (eg. hospitals, water pumping stations, kidney dialysis machine users, etc) of a planned supply outage - particular when one that has to be done with little notice - an on-screen selection of the section of the network to be switched off can return the contact details for the customers concerned along with notations about their special needs.

☐ Vehicle Routing

Vehicle routing software can use map data on roadways, typical speeds of travel, and access restrictions (eg. one-way streets, load limits, etc) to select the most efficient route for vehicle to reach their destination, or a number of destinations in sequence, optimising the distance travelled or the time of travel.

Where delivery of materials to work sites is involved these systems can also take into account vehicle types and load capacities in planning the most efficient routing

Reported improvements from the use of vehicle routing systems have included reduction in labour used for planning vehicle routing of 80% while simultaneously improving efficiency of vehicle use by 20%.

□ Vehicle Tracking

Using Geographical Positioning System (GPS) technology it is possible to have key vehicles, such as Emergency Service Vehicles, tracked on screen showing the location, and recording the speed & direction of travel. A GPS unit fixed to the vehicle periodically transmits its location & other information over the vehicle's 2-way radio to the control centre where the data is extracted and used to update an on-screen symbol representing the vehicle.

With the vehicle's location displayed over on-screen mapping enables the control centre to also be able to direct the vehicle if the driver is unsure of his route to the intended destination or its relationship to the vehicle's present location.

□ Power Line Easement Management

Encroachment of trees into power line easements needs careful management. PC mapping systems can provide the basis for an ongoing management of a tree growth control program for action by utility staff or contractors.

□ Call Before You Dig (CBYD) Services

PC-based mapping provides a very cost effective solution to determining if the utility has any assets in the vicinity of a proposed dig and providing a map of the area, if required, showing the location details to ensure the assets are not accidentally damaged.

□ Management Reporting

The provision of in-built graphing and statistical functions that allow graphs to be superimposed on maps facilitate a new era in management reporting where the old adage is really fulfilled: "a picture is worth a thousand words".

Presenting performance data on regional areas - especially where decentralised responsibility has been delegated - by way of comparative statistics is a very useful management tool whether the data be rates of new connections, productivity statistics or electricity outage statistics.

Mapping System Data & Information

An important issue to be addressed when it decided to implement a GIS system is what will be the sources of data from the system?

What existing data, geographical and attributes, can be imported from existing systems - from existing maps & drawings and from databases and spreadsheets? And what data will need to gathered in the field, or from other sources. What third party sources exist for digital mapping data, what is the quality of that data, and what is the cost?

An important source of digital mapping data is national and state land survey and mapping authorities (such as the Land Information Centre in New South Wales, Australia and AUSLIG, the Australian Survey and Land Information Group). However, these are ***not*** the only source of useful digital mapping data and other sources should be checked.

Geographic Data Migration

The migration of existing data from CAD drawings and other GIS systems is a usually possible.

The most commonly available format for file transfer is the AutoCAD DXF (Drawing Exchange Format) file.

While the DXF file format supports the export of a considerable amount of detail and complexity (including not just lines, curves and text, but even 2-D and 3-D objects) not all implementations are the same. Some implementations may only quite basic line and text data.

Oher data formats may be able to be imported through the use of data conversion utilities.

Commercial services are also available to carry out data conversions between different formats and can also provide quality checks and, if required, manual adjustment of data. Some services of this type are located offshore in countries with labour cost are low even for workers with good levels of technical expertise.

Potential Problems

Some of the problems that may be encountered in importing CAD files into mapping systems include:

- identifying geographical reference points for the file to be imported
- drawings not true to scale
- joining up individual drawings as individual tiles in a region-wide map
- lines that appear to be continuous may not be at all. The drawer of the line may have drawn it in several sections which when viewed on screen or when plotted appear continuous. If continuity is important - and it often is - it may be necessary to manually convert individual lines to poly-lines
- extraneous lines may sometimes be connected when they should not be - eg. an arrow for a label - and may need to be manually split off.

Data Collection

Accuracy requirements

Careful consideration needs to be given to the accuracy requirements for any GIS location data. The is a natural tendency to think good engineering practice would be to require centimetre, or sub-centimetre precision. And there is some data that does need this level of precision - but much of the data does not!

The experience of some organisations that have set out to map their assets as accurately as possible has been that not only is it extremely expensive, but it *can also severely limit the useability* of the data collected.

For example, an authority that was mapping its cables located in footpath easements in an urban area, with easement often less than a metre wide, with some cables located above others. They found that, if all cables we mapped in their exact location, unless the user zoomed in extremely closely the various colour coded cables simply merged into a single black line with all the carefully recorded detail effectively lost!

Their solution was to abandon exact mapping and lay out the cables - virtually across the width of the footpath - so that users could readily see what assets they had in that area and, to compensate for the loss of plotted accuracy, they added location information - eg, cable easement cross sections, distances from property boundaries, depths, etc.

Survey

Use of licensed surveyors, or surveyor quality equipment - eg, theodolites, Survey GPS etc. will yield highly accurate data, but it is a very costly and relatively slow way of collecting data. Often its use is limited to special situations (collecting new base map data) or for establishing control points between which data will be collected by other lower cost methods.

Hand-held computers

Current portable computer technology makes it possible to collect both attribute and location data in the field. With a GPS unit connected to a portable computer it is possible t log location data while recording attribute data. There are also "tablet type" portable computers that make it feasible to take PC mapping software and digital maps into the field. In urban areas, if the user has full cadastral data (property boundaries, etc) it is possible to manually record the location of utility assets (poles, pillars, manholes, etc) with sufficient accuracy for practical purposes. In urban areas where there may be difficulties in using GPS units because of "shading" by buildings & trees or reflected signals, manual recording techniques have been found to be quite adequate.

Geographical Positioning System Units

Geographic Positioning Systems (GPS) units are now being increasingly used to record location details.

Without correction being applied to the data GPS units provide accuracy to within 100 metres of true position - but only because the data from the satellite system is deliberately degraded by the sponsor of the system, the US Department of Defence. The degradation varies with time and the accuracy of locations indicated is "within 100 metres 95% of the time".

However, if Differential Correction is applied to the data, accuracy in the range of 2 to 5 metres is possible, even with relatively low cost (< A$1,500) GPS units.

Differential correction can be applied:

- in real-time by having a radio link from a differential correction base station to the operator carrying out the in-field location detection, or
- by post processing, where the data recorded in the field is bought back to the base station to be corrected using the data recorded at the base station simultaneously with in-field data.

While GPS locations are usually carried out by hand, motor vehicles can also be used in suitable circumstances. Helicopters have also been used. One utility is known to have collected information on all its aerial lines by using a helicopter using GPS to record location details and using a video camera to record details of the pole construction for later encoding of attribute data in the office while reviewing recorded video frames .

Laser Measuring

Laser devices are now available that enable accurate measurements and locations to be carried by a operator, without assistance, using advanced reflective technology.

These devices are well suited to areas where other methods may not be effective because of the environment **eg**. GPS units in the vicinity of all buildings, overhanging trees, etc.

Aerial photography & Satellite Imaging

Aerial photographs and satellite images can be used for locating assets and to provide relatively low cost base map data. With mapping systems that allow importing of raster images (scanned photographs) to be used as base maps - with appropriate control points identified for registering the image to geographic coordinates - it is then possible to add layers over the raster image base map.

System Integration

Client/Server architecture

The trend now is to establishment of large scale Geographic Information Systems incorporating all the essential data of an organisation into large central databases.

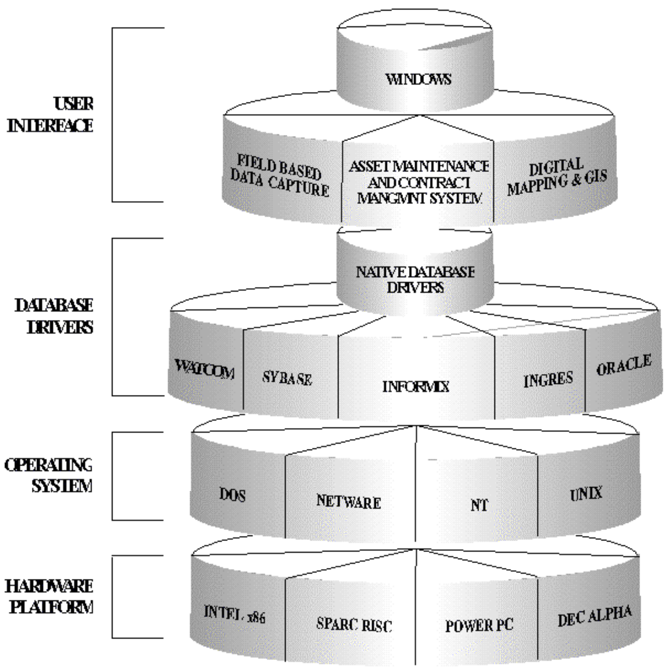

Figure 3. System Architecture - "COMPASS" Asset & Contract Management System

Through the development *of Client-Server computing architecture* and the rapid development of PC software utilities supporting the Client/Server model, PC-based Mapping Systems can play a key role in these technologies.

In a *Client/Server* computing architectures, a C*lient*, such as networked PC-based mapping application, makes a request - eg. a request for information from a database. The request is transmitted over the network that the *Client* computer is connected to and is fulfilled by a S*erver* that has access to the data requested. The requested data is transmitted to the *Client* without the user being unaware that their request was serviced remotely by another computer.

Interfacing to other GIS/Mapping Systems

A number of translators are now available for one-way, or two-way, data translation between desktop mapping systems and high-end GIS systems. These enable desktop mapping systems to be used as low-cost front-ends to these systems accessing their graphical data either on a "read-only" basis or, if updating of the data is to be carried out in the desktop system and saved back to the host system, in "read-write" mode requiring two-way data translation.

When considering the use of translator products it is important to know what are the limitations of the translator, as most do not provide for the full translation of all graphic and attribute details, especially in two-way translation … but for many applications full translation is not necessary.

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