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NEW DEVELOPMENTS IN THE USE OF GEOGRAPHIC INFORMATION AS APPLIED TO OVERHEAD POWER LINES

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New developments in the use of Geographic Information as applied to overhead power lines

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1. INTRODUCTION AND PURPOSE OF THE DOCUMENT

1.1. Historical Perspective

The earliest examples of geographic information system (an image and attribute information) may be traced as far back as the images drawn on cave walls near Lascaux, France by Co-Magnon hunters approximately 35 000 years ago. These images depicted animals that were hunted as well as their population numbers and migration routes. Further early examples include the mapping of cholera cases in 1854 by Dr. John Snow and the discovery thereby of the source of the disease: a contaminated water pump.

The development of Geographic Information Systems (GIS) as computerized capture, storage devices for, manipulation, analysis and management of information with a geographic location, started after the Second World War with the development of computers, pattern recognition and spatial analysis theory. In this regard the world's first true operational GIS were developed in 1964 in Ottawa, Ontario by Roger Tomlinson of the federal department of Energy, Mines and Resources.
(http://en.wikipedia.org/wiki/Geographic_information_system)

Today, with rapid development of the technology, these computer systems are very sophisticated and are used in many applications across the world with the Electricity Industry and Utilities being no exception.

In some cases records of infrastructure and safety clearance margins are either non existent or not reliable. This makes the optimal operation of a transmission system very difficult.

The bio-physical and social environment around lines is also dynamic and changes all the time. These include public acceptance, market and legal obligations and ongoing management of relationships with vegetation and other infrastructure such as railroads, pipelines or roads in the vicinity. In all these and other issues, GIS has shown itself to be a most useful planning and asset management tool for the electrical utility.

1.2. Advantages of the document to the utility

This document is not another GIS handbook, dealing with the technical aspects of the GIS in detail, but it is a strategy document that may be used by a utility to gain an understanding of best practices in GIS and highlight advantages of its application. The focus of this document is on the transmission function of that business.

In this document, the authors do not wish to apply any specific definition of GIS but will rather refer to the use of any geo-referenced information and associated systems that may apply to the electrical utility. Readers are referred to is:" *Empowering electric and gas utilities with GIS"* by Bill Meehan which cites numerous examples of GIS application in the electrical and gas industries.

Not all utilities will derive and experience the same advantages from the implementation of GIS. For example the organisation may be an established business with very little expansion and consequently little activity in the early part of the power line life cycle. This document is arranged in the stages of the life cycle of a power line, with examples of best practices cited. Social, economical and environmental benefits are described in accordance with triple bottom line accounting approach to sustainable development, where possible.

2. DESCRIPTION OF THE LIFE CYCLE PHASES OF A POWER LINE

2.1. Introduction

Numerous authors refer to the life cycle concept or “cradle to grave” concept in environmental management. (Ryding, 1992. p435) (Vigon et al., 1994 p1). Although definitions may vary according to differing circumstances, the life cycle of a power line includes planning-, permitting- construction-, maintenance- and decommissioning phases of the line. This is depicted graphically in Figure 1, although the terminology may vary slightly from one country to the next. The application of GIS to each of these phases reduces successively as shown in Figure 2.

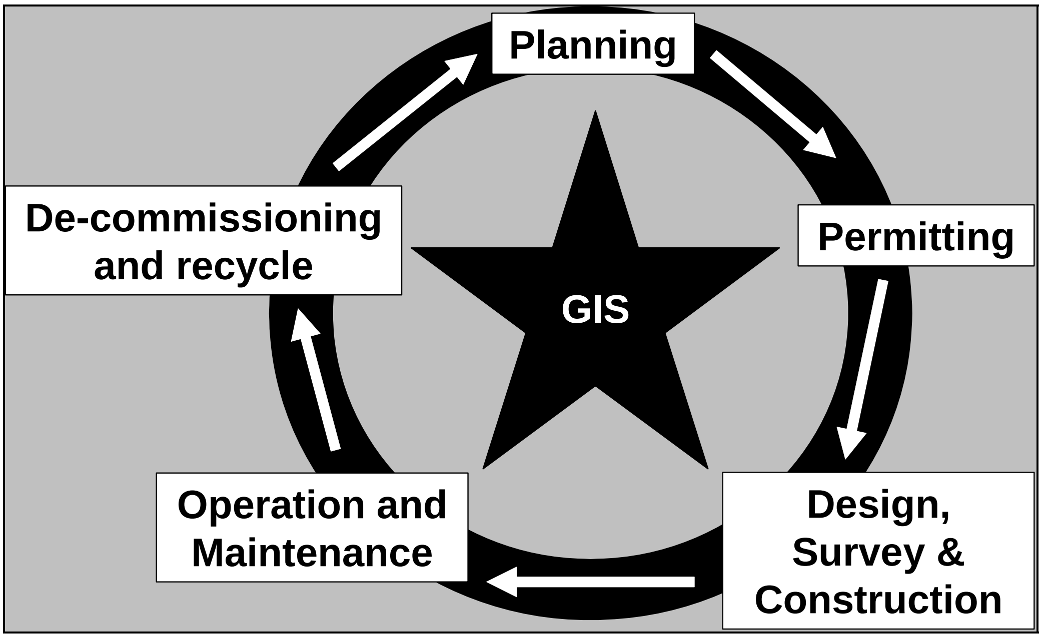


Figure 1 A diagrammatic representation of the life cycle of a power line.

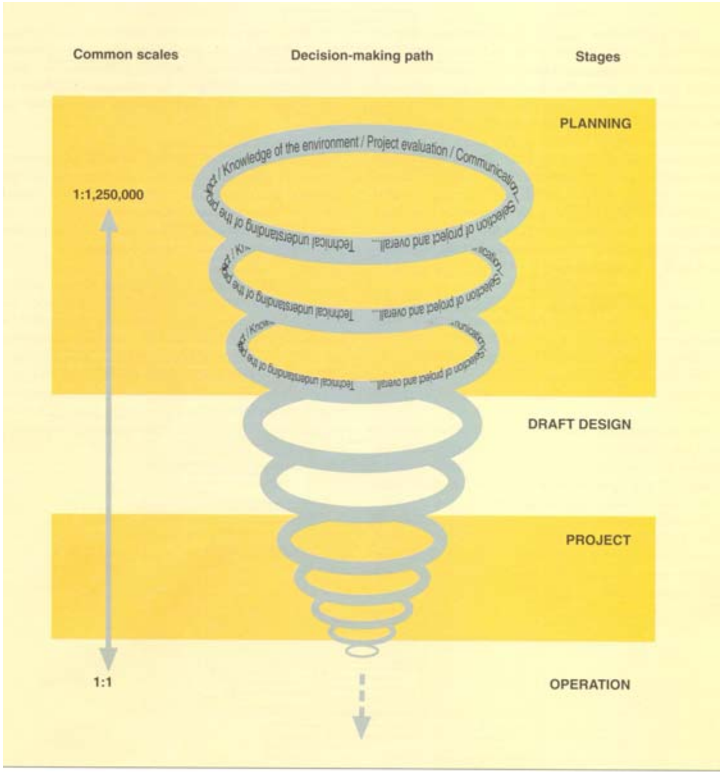


Figure 2. The successive reduction in the range of issues and influences under investigation is related to the different phases of the life cycle of an overhead power line. (Source: Hydro Quebec, 1990**)**

At the planning phase, a wider area is covered, while at the operational phase, the immediate vicinity of the overhead line is considered. The different phases of the life cycle do not, however, act independently but have an interaction and affect on each other.

The impact of a power line on the biophysical and social environment during the construction phase of the line is very apparent but temporary where managed appropriately. Examples are the impact of large equipment that is used to dig and construct foundations and erect towers. Also the stringing of conductors requires drum stations with large construction crews.

Long-term impacts of power lines include visual impacts bird collisions and electrocutions which endure for the life of the power line unless mitigated.

In the maintenance phase GIS based monitoring systems can provide a reliable asset and right-of-way condition information management tool. Poor maintenance of existing servitudes not only results in poor power quality, but also in disenchanted land owners and claims against the utility. During the acquisition of servitudes or right of way for new line projects, these landowners become reluctant to grant further servitudes and often resort to exaggerated environmental concerns in an attempt to either stall the process or get the line off their property. Either way, the implementation of a new line project is affected by legacy attitudes of land owners and the public with associated costs to the utility and ultimately, to the electricity consumer.

In a similar way, poorly conducted Environmental Impact Assessments (EIA) or negotiations during the early phases of the life cycle of the line, result in

problems for the maintenance personnel such as poor relationships with land owners, difficult access to lines and exaggerated claims for damages.
The personnel that carry out the EIA process and project manage the construction of a new line are normally based at Head office while the maintenance personnel are often situated throughout the countryside. As a result the communication between the groups is not always optimal. It is therefore important that there is an awareness, by all parties of a Life Cycle Management Plan (LCMP) to bridge this gap and play an integrating role. Although the aspects dealt with in the LCMP from one organisation to the next, it essentially documents how the organisation wishes to deal with the management of power lines, covering the total life cycle.
The integration of these phases using GIS is a key message of this document. The following sections discuss and define the various phases in the life cycle of an overhead line.

2.2. Planning phase

The planning phase refers to the time when the utility examines its network for the purpose of complying with the changing needs of the Market. Those requirements may come from the demand and reliability considerations.
During planning for the expansion of a transmission system, the interaction between the economy, natural resources and the transmission system are studied in order to ensure a timely and appropriate electrical infrastructure. GIS can prove useful in this phase.

2.3. Permitting phase

The permitting phase refers to the activities that a power line utility undertakes to enable it to expand its networks in response to the outcomes of the planning activities. These actions are typically undertaken as a result of, or, in terms of local environmental and other laws of the country in which the utility operates. GIS plays a vital role in the permitting and authorisation process where it enables the selection and comparative evaluation of route corridors. Many examples exist of the use of geo-referenced data during the authorisation process.

2.4. Survey, design and Construction phase

The survey, design and construction phase generally takes place after the obtaining of permission to construct a new power line project. All the GIS data captured during the previous phases can be used during the construction phase. Sensitive areas identified during the EIA are dealt with in terms of a management plan. The design of a new power lines makes extensive use of technology. GIS and LIDAR (Light Detection & Ranging , see page 78) makes a big contribution in this part of the process
An important but often overlooked aspect in this phase is the obtaining of accurate “as-built” information at the conclusion of construction. This will ensure that the overhead built by numerous participants (utility management, survey, design, negotiations, construction) complies with the original intentions of the planning phase. The GIS can (and should) play an integrative role in this phase and ensure that correct information regarding structure

location and comprehensive information on hardware components are transferred to the next phase.

2.5. Operating and Maintenance phase

The operating and maintenance phase of an overhead line commences with the commercial operation of the line and ends with decommissioning of the line. This phase can be up to 100 years or longer, much longer than any of the other phases. During this period of operation and maintenance of the power lines, the monitoring of the technical condition of the asset is very important for reliable, safe and efficient operation. GIS plays a key role here.

2.6. Decommissioning or re-cycling phase

Under certain circumstances it may prove necessary to decommission a power line or re-use either the structures or the right of way. These activities are covered under this heading. During the decommissioning or “re-cycling” of power lines, a full EIA is often required in some countries and GIS may be used in a similar way to that of 2.3 above. This section will concentrate on the re-use of Right of Way (ROW) and will not consider the hardware of the lines. This was covered in a previous Life Cycle Assessment Technical Brochure (O’Luin et.al, 2004).

3. PLANNING OF POWER LINES

3.1. Introduction

Load forecasting for the purpose of planning and expansion of power line networks used to be a simple procedure and for most utilities the customer consumption remained fairly constant from one year to the next. During the sixties, straight-line extrapolations of historical data were good enough for load forecasts. The electrical industry was experiencing stable prices and planning was straightforward. In the 1970s, fuel prices rose and more recently regulatory pressures intensified. In certain developing countries rapid development and structural changes in the economy made the forecasting of future load more difficult.
Distant actions also impacts on the planner. The “environmental” decision in Europe or the USA, to add platinum to motorcar exhaust systems (for catalytic conversion) , resulted in an increase in platinum mining activities in South Africa which resulted in new demand for electricity (see Figure 6). Business and regulatory imperatives required that the forecasts had to be more accurate. Plant construction lead times vary between 7 to 12 years and equipment manufacturers now require lead times of several years for the supply of some new equipment. The acquisition of rights-of-way is becoming increasingly difficult which adds to the lead time required to implement new schemes. These lengthy lead times places a major financial burden on a utility but also makes the job of the planners more difficult. Confident load prediction has become more difficult over the past decade, especially in countries with high load growth and dynamic economies. Even with more sophisticated techniques, utilities have more often been wrong in their predictions than being correct.
The essence of the planner’s work is to answer the three questions:

- <u>How much</u> load is required?
- <u>When</u> will this load be required?
- <u>Where</u> will this load be required?

It is essentially with the latter question that GIS is helpful.

Theoretical approach of the planner

The expansion of a power system requires load studies, fault calculations and stability studies. With load studies, voltage, real power (P) and reactive power (Q) are determined at various points in the electrical network under normal operating conditions. According to Stevenson (1975) power system engineers are interested in studying a power system as it will exist 10 to 20 years into the future.
The planning horizons that the utility may use can be stated in three categories, namely:

- **Long-term planning**. (strategic in nature)
- **Medium-term planning**
- **Short-term planning**. (Lead times are important. Must fit in with the strategic planning)

Table 1 The planning horizons for power lines (*source: Kiessling et al.,2003*)

	Long-term planning	**Medium-term planning**	**Short-term planning**
Years	**15**	**10**	**3**
Problems to be considered	Required power, overloads, stability.	Required power, overloads, stability, voltage levels, short circuit.	Required power, overloads, stability, voltage levels, short circuits.
Parameters to be defined	Capacity (ratings), voltage levels, terminal areas, approximate years.	capacity (ratings), losses, operative voltages, terminal substations, years of operation	List of operational constraints, needs to upgrade lines, anticipating of programmed facilities.
Model size	area or supply region	interconnected system	utility system

According to Tigas et al (2006) the planning of new high-voltage transmission lines displays a strong geographical character and requires as input, technical and economic data that will influence this process.
The input into the transmission network comes either from electricity generated by the utility's power stations and imported electricity from other sources. The electricity is then distributed by the transmission network to a number of distribution networks, power station loads, and exports to other utilities. By transmission, the bulk transfer of power by high-voltage links between generation plants and main load centres and between main load centres is implied. The distribution networks are connected between the transmission network and the end-use customers. Some authors however classify the electrical networks as the transmission system, sub-transmission system and distribution networks. For the purpose of this discussion the transmission network is defined as the electrical network connected between the generation plants and the distribution networks. The backbone of the transmission network is the electrical network not directly connected to the distribution networks, but supplying a number of transmission substations.
The main energy sectors that are considered in the planning process are residential, commercial, industrial, mining, agricultural and traction (rail transport). Over the years these sector loads have fluctuated in response to the economy with significant impacts on the area loads. It is therefore important to study the energy sectors to determine the impacts on the transmission networks, and provide answers to the questions; how much, when and where. In South Africa, for instance, a large down-scaling of gold mining activities took place in certain areas since the early 90s in response to both local and international economic factors, demonstrating the importance of area- and sector load forecasts and demonstrating the importance of these questions. As stated above, the "where" question is answered particularly well with the help of a GIS.
Gellings (1996) mentions that a number of important, and sometimes countervailing, factors are acting to change the future pattern of electricity demand in the United States. Some factors reflect major structural changes

in the economy and others include information about a shift in population and economic activity between regions. The simple extrapolation of historical trends into the future is no longer appropriate and the need for forecast results that include information about those factors becomes more critical. The depiction of these dynamics on a GIS system also aids their better understanding.

3.2. Activities in the Planning phase

The transmission load forecast process essentially consists of three activities:

- Historic load data analysis
- Transmission and distribution electrical networks modelling
- Forecasting the expected future loads over a twenty-five year horizon.

Each of these activities will be discussed below. The outputs are used for electrical network load modelling and identification of networks exceeding their firm capacity limits.

Historic load data analysis

This activity is essentially a statistical exercise and data analysis activities are carried out to:

- Check for incorrect data and faulty metering equipment
- Consider the load variation due to different network operations and network topology changes
- Determine the load variation due to different generation patterns
- Determine correlation between different loads
- Determine different network load conditions that may come about
- Check for trends, cyclical patterns and seasonality impacts on the network
- Establish load behaviours and distributions changes over the years
- Establish co-incidence and load factors changes over the years

In addition to the use of statistical methods, a number of expert views are incorporated in this task.

Electrical Network modelling

The modelling of electrical network includes the following activities:

- Selecting the distribution networks for load forecasting and network expansion studies
- Checking the electrical networks topology changes, and N/O and N/C point changes.
- Determining distribution inter-connections between transmission load substations

This exercise does not use GIS but rely on network analysis software such as PTI-PSS/E, ATP-EMTP or DIgSILENT. Load-flow analysis, short circuit transient simulations, protection coordination and harmonic analysis are some of the activities that are normally performed with this software. GIS does not play any role here.

The forecasting process

The forecasting activity is a sub-process within the main load forecast process. Through surveillance (scanning, monitoring and tracking) factors are studied that have significant load impacts on the transmission network. The factors are:

- **Regulatory aspects**. This includes national policies that affect the supply of electricity
- **Customers' reactions and preferences**. In some cases customers may change to other forms of energy. In other cases that option may not exist.
- **New technology developments**. This could include more efficient technologies or the introduction of DC in place of AC lines.
- **New generation methods**. The introduction of wind and solar power will also affect the planning process
- **Network topology changes.** In some cases a load growth will develop in areas with no existing infrastructure which may necessitate topological changes in the network.
- **Sector developments.** In countries where natural mineral resources are extracted, some sectors may show an increase in activity (e.g. platinum) whilst others may decline (e.g. .gold)
- **International and national impacts.** International macro economic development will influence the economic activity and the power demands associated with it.
- **Environmental aspects**. Aspects such as climate change and the environmental movement of the late 1960's have had numerous impacts on the electricity industry. This is likely to continue and increase and the planner needs to take this into account in his planning

In the next step different load forecasts are developed on the basis of the impacts of the above factors. A mathematical model structures the different forecasts as hierarchical and matrix structures and an algorithm and checks are carried out between the different forecasts for consensus. If consensus exists the results are used for network studies and modelling. The different load forecasts are:

- Maximum system load (demand)
- Available generation
- The transmission electrical losses
- The power station loads supplied by transmission
- The exported loads to neighbouring countries
- Geographical area loads
- Transmission load substation loads
- Distribution substation loads
- Area per sector loads (based on key customer and larger re-distribution customer load forecasts)
- National sector load forecasts

Geographical Information Systems (GIS) and qualitative based area forecast methods are studied for more informative load forecast results. The area forecast method steps are:

- **S-Curves** – plotting the expected loads. See Figure 3 below.
- **Objectives** - defining the reasons for the expected growths
- **Scenarios** - High , medium and low for each objective
- **Decision trees** – per scenario set

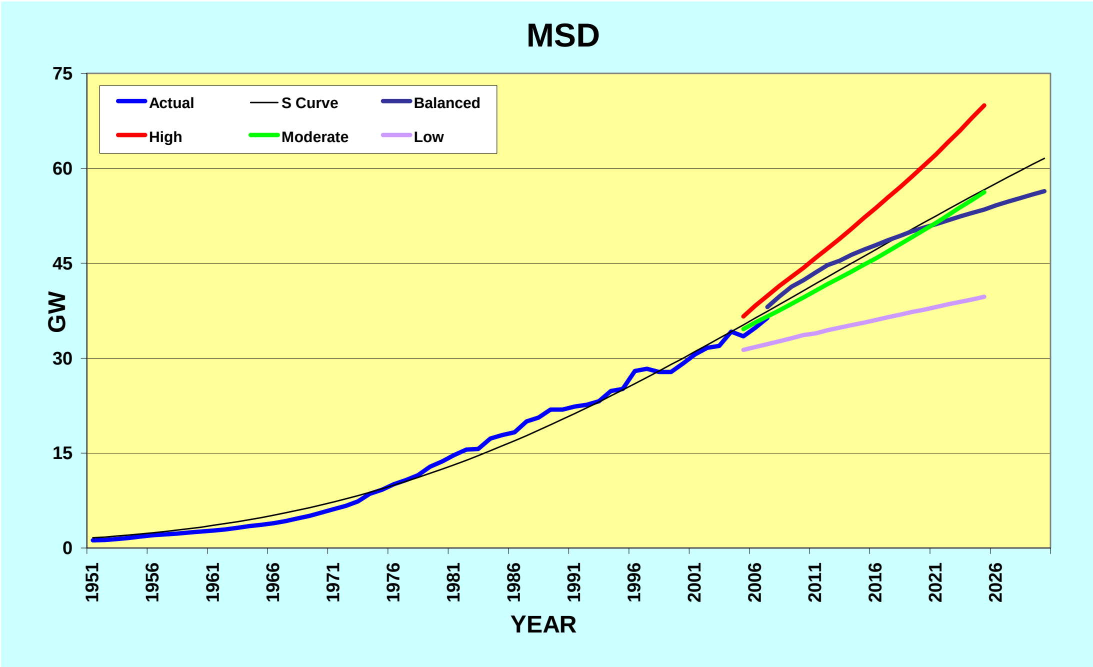


Figure 3 A long term load growth graph used in the planning process.(*source: Eskom 2007*)

As shown above, the load forecast exercise is a complex one and influenced by many internal and external factors. GIS can be a useful tool to the planner. In the section below, some applications of GIS in the planning will be discussed.

3.3. GIS applications

A Component based approach

A component-based approach (for load modelling) was developed by EPRI in 1976. The load supplied in bulk is sub-divided into load classes such as residential, commercial, industrial, agricultural and mining. Each category of load class is represented in terms of load components such as lighting, space heating, water heating, etc. Static load models (polynomial models) are commonly referred to as ZIP models. ZIP models are composed of constant impedance (Z), constant current (I), and constant power (P). The distribution

substation sector loads can play a major role to assist load modelling for more accurate representation of the real conditions.
In the examples below (Figure 4), some of the above components are shown in the model. These include activities such as mining and metals extraction (energy intensive activities) as well as population densities and existing electrical infrastructure.

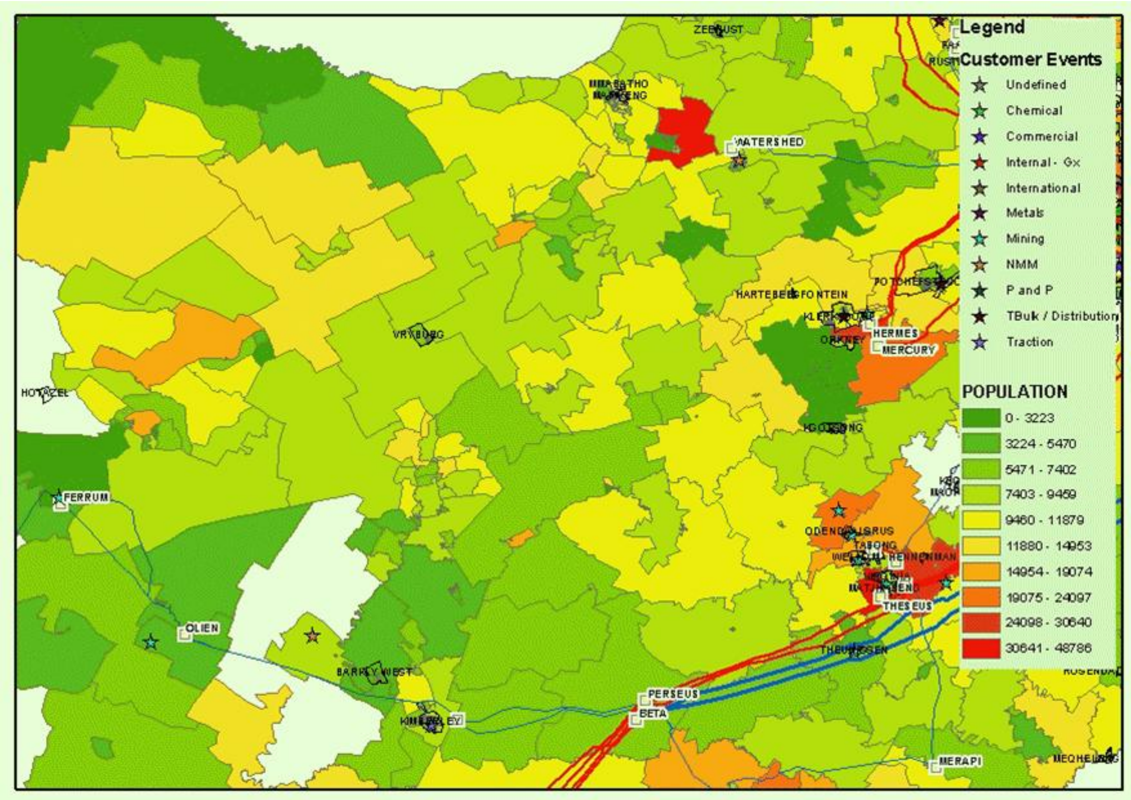


Figure 4 An example of a GIS used in the planning process. This map shows population, existing transmission resources and economic activities that will have an impact on future loads.(*source: Eskom 2007***)**

The location and quantity of energy sources for future generation plants can also be informed by GIS. In the example below availability of coal reserves are mapped and provide the planner with a visual representation of the areas where the deposits are. In Figure 5 and Figure 6 these are shown.

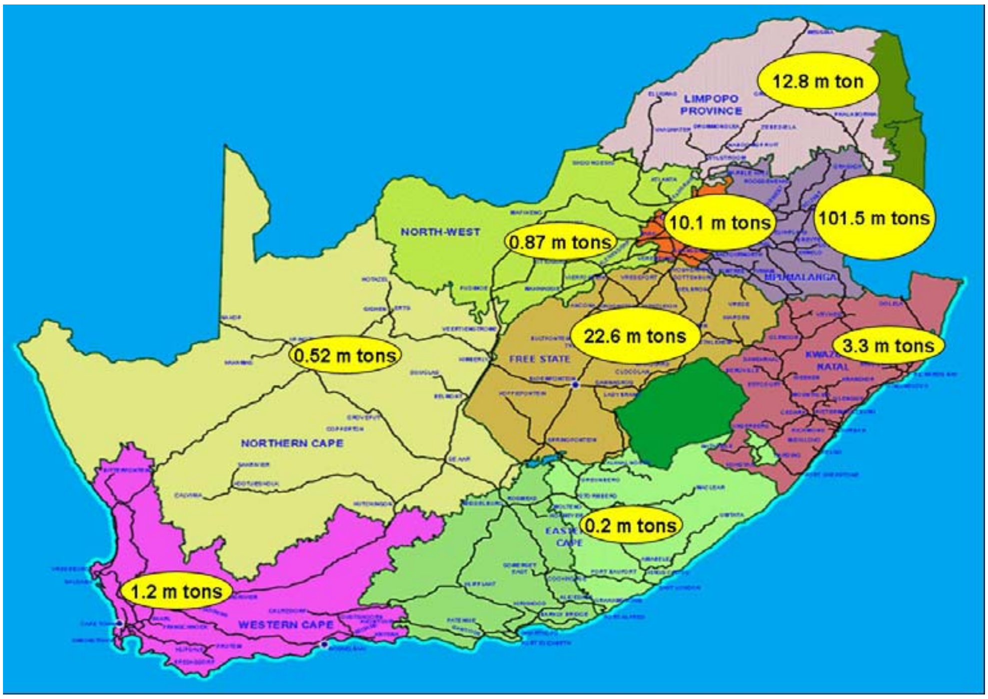


Figure 5 With the help of GIS the annual coal production figures and their location aids the planning process. (*source: Eskom, 2007)*

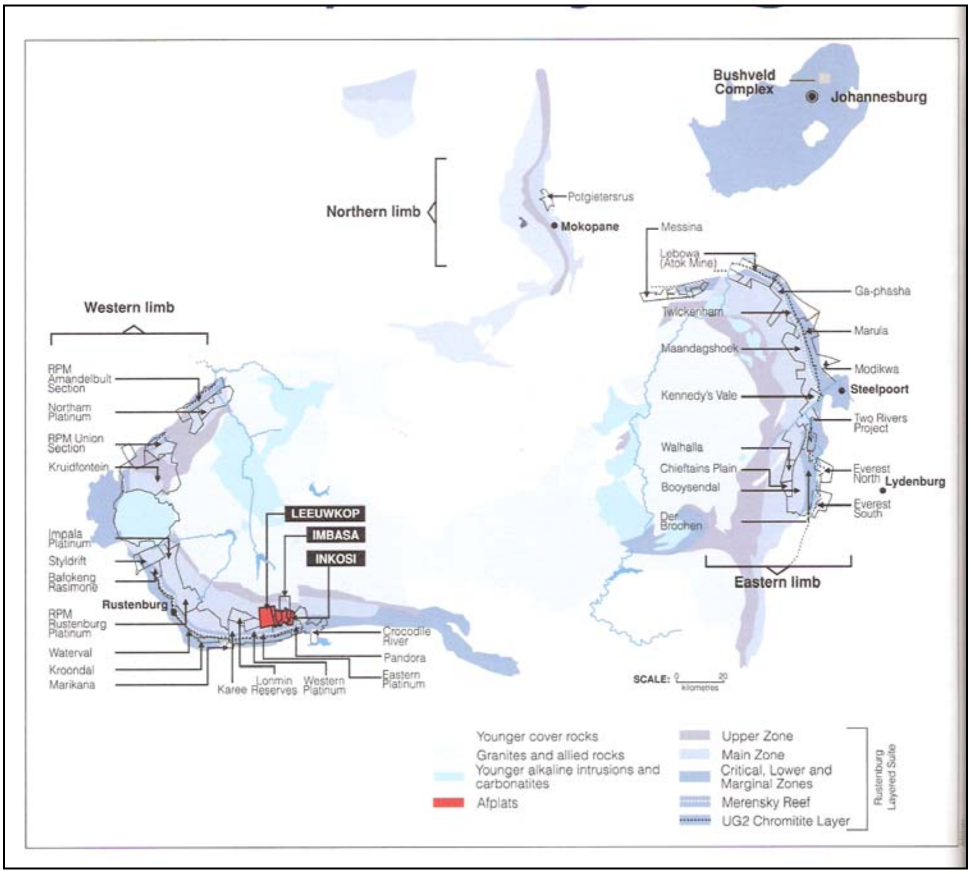


Figure 6. Planned mining activities will have a marked influence on the work of the planner. In this article the future mining of platinum is discussed. (source Mining Weekly Vol. 13 No. 15**)**

A case study in Greece

In an example cited in Greek islands of Laconia and the Kythnos, planners have built a model for planning the expansion of the electrical infrastructure (Tigas *et al*, 2006).
In this paper the authors describe the integration of technical, geographic and financial information used in the planning process. The core of the system that described in Figure 7 is based on the integration or ESRI map objects into Borland Delphi development platform. Three subsystems exist inside the core namely the mapping and electrical network model component – components as well as the scenario manager. The core system also interfaces with other programs such as PTI PSS/E and ATP EMTP

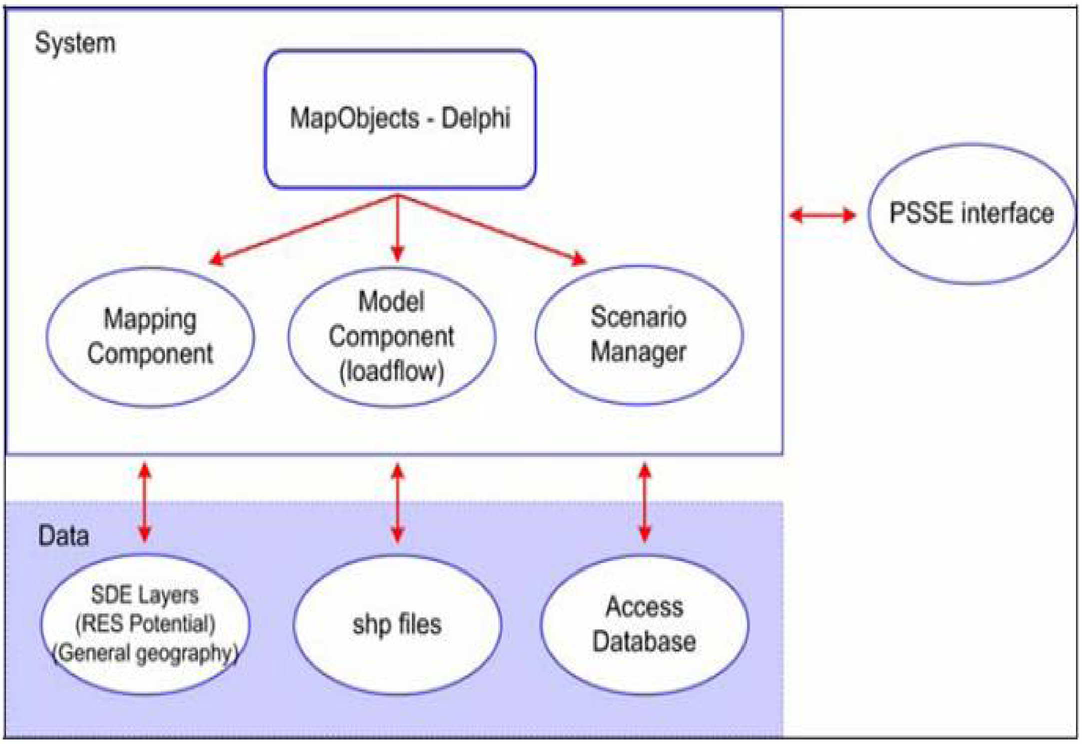


Figure 7 A graphic representation of the system used in the planning of electrical infrastructure in Greece (Tigas et al., 2006**)**

Three databases are used by the system. The SDE layers database holds the general geographic information and RES potential. The nodes and the segments of the digitized networks are stored in the shape files database. Finally the core interfaces with the Access Database. In larger applications an Oracle database may be used. The system has in the opinion of the authors has proved itself as a very useful tool in the optimisation of the planning process.

3.4. Benefits of using GIS in the planning phase

As described above, new challenges are emerging for the network expansion planner. The planning horizons are moving further away as longer lead times are required for new plant to be built and equipment to be bought. New customers have increased demands, not only for more power but the environmental requirements are becoming more severe. The planner needs to look at more alternative ways in which to supply in the demand for electricity and communicate his process clearly to the stakeholders. It is no longer good enough to use statistical methods alone. The geographic component that the planner has to consider has become both more important as well as more dynamic. Against this background the planner needs to be accurate as Regulatory requirements force the development of 5 and 10 year plans. If the forecast is not accurate, the demand will not be met or the utility will suffer financially as a result of over expenditure.

The weather (short-term) and climate (long-term) play an important role on the area loads (Cardelli *et al*., 1980). As climate change takes place, different energy (electricity) use patterns occur and the prediction of this phenomena and its impact needs to be modelled and predicted during the planning process.

Although it is not general practice, GIS makes it is possible to import information about factors and mapped it to the electrical networks. This helps the load forecaster understanding more clearly the most likely sites, where load centres can develop (question about where). By capturing different views of experts, scenario planning can be much easier and also gives a GIS overview to identify load growth centres.

GIS Intelligent systems can be applied in scenario planning to determine the most likely outcome of events. Therefore forecasts can be more informative and thus reducing the risk of the uncertainty associated with future load growths.

Other advantages are that planning engineers can clearly visualize the load developments in an area and therefore determine new substation sites and servitudes to bring in new overhead power lines as well as the ageing portions of the grid.

Long term load forecast has become extremely difficult over the years. Straight line projections no longer predict expected future loads adequately. A comparative load forecast method was developed by one author and it help to overcome some of the shortcomings of prior methods (Payne, 2004). This comparative method checks for consensus between different electrical load forecast (for example the maximum system peak, area loads, etc.). First a feasibility check is run and if consensus exists then the expected loads are determined. These forecasts are based on a set of factors capturing information about the most significant load growths. Combining GIS applications with the comparative systematic load forecast approach will most definitely be a powerful tool for the load forecaster to predict future expected loads. This will most definitely reduce the uncertainty of predicting future expected loads.

Whilst the benefits that may be derived from GIS in this phase of the life cycle may be easy to describe, the question of cost of these systems are more difficult. As will be described further in this document, cost of computer systems is only one part of the expense. The purchase of suitable data and the training of personnel could prove to be costly. It is however true that without these systems important decisions of the utility will remain to be at best an estimated guess.

3.5. Conclusion and recommendations

From the above discussion it is clear that the planning process is a highly complex one and is influenced both by the demands of external considerations such as the economy, power usage patterns and even atmospheric changes, to the demand placed upon it by the utility owners for a accurate planning process which will result in the timeous implementation of new extensions to the transmission system. This process is particularly demanding in countries with high growth in electrical demand. Requirements emanating from environmental, regulatory and social sources require that the planning process should cite alternatives that have been considered and describe why the particular choice is best. Price and technical considerations are no longer the only criteria to be used.

The use of GIS in this phase of the life cycle of a power line was discussed in this section as it fits in the variety of statistical and other methods used by the planner. The examples of where GIS technology is applied, however, remain few. The benefit to the utility in terms of an accurate and transparent planning process using GIS is evident, although it remains difficult to quantify in monetary terms.

The planning process, however, is not a means unto itself. It should inform the permitting phase. Although the use of GIS is still limited at this time, it will prove to be a useful vehicle to bridge the gap to the next phase in the life cycle of the power line, namely the permitting phase as it will enable the utility to clearly demonstrate the need for the new line.

4. PERMITTING PROCESS FOR NEW POWER LINES

4.1. Introduction

In the past, the prime questions that power utilities faced were how to optimize the transmission line and when the new line could be energized. Recently, in most industrialized countries, opposition to new transmission line systems has become severe. Currently the power utility has to find answers to the following questions: how can the acceptance of society be obtained, and how can legal problems be avoided, while still fulfilling the requirements of the authorities during the permitting process.

The goal of the permitting phase is to submit the project to the authority and have it approved with respect to the need for the project, environmental impacts etc., and also to give the general public and stakeholders an opportunity to express their opinion. In addition, improvements can be made to the project. Depending on the legal requirements, which may vary from country to country, different documents, are to be prepared, such as the environmental impact statement. The use of GIS can considerably assist the EIA process by overlaying different aspects applicable to the study as well as enhance the ability to view various impacts or consider alternatives.. Nevertheless, the amount of documentation for an environmental impact assessment (EIA) can be impressive, as shown in Figure 8. Such an enormous amount of investigation and effort can be more easily handled and coordinated through the use of a document system connected to the GIS systems.

Figure 8 Environmental impact assessment documents in voluminous paper form (Source: Verbund, 2007**)**

4.2. Activities in the permitting process

Environmental evaluation of the project

The goal of the EIA carried out for permitting purposes during the draft-design phase is to determine the optimal siting of the transmission line. It also aims to assess the project's impacts and identify mitigation measures allowing the project to be integrated as harmoniously as possible into the environment, with a view to sustainable development. This requires a rigorous scientific approach that can be replicated. Both quantitative and qualitative methods may be used, provided that the results of the qualitative analysis are fully validated. In addition, the method must be able to be replicated from project to project and within the same project in other words, given the same dataset and using the same approach, the route or corridor study must lead to the same results. In this situation, a Geographic Information System (GIS) can act as a useful decision support tool.

A communications program to inform and consult affected groups throughout the design phase is required. Consultation and communication activities must be defined and linked with the various stages of the EIA, and the anticipated outcomes must be specified.

- The draft-design phases have two main objectives:
- Optimum siting of the project from an environmental perspective
- Assessment of the project's impacts on the environment

The permitting process includes two major steps relevant to this document. The first is scoping for the corridor selection and the second step aims to define the final route. In the table below, the activities where GIS is most applicable are shown in red. These will be discussed in more detail in the text.

DRAFT DESIGN - STEP 1: Scoping for corridor

ACTIVITIES	TASKS (tasks in red are supported with GIS)	SPECIFIC OBJECTIVES
1. Technical understanding of the project	1. Delineation of study area (eg. 1:125,000)	Validate definition of study area and establish survey program.
	2. Information on project to the public concerned.	Environmental screening, identification of issues, communication with affected groups.
2. Knowledge of the environment	3. Inventories of study area (eg. 1:50,000) 4. Analysis and classification of elements.	Carry out survey on particular environmental sensitive elements (environmental, technical, landscape); classification by level of sensitivity.
	5. Identification of siting criteria	Identify restrictive or incentive elements or spaces.
3. Project evaluation	1. Definition of corridors.	Corridors are defined by means of a summary of the environmental, technical and landscape elements and all the elements that constitute siting criteria.
	2. Comparative evaluation of corridors.	Corridor evaluation by distance crossed in sensitive elements and by importance of impacts to determine preferable solution.
4. Communication	1. Consultation with affected groups.	Presentation of the preferable corridor; take note of advantages, disadvantages and the values attached to the elements by the population concerned. Visual demonstration of the extend of the public consultation
5. Corridor selection and final evaluation	1. Selection and adjustment of corridor retained.	Improve the preferable corridor by integrating the public's concerns.
	2. Final report for phase 1 of the draft design.	Summarize the issues underlying the final corridor selection .

ACTIVITIES	TASKS (tasks in red are supported with GIS)	SPECIFIC OBJECTIVES
6. Communication on selected corridor	1. Presentation of the final solution to the public concerned.	Public information.

DRAFT DESIGN – STEP 2: Final routing

ACTIVITIES	TASKS (tasks in red are supported with GIS)	SPECIFIC OBJECTIVES
1. Technical understanding of the project	1. Inventories of the corridor retained in phase 1 (eg. 1:20,000)	Validate definition of corridor and establish survey program. Environmental identification of resistance.
2. Knowledge of the environment	2. Analysis and classification of elements. 3. Identification of siting criteria	Carry out survey on all environmental elements (environmental, technical, landscape); classification by level of resistance. Identify restrictive or incentive elements or spaces.
3. Project evaluation	1. Definition of routes. 2. Comparative evaluation of routes.	Routes are defined by means of a summary of the environmental, technical and landscape elements and all the elements that constitute siting criteria. Routes are ranked by distance crossed in sensitive elements and by magnitude of impacts, in order to identify the preferred solution.
4. Communication	1. Consultation with affected groups.	Presentation of the preferred route; take note of advantages, disadvantages and the values attached to the elements by the population concerned.
5. Route selection and	1. Selection and adjustment of route retained.	Improve the preferred route by integrating the

ACTIVITIES	TASKS (tasks in red are supported with GIS)	SPECIFIC OBJECTIVES
final evaluation	 2. Final evaluation of impacts and mitigative measures. 3. Overall environmental evaluation of the project. 4. Monitoring and follow-up program. 5. Final report for phase 2 of the draft design.	public's concerns. Complete evaluation of the final solution and identify mitigative measures required. Summarize the evaluation and determine mitigative measures that call for special monitoring. Establish guidelines for monitoring and follow-up programs, in order to provide a framework for activities during the next phases. Summarize the issues underlying the final route selection .
6. Communication on selected route	1. Presentation of the final solution to the public concerned.	Public information.
7. Production of the environmental impact statement	1. Production of the final report	Establish the final impacts of the project.
8. Permitting – Government authorization	1. Evaluation of the project by the government authority	Issuing of construction permit.

4.3. GIS applications

The following section will describe in details the tasks as indicated in red in the previous table.

Definition of study area

The design of any new transmission line project must be based on a technical understanding of the project and knowledge of the environment. The technical characteristics of the project are defined beforehand in the planning stage and include such things as:

- equipment voltage
- the points to be connected (usually from a powerhouse switchyard to a transmission or distribution substation)
- a clear definition of the technical solution, including all required components (e.g., ground wire)
- any other specific requirements for the line design

Acquiring knowledge of the environment involves delineating a justified study area and conducting an inventory of the environment within it. It also requires a good understanding of the organization of the territory and related social and economic aspects in order to draw up a portrait of the entire territory. This must be based on considerations such as:

- areas or features with a distinctive character (e.g., tourist region, natural resources, conservation area)
- homogeneous components (e.g., large-scale farming operations)
- regional dynamics (e.g., land use)
- structural landscape elements (e.g., topography)

The definition and justification of the study area must take account of the characteristics of the biophysical environment, land use, administrative boundaries, the points to be connected in the line project, and obligatory points of passage such as an existing substation site or a crossing point for a large river. This is shown in Figure 9.
Depending on the scope of the project and the length of the line to be built, draft design can be carried out in one or two steps. According to government regulations, the requirements could be different from country to country .However in most countries two steps are a general practice. In the first step, the study area should be large enough to allow at least two separate corridors to be identified. During the second step, several alternative routes can be defined within the selected corridor.

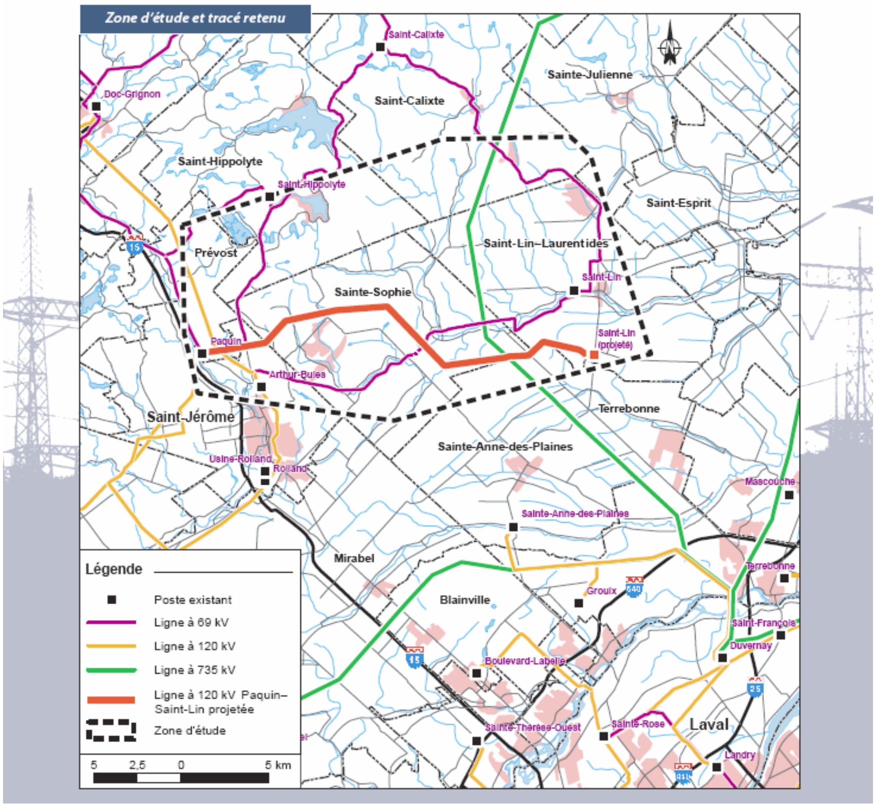


Figure 9 Example of definition of the study area (Source: Hydro-Québec, 2007)

This task is facilitated with the use if GIS where existing data can be easily visualised and imported to be combined with actual information for the project.

Data collection for the study area

Elements to be inventoried in the study area must include components of the biophysical environment, the human environment and the landscape that are relevant to the project. They must also comprise regulated elements, in other words, those required by law or regulations, as well as environmentally sensitive elements often valued by affected groups (see Figure 10).

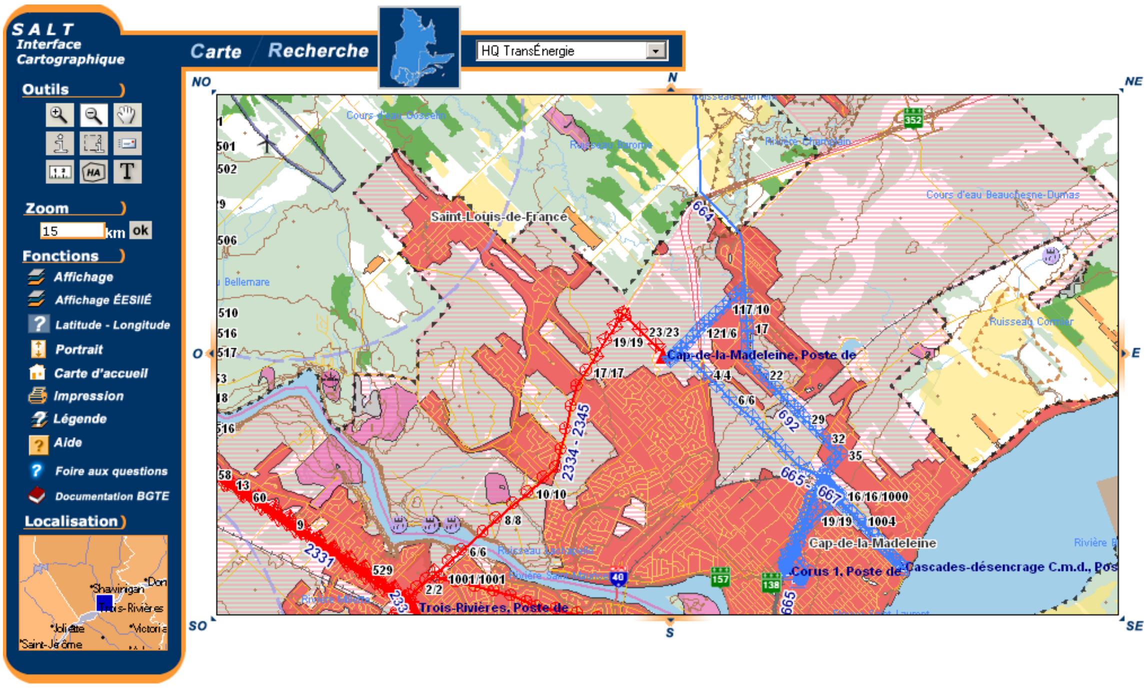


Figure 10 Data collection for the study area as shown in the GIS (Source: Hydro-Québec, 2007**)**

Survey data must be analyzed and classified so that their environmental sensitivity (corridor study) or resistance (route study) with respect to the project can be identified. The level of sensitivity or resistance is based on both the anticipated impact and the value assigned to the element.

In the corridor study, the value will generally correspond to that assigned by scientific experts while, in the case of the route study, the know-how of the project team members and the stakeholders consulted must also be taken into account. The anticipated impact and value assigned to each element must always be validated.

Data classification must be accompanied by an analysis of the structural components in the study area and zones associated with one or more aspects characterizing the territory in terms of the siting criteria retained. The results of this analysis will be used to identify elements to avoid or attractive elements in the line siting.

GIS provides access to large amount of data which can be used for example to the corridor study. Data can be transferred to display units. GPS can used to capture relevant and detailed information. Constraints observed are added and areas which require further study may be identified. Areas which are not accessible by road can be observed from the air using a helicopter and waypoints captured on the portable computer (Figure 11). Photographs can be linked to these waypoints. This system is invaluable in refining the feasible alternative corridors within the study area.

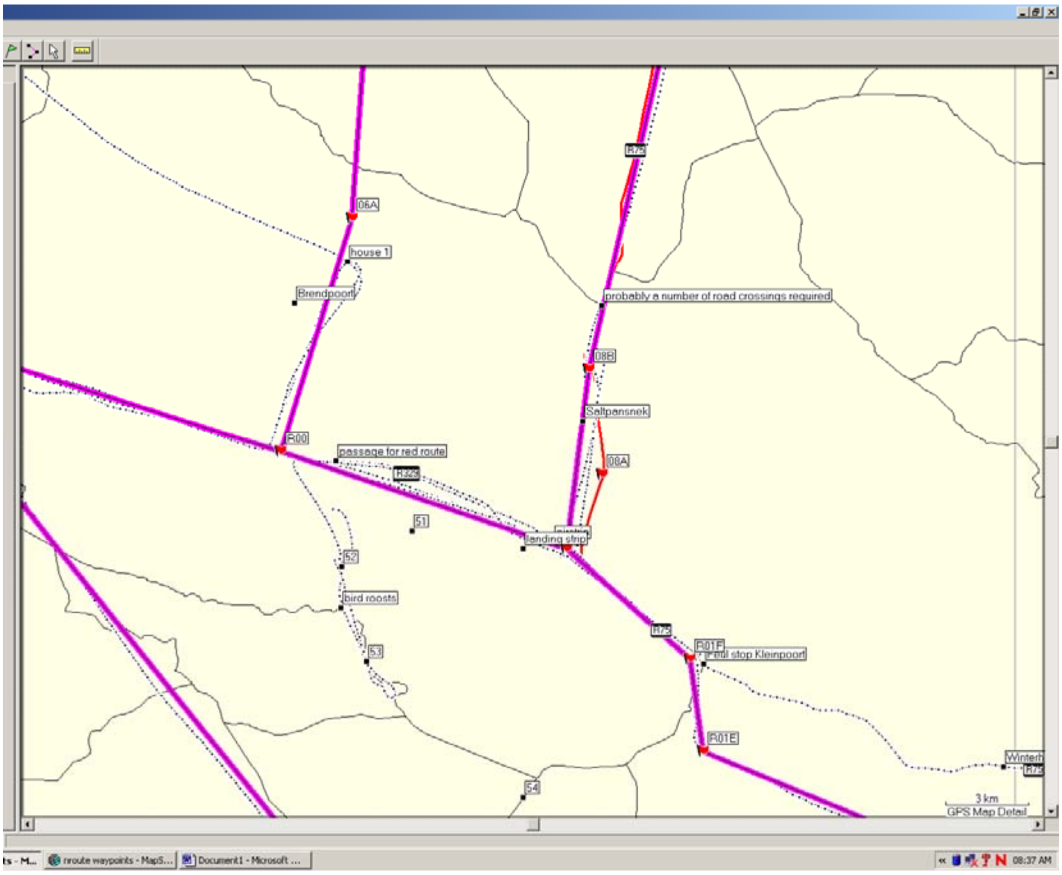


Figure 11 Collecting data in the study area for importing to the GIS (source: Eskom, 2007**)**

Definition of corridors and final route

Any siting study must provide at least two distinct variants, or alternatives, for both corridors and routes. Each variant must take account as much as possible of all the important environmental issues identified, the siting criteria selected, the inventory data classifications, structural components and any other aspects characterizing the territory.
Therefore, each variant should represent a choice in favour of one or more of the siting criteria. All proposed variants must be favourably accepted by the communities affected and must be also acceptable to the utilities company from a technical, economic and environmental standpoint.
GIS is useful in the initial stage of an EIA as it enables us to identify existing power line corridors using in-house data as well as other existing infrastructure data sets such as roads and pipeline servitudes. Restricting service infrastructure to corridors is a recognized environmental best practice.

Comparative evaluation of corridors and routes

Comparison of the variants must be done rigorously, and all long-term impacts of the new power line must be anticipated. In the corridor study, this

comparative analysis must include a qualitative assessment of the project's impacts on the entire territory. The impacts of the new power line on spatial organization, landscape and land use must all be considered.
In the route study, this analysis must be supplemented with a comparison of the surface areas of the elements affected by each proposed route.
Preferably, the new line should fit harmoniously into the landscape and, as much as possible, avoid de-structuring, or fragmenting, the territory (or ideally, even have the opposite effect in some cases). The variant retained from this comparison will then be subject to public consultations.
Data sets can be imported into the existing GIS system to further aid a more comprehensive understanding of the area for the purpose of comparative evaluation of new power line corridors,
Avoiding the mountain ranges indicated in Figure 12 would be preferred as they are representative of sensitive soils, ecology, as well as greater financial and construction burden. Formal conservation areas in Figure 13 indicate no-go areas for a new power line. Figure 14 indicates the formalized human settlements which the proposed corridor for a high-voltage power line would ideally wish to avoid.

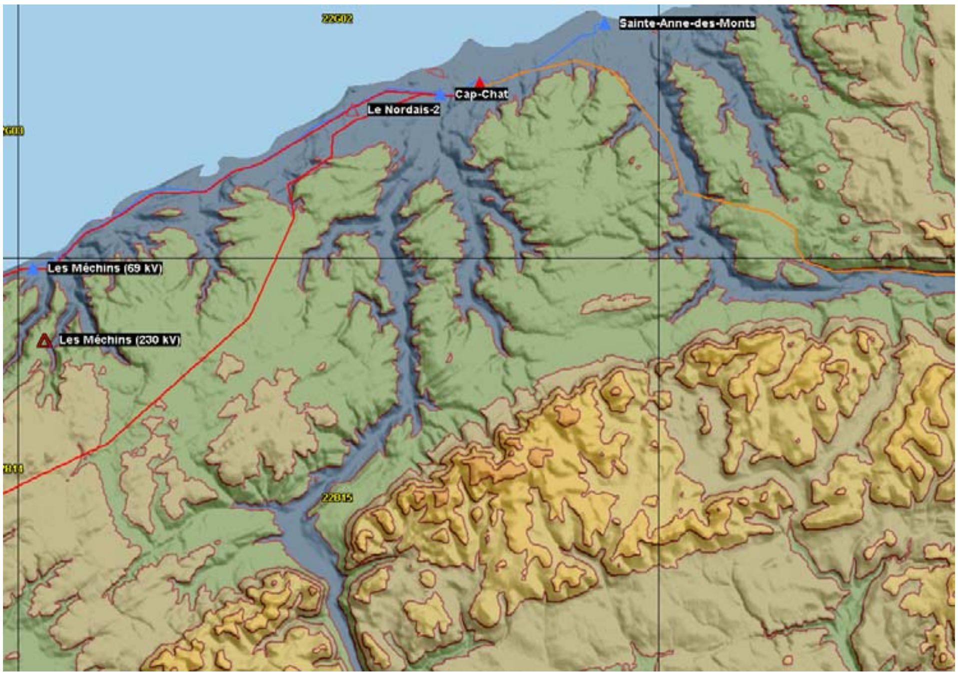


Figure 12 Topographical constraints in a study area. (Source: Hydro-Québec, 2007)

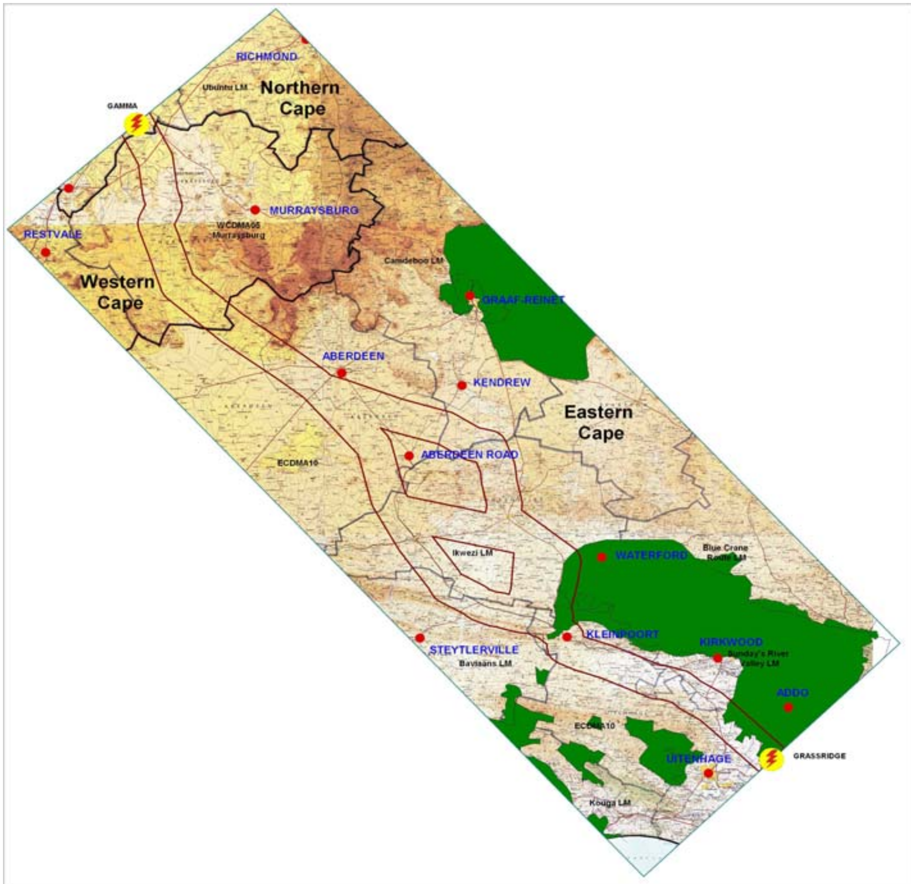


Figure 13 Conservation exclusion areas (Source: Eskom, 2007**)**

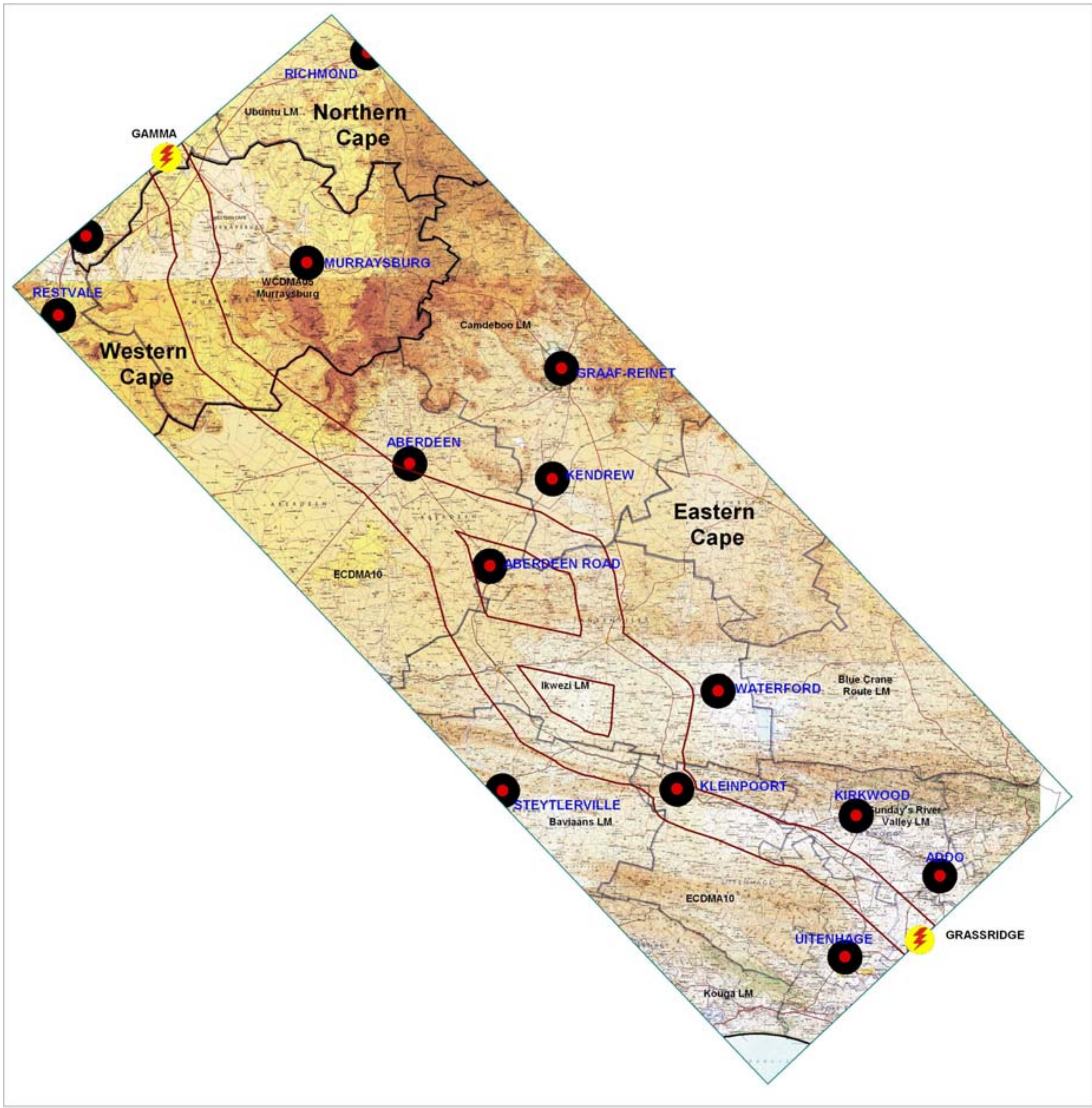


Figure 14 Human settlements within a study area (Source: Eskom, 2007**)**

Consultation with affected groups

Identifying affected landowners and capturing the contact details is imperative during an EIA, as well as recording their issues and concerns regarding the proposed project. Details of all these interactions can be captured graphically using a GIS. Figure 15 and Figure 16 maps the potentially affected properties and their identified landowners early and later during the study, as well as all communications with them.
In certain countries record of the consultation process is required for permitting authorities or in-house use to demonstrate sufficient public

involvement.

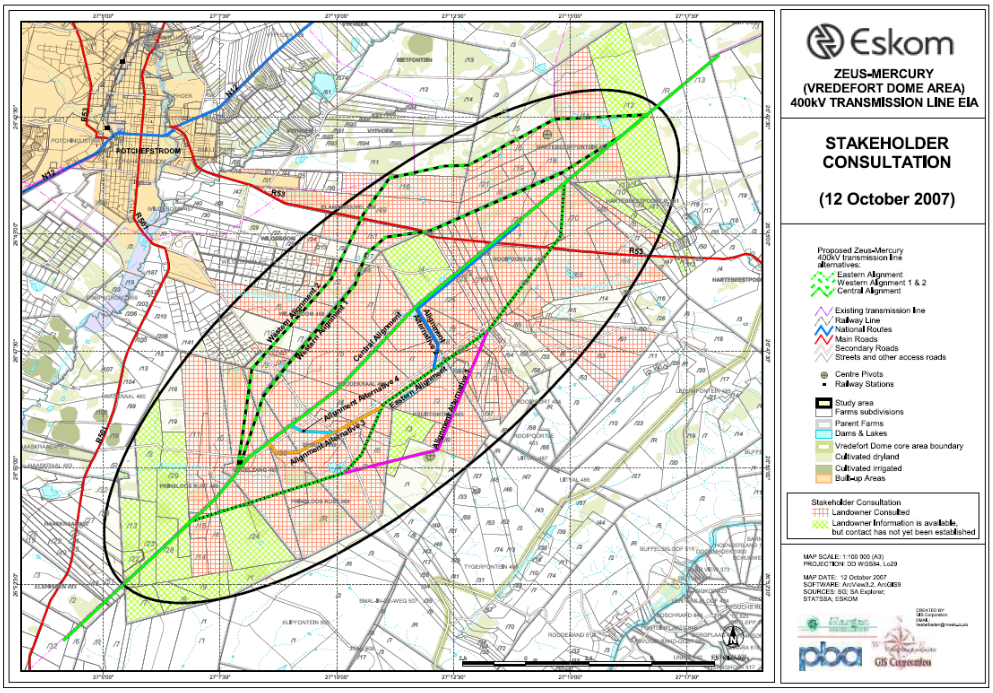


Figure 15 Record of identified land owners early in the study corridor (Source: Eskom, 2007**)**

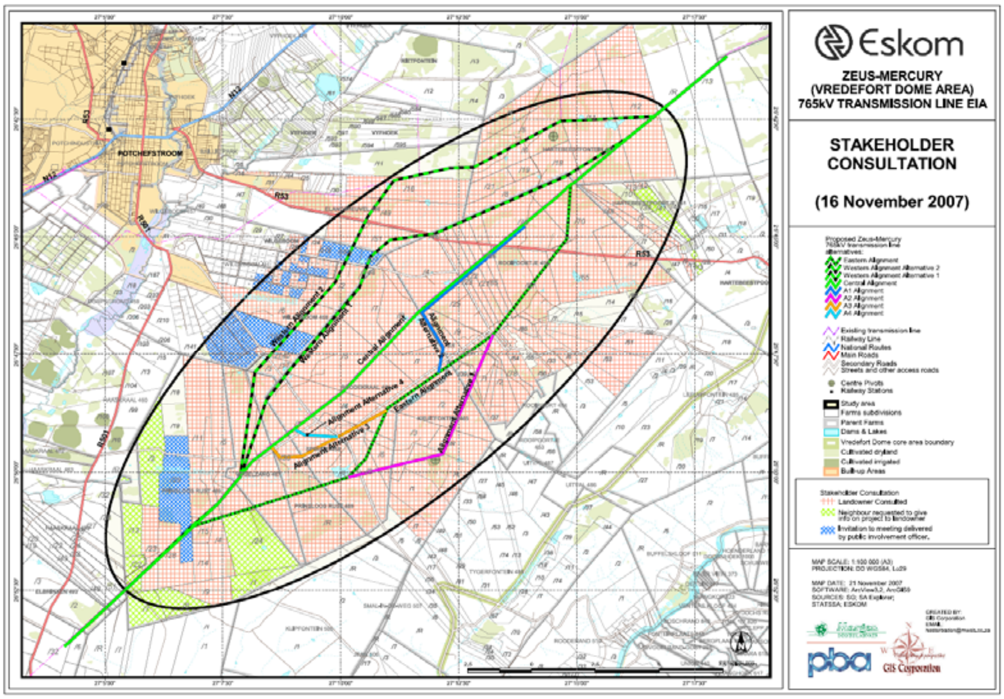


Figure 16 Record of identified land owners later in the study corridor (Source: Eskom, 2007)

Selection and adjustment of corridor and final route

The variant selected must reflect the principles of sustainable development, in other words, it must:

- have the least impact on the environment,
- best meet the siting criteria selected,
- take account of the results of the public consultations, and
- meet the technical and economic criteria for the project.

Requests for adjustments to the preferred route resulting from the consultations may be deemed acceptable as long as they respect the environmental issues and siting criteria.

Refining the corridors to eventually arrive at the final route for a new power line can take many months and may involve various specialists and an extensive public participation exercise. The public has valuable information and knowledge of their area. This information is required in order to ensure that a comprehensive study is undertaken.

The information gathered during an environmental impact study can be stored in the GIS (Figure 17*)* and then can be made available for evaluation by authorities.

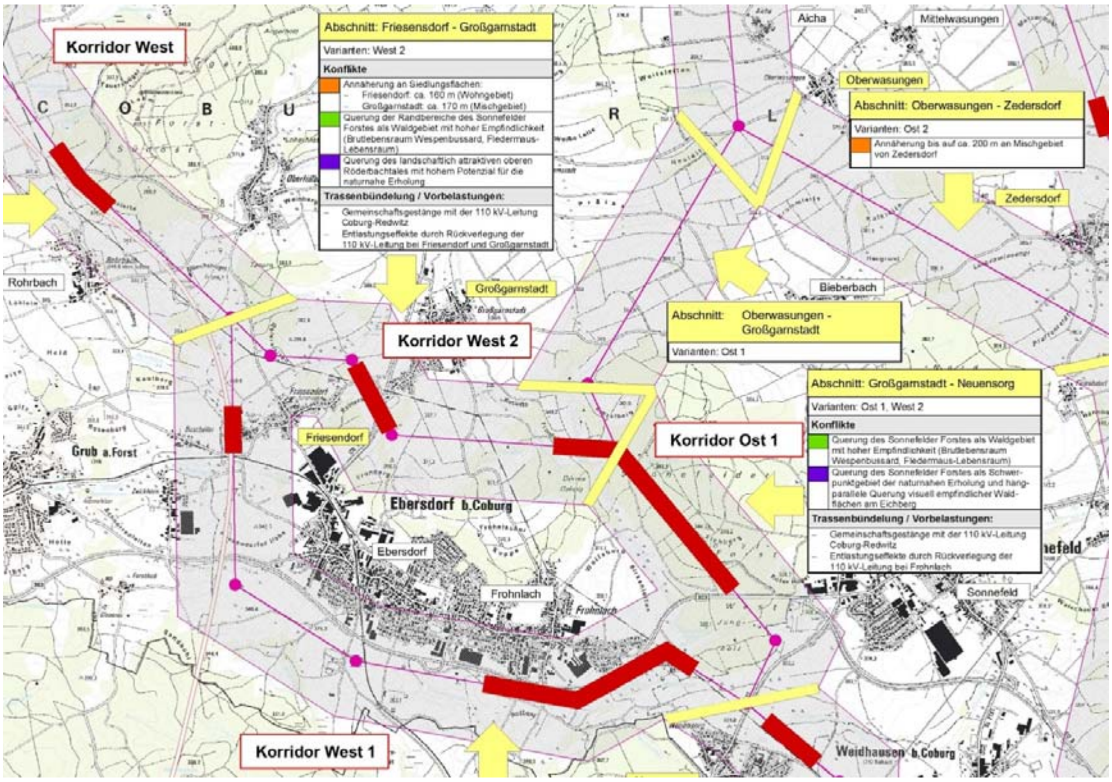


Figure 17 Constraints and remarks on the corridor from environmental impact study including mitigation measures. (Source: E.ON Netz, 2007**)**

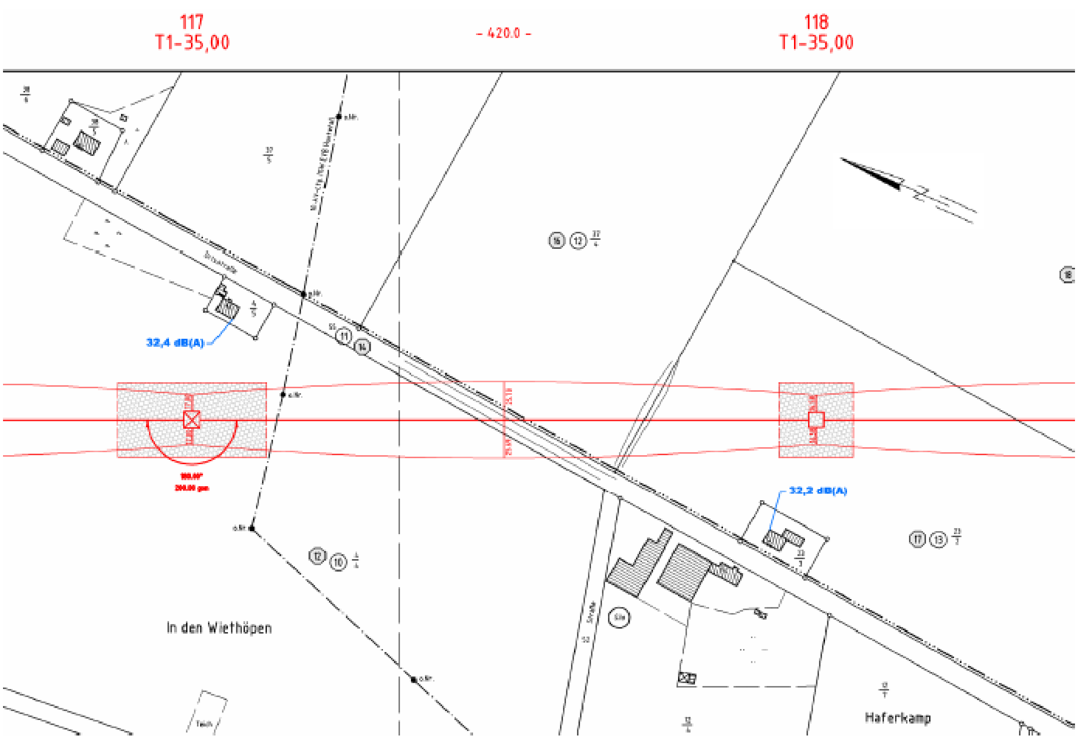
Presentation of the final solution to the public concerned

During the permitting phase the public is asked to express their opinion on the project. It is important to present clear explanations on the decisions taken during the design process. The various questions on line routing, technical configuration, impacts from electric and magnetic fields (EMFs), audible

noise, visual impacts, etc. often lead to intensive debates and call for clear explanations.
To present the preferred solutions (both corridor and route) to the groups affected, maps are required illustrating sensitive environmental elements and the issues taken into consideration in the analysis. GIS systems can be a very useful mapping tool in this context. Figure 18, Figure 19 and Figure 20 are examples of EMFs, audible noise and visual impact simulation. Figure 21 illustrates the corridor viewshed.

Figure 18 **Electric and magnetic field (EMF) representation. (***Source : Hydro-Québec, 2007***)**

Abbildung 3: Maximale Koronageräusche im Bereich der Alleinführung am nächstgelegenen Wohngebäude (Mast - Nr. 117 bis Mast - Nr. 118)



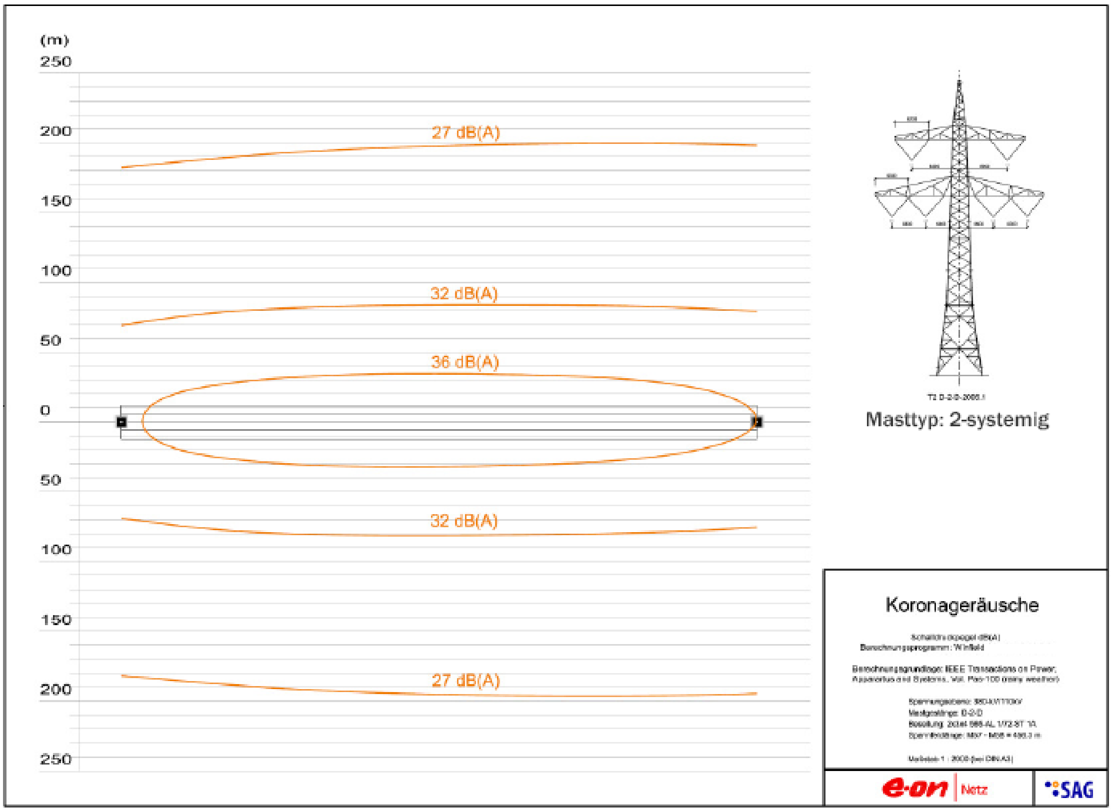


Figure 19 Audible Two examples of depicting audible noise (Source: E.ON Netz, 2007)

Figure 20 Photo-simulation for visual presentation. (Source: E.ON Netz, 2007)

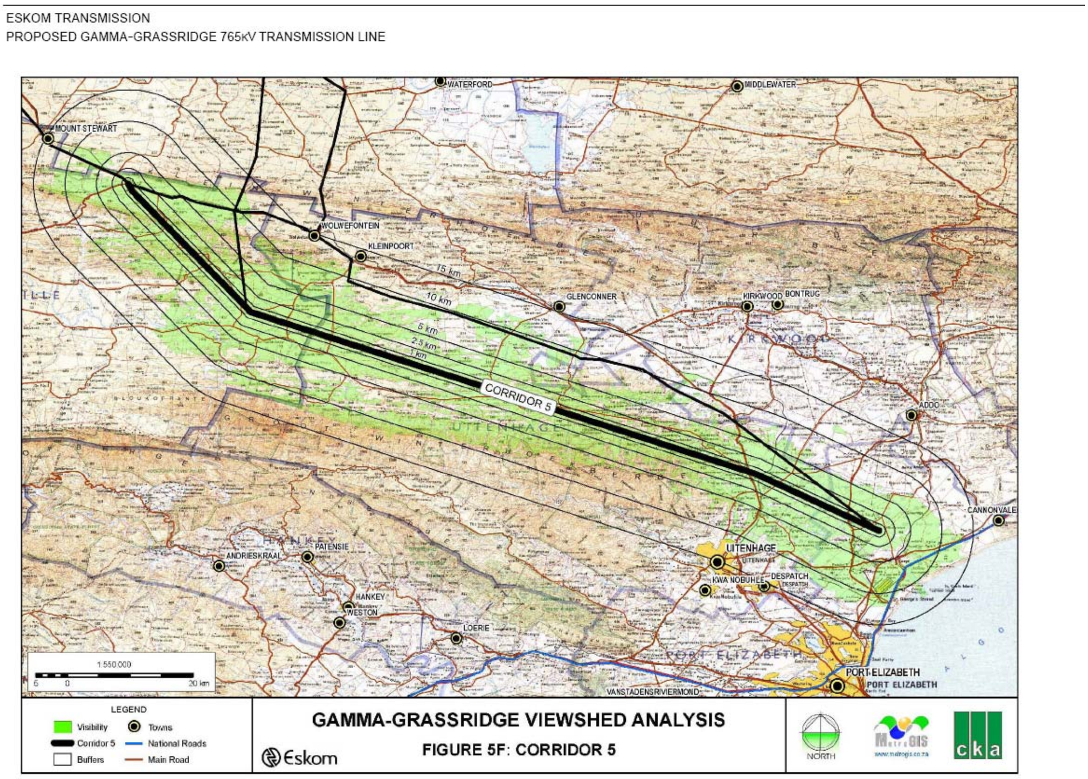


Figure 21 Corridor viewshed analysis illustrates the green shading area where the line can be seen from. (Source: Eskom, 2007**)**

4.4. Benefits derived from the use of GIS

Several map based documents have to be produce for the permitting process. The use of a GIS during the draft-design phase has a number of advantages. The purpose of the environmental impact assessment is to determine the optimum siting for the new line and accurately evaluate the project's impacts. With the conventional approach, preparing maps and analyzing environmental aspects were done by overlaying thematic maps manually to avoid areas of constraint and to choose areas presenting opportunities of low impacts. Engineers managing infrastructure, such as a new transmission line, were then limited to compiling facilities data manually. The difficulties with the manual overlay method include registering maps which may be published at different scales or projections. The more layers of maps required, the more the likelihood of human error entering the analysis and the longer the process takes. New technologies and approaches with GIS can take maps from different sources and different formats, and register them easily. This ensures consistency in multiple layers integration as well as allowing the flexibility to try alternate scenario analysis.

The effectiveness and efficiency (i.e. benefit against cost) of the GIS will depend largely on the quality of initial field data captured as well as updates. The database itself presents the most important component for GIS implementation success.

GIS systems are an effective tool in integrating environmental, technical and economic data. They offer the following key advantages:

- comparative scenario analysis
- spatial and visual analysis
- data integrity
- decision support
- improved in-house communication

Comparative scenario analysis

Any new transmission line project must include the study of different technical scenarios. A qualitative analysis of the effects of the future line on the territory as a whole is required, including the spatial organization of the territory, landscape and land use. In this context, a GIS makes it easier to compare the alternatives under study.

The production of thematic maps is facilitated, such as maps of land use, vegetation and topography. The unique combination of certain features helps the creation of such thematic maps. With the various modules and functions available, it is possible to calculate surface, length, width and distance. Lastly, in the route study, the analysis can be supplemented by a comparison of the area of the environmental components affected by each proposed route. Such calculations can be carried out automatically, thus providing quicker results that are demonstrable and replicable.

Visual and spatial analysis

Digital Terrain Modeling (DTM) is an important utility of GIS. Using DTM/3D modeling, landscape can be better visualized, leading to a better understanding of certain relations in a specific study area. Many relevant calculations or infrastructure modeling become easier, such as simulating tower siting in such a way as to minimize visual impact as well as to optimize the number of towers.
Geographic information systems facilitate data integration. Owing to their multiple functions, they allow various “what if” analyses that would be difficult using a conventional approach. Such systems also allow greater flexibility in comparing data. Their quick processing speed enables users to explore various hypotheses and discover interesting solutions.
Not only in the previously mentioned fields but also in the social sciences, GIS can prove extremely useful. Besides the process of formulating scenarios for an EIA, GIS can be a valuable tool for sociologists to analyze statistical data such as population distribution, market localization and other related features involving an important spatial component.

Data integrity

Working in a line project involves many users as well as different data sets. The users are under a hierarchy level which will require different data accessibility which will be well controlled by the GIS system. Limited number of people will have the rights to import, read and modify data. This will ensure data integrity.
The database is stored on servers which provide secure backup structures.

Decision support

The adage "better information leads to better decisions" is as true for GIS as it is for other information systems. A GIS, however, is not an automated decision making system but a tool to query, analyze and map data in support of the decision making process. GIS technology presents advantages to assist in tasks such as presenting information maps for communication purposes.

Improved in-house communications

A GIS requires the establishment of a shared geographic database of geo-referenced data. In-house data sharing (over an Intranet, for example) provides a very advantageous means of internal communications. Users will find that a GIS improves communication, reduces needless duplication and increases overall productivity, therefore benefiting the entire company.
Using a GIS also improves external communications. For example, with a GIS, an electrical utility can maintain a database on the landowners affected by its facilities and, when required, produce information letters on a proposed project simply by using a spatial intersection query on the proposed route and the lots affected.

4.5. Recommended guidelines

The following recommendations focus on the permitting phase of a line project life cycle. In different countries this permitting process will differ but these guidelines could be adapted in order to meet the individual requirements.

Shifting to new technologies

Since computer technologies are continuously advancing, it is important to keep up with them. In particular, it is crucial to assess right now the consequences of not being ready to adopt the new spatial reference system technologies and particularly to identify the prerequisites for adopting the new technologies within a reasonable timeframe and at an acceptable cost.

Building a database on the territory and environment

To carry out various technical and environmental analyses for new transmission line siting and construction projects, a thorough knowledge of the territory is crucial. Using a GIS requires extensive information on the territory, land use and the spatial distribution of certain phenomena. Therefore, we believe that the shift to this new technology must begin with the setup of environmental database to meet our needs for the permitting process. An example from Europe is the INSPIRE Directive that proposes to create infrastructure for spatial information. RTE's north-western region is participating in this venture with digitizing of the cadastre.

Electrical utilities would greatly benefit from a large-scale thematic inventory project in which each discipline could contribute a piece of the puzzle and thus make the task less onerous. A joint project by a consortium of government, regional and private partners involved in land management and development to harmonize the database content and terminology would have many advantages. Each partner could make a contribution to the data in its own area, using jointly agreed-upon terminology with clear definitions of each inventory element. In addition, technical specifications for data digitization would have to be developed to ensure consistency from the various producers of geo-referenced data. Such documentation should include appropriate mapping scales, a protocol for the cartographic representation of various inventory elements and data exchange formats. A protocol must also be in place to ensure data integrity. This type of approach would favour the creation of a multi-use database and significantly lower development and implementation costs.

Lastly, the flexibility provided by digital mapping and geographic information systems allows different information to be combined depending on the nature of the individual project, thus providing the possibility of an infinite range of products arising from a common source of geographic data.

The maintenance of the database is very important. In order to reduce effort in updating all the layers of information, a good practice is to set up a regular program to import current data directly from the different sources.

Promoting advances in remote sensing

Advances in remote sensing are required for the rapid inventory and updating of different types of thematic data (particularly in agriculture, forestry and urban planning). Satellite images, airborne scanning systems which have become increasingly less expensive, cover a wide area and provide recent information on the environment. Partnership and cooperation between the various organizations involved in both image acquisition and processing could be very fruitful when requirements are shared and efforts are centralized.

Developing specific computer applications

A number of GIS products are currently available. Therefore, we do not recommend any particular product but open source interface is essential in choosing a product. This will enhance the products' ability to accept data from a variety of sources. On the issue of functionality, an appropriate software package should be chosen that provides those basic functions the utility requires. Any further special functions required, for example to optimize the search for the preferred solution (route or corridor), can be developed and added.

When an existing methodology, involving description of all detailed draft design activities, is available in-house, it becomes much easier to transpose the processes into computer applications. Analyzing what to do and how to do it in great detail is a long and arduous task but forces one to clarify all the grey areas that often occur with conventional methods. It must be understood that, in order to obtain a computer generated product that follows the same logic as a conventional approach, no stone must be left unturned. This means that designers of computer applications must take account of all intuitive decisions and judgements that analysts make during a project and then determine whether they are part of the logical method developed for the process. If the answer is yes, the designer can transpose them, point by point, to the GIS system and insert them in the correct sequence in the computerized process.

There are two essential activities during the environmental assessment process for a transmission line project. The first one is the definition of the corridor and the second is the route selection. These two activities are based on the classified environmental elements and their evaluation. Using a GIS, different corridors can be defined by giving preference to areas that meet the greatest number of predefined criteria, owing to the multiple layers of information in the geographic database. Once the corridor has been selected, the GIS can be used to systematically scan the corridor to find the route that best meets technical and environmental requirements.

Developing an expert system

All the activities in the project phases, before and after the environmental assessment, should be systematically integrated. This approach can be used to design an expert system, which encompasses all the work involved in such projects. When well conceived and designed, expert systems provide a valuable tool offering instantaneous solutions based on the knowledge and know-how acquired from years of experience with such projects.

The main challenge: Resistance to change

Resistance to change is often the main difficulty in using new technologies to increase the efficiency of the environmental assessment process. However, to make the shift, overcoming such resistance is necessary.

Remember what it was like when computers first appeared in offices 30 or 35 years ago? For those who had been using traditional methods for a number of years, adapting to the new machines was somewhat daunting, and for some people downright terrifying. After a learning period, however, most of us managed to adapt and now cannot do without our computers. The same thing is true for GIS and computer applications. However, firms must devote sufficient resources during acquisition and set-up and enough time, effort and thought to the learning and adoption process. Appropriate training of GIS staff remains essential for a successful system.

Ensure awareness building and training for professionals

Building awareness and training are an important investment in converting traditional environmental analysts to the new technologies and then facilitating the adoption and use of these approaches. Utilities must provide a bridge between traditional ways of doing things and new working methods appropriate for the technologies. Computer applications must be developed with experts input.

Looking toward the future

Once new technologies have been solidly accepted and used, the focus should be on integrating layers created on different GIS. There will be an increasing demand for up to date information for all activities in the project phases, from planning to asset management.
With the assistance of GIS, many more scenarios can be studied, optimal solution found and improve communication in the organisation. The benefit of an integrated approach is discussed in chapter 8.

5. DESIGN AND CONSTRUCTION OF NEW TRANSMISSION LINES

5.1. Introduction

In recent years, the building of new transmission lines in many countries has become increasingly controversial and subject to external regulation and levels of scrutiny not previously seen. The need for detailed, high quality geospatial data has become a vital aspect in this process. The ability to rapidly collect this data and analyse numerous design options/alternatives is an important element in the process. At the same time, access for ground survey can often be difficult, particularly in circumstances where there is local opposition from landowners to a proposed project.

GIS fulfils an important role here in the transition of information collected as part of the permitting phase to the design phase where all specified constraints must be adhered to. GIS forms both an input to the design stage and an output in that the final as-built design record must also be captured for later use in the operation and maintenance phase of the life-cycle.

For the upgrading or reconstruction of existing lines (e.g. for up-rating/ re-conductoring purposes), the need for high quality geospatial data is just as vital to ensure that the most economically efficient means of upgrading the lines may be undertaken. In these cases, existing GIS datasets and/or additional data collection may be integrated to provide solutions. The design and construction elements of upgrading projects may vary from minimal (e.g. re-stringing with new higher rated/temperature conductors or optic fibre equivalent ground wires) right through to complete re-build/replacement of existing structures, equivalent in scale and impact to the construction of an entirely new line.

With the increase in underground cables that are entering the Transmission landscape, the methods cited above may be used during the design and construction of these lines. Alternative methods will have to be introduced for the detection of the cable during fault tracing in the operation and maintenance phase.

5.2. Activities in design and construction phase

Alignment of the final route : At the conclusion of the permitting phase, a decision is made regarding the final alignment of the route. Depending on the case, final negotiations with land owners or authorities will ultimately determine the line route. This alignment is used for the topographical survey that follows.

Topographical survey : Depending on the size of the project, this may be done using conventional ground survey techniques or for larger projects photogrammetric (aerial imagery) surveys and LIDAR (airborne laser scanning) surveys, often supplemented by ground survey.

Design. This process can be done using conventional templating methods or computerized methods. In the latter case digital terrain models (DTM's) are used to define the profile of the line route and design systems are often used to optimize the placement of towers. Constraints obtained during the previous phase must be imported into the model at this stage. These constraints could include environmental, technical and land owner conditions. The positioning of the towers is fed back to the permitting phase, where it is used in the final interactions with the land owners and authorities. This information is also used for the calculation of quantities and for the commercial and tendering processes.

Construction. During the construction of lines the design information as well as input obtained during the permitting phase, has a direct bearing on the activities of the construction process. This includes land owner requirements, environmental and technical issues as stipulated by permitting conditions. Decisions on access routes and vegetation clearing are also made at this time. Environmental monitoring and auditing also takes place at this phase to ensure compliance with the conditions of the permit that was issued.

5.3. GIS applications in design and construction phase

Alignment of the final route, topographical survey and Design

The main use of GIS in the design of new power lines comes from the input received from the permitting phase. All environmental restrictions have been captured in the GIS which include factors such as protected species, sensitive habitats. Other aspects that will influence the design are pollution areas, wind and ice zones, erosion, avalanche as well as lightning densities. These data sets are available to the designer on a variety of GIS data bases.

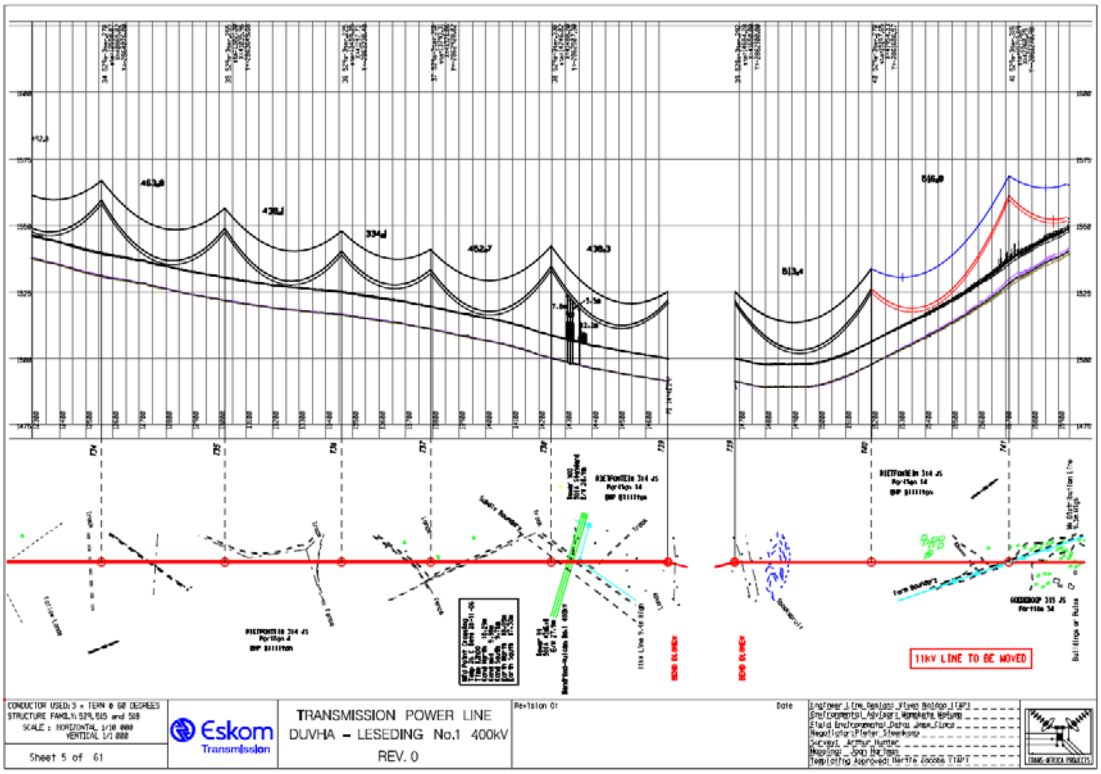


Figure 22. A typical profile of a new power line where data was obtained from different sources and the optimised placement of towers was calculated with PLS Cadd (source Eskom,2007**)**

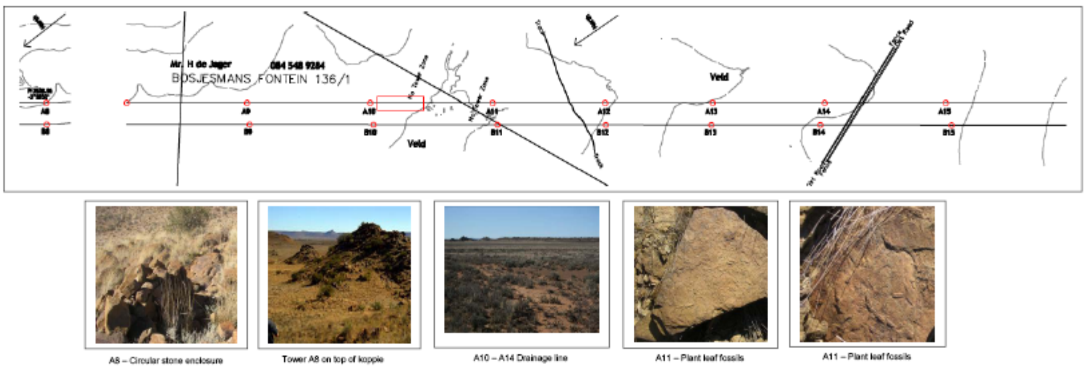
Archaeological information may however in some cases be available from GIS but generally field surveys have to be carried once tower positions have been supplied to heritage authorities. All the above information will finally be shown on the profile maps of the line when the design is done. Examples are shown in Figure 13 and Figure 14.

Factors resulting from geophysical surveys will also influence the design process. This information is normally not available from authority GIS databases but have to be obtained from field surveys at the tower positions.

Topographical Surveys : This step yields a topographical representation of the ROW which may or may not be stored in the GIS. Traditional methods of geospatial data collection for design and construction of transmission lines relied exclusively on ground survey techniques for production of centreline ground profiles. These methods were costly and time-consuming and generally yielded little additional information about the corridor (e.g. ground conditions, vegetation, land use, access for construction etc.). If aerial imagery and mapping were utilised, these were frequently from other sources (e.g. National Mapping Organisations) and usually not collected at the same time as the ground surveys. Prior to availability of CAD/GIS systems, it was often difficult to integrate data from different sources. However, with the development of modern CAD/GIS systems, photogrammetric and LIDAR surveys have become commonplace for the production of mapping/profiles for design of transmission lines, giving designers reliable, up to date information on the route corridors. A detailed review of current methods of topographical data collection is given in section 10.

Design : At the final design stage, there is often an iterative process between the design and the GIS data that have been used in the permitting process leading up to the final route. The structure locations may need to be represented in the GIS along with information that can only be established as the design progresses. This can include archaeological and geophysical information data collected from field surveys as mentioned above. Archaeological information may however in some cases be available from GIS but generally field surveys have to be carried once tower positions have been supplied to heritage authorities. All the above information will finally be shown on the profiles/maps of the line when the design is done. See Figure 22. Factors resulting from geophysical surveys may also influence the design process. This information is normally not available from available GIS databases but have to be obtained from field surveys at the tower positions.

Construction. During construction, care needs to be taken to respect the conditions imposed by the permit that was issued by the Authorities. One or more persons are assigned to monitor this process during construction. They rely heavily on information obtained during the permitting phase. Hard copy of the GIS information that has been collected during the previous phase is supplied for this purpose. This information is normally referred to as an Environmental Management Plan (EMP). Some examples are shown below



Farm Name	Bosjemans Fontein 136/12
Owner	De Put Rust
Contact name	H de Jager
Tel No.:	053 631 0152
Cell No.:	084 548 9284
Special Conditions	Contact owner prior to construction

TOWER NUMBER	ENVIRONMENTAL ASPECT	MITIGATION MEASURES	RESPONSIBILITY OF	PENALTY	METHOD STATEMENT REQUIRED
A8	Presence of an archaeologically significant circular stone enclosure at the coordinates of 30°52'11. 7"S, 23°57'26. 9"E. **IMPACT:** Damaging of circular stone enclosure.	• Area should be demarcated as a no-go zone by use of fencing during construction, and access thereto by the construction team must be denied. • No construction camp shall be erected within a radius of least 50m from the identified site. • Defecation and or urination inside or next to the structures must not be allowed. • No artefacts may be tampered with or removed from the site	ECO / PM / ELO	Fine and or imprisonment in terms of the National Heritage Resources Act no. 25 of 1999	-

Environmental Management Plan
Eskom Holdings Limited
42
November 2007

Figure 23An example of a line EMP that contains information from the GIS (source Eskom,2008)

GIS may be used for the purposes of identifying the best access to sites for construction and stringing activities with regard to minimising environmental impact for both proposed final designs and for upgrading of existing lines. An example- of this is the use of geo-referenced video and mapping within a GIS environment employed by Venezuelan utility company CVG EDELCA (see Ref. B2/D2-110). This system integrates video footage within a GIS.

5.4. Benefits of GIS in design and construction phase

Alignment of the final route, topographical survey and design

The major advantage of GIS to the design and construction phase of the life cycle is the ability to adapt designs taking information from a wider range of data sets and being able to integrate these data sets onto a single platform. At the design stage, the availability of reliable and consistent geo-referenced datasets assists greatly with this process as does the improved access to it due to electronic storage of the data. The ability to verify the suitability of the tower positions emanating from the design process is another useful benefit. At the construction stage, the preparation of integrated information for the construction process as displayed in the EMP.

It should be noted that GIS does not function as a decision tool in the design and construction phase. The benefits of GIS are derived before and after this phase and no major decision making benefits are experienced here.

With the increasing use of LIDAR data as a design tool, the management of the large volumes of data that are typical of these projects and how it is utilised post-construction becomes an issue. Ideally, the large volume of information that may be captured on these projects should be retained as part of the asset information after commissioning of the line. However, the management, access and distribution of the large datasets associated with these projects pose many challenges.

Examples such as GRIDMC (GRID Monitoring Centre) as implemented by Electro-Slovenia (see CIGRE paper B2/D2-109) point the way in terms of providing distributed access to geospatial data collected for both existing and newly designed transmission lines.

5.5. Conclusion and recommendations

Integrated information for the construction process is contained in the EMP. This document is derived from the permitting process and it’s associated GIS inputs as described earlier. The designer may also experience benefits from GIS due to easier access of data sets that are stored electronically rather that on paper and being able to integrate these data sets. Other than that, GIS is not widely used as a decision support tool in this phase of the life cycle. The benefits are derived before and after this phase and no major benefits are experienced here.

6. OPERATION AND MAINTENANCE PHASE OF POWER LINES

6.1. Introduction

The operation and maintenance phase of power lines is the phase with the longest duration. During this phase the utility will benefit from the use of GIS technology. In this chapter examples will be cited where GIS technology is used in the day to day running and maintenance of power lines.

6.2. Main activities of this phase

Some of the main activities that are performed during the operation and maintenance phase include the following:

- Maintenance of information about the asset, ROW, land owner information and land use.
- The recording of defects during line inspections. This may include land based or aerial inspections and covers visual and instrumentation remote control methods.
- Repair and refurbishment
- Vegetation management
- Line fault detection (fault management) and field investigation
- Condition monitoring of power lines

In the section below some applications of GIS will be discussed.

6.3. GIS Applications in operation and maintenance phase

One of the most important aspects in the operation and maintenance of power lines is having good, accurate and reliable information about the asset. No decision making can be optimal in either technical or financial terms, if the information that the utility has is not sound. To this end, utilities employ numerous ways of collecting data about the asset and it will be shown that the GIS offer the ideal repository for the storage and analysis of the data. The traditional method followed to gather information about the condition of the asset is by way of inspection. The inspection of power lines takes many forms. Some of these are:

- tower base patrols
- legal patrols
- helicopter patrols
- thermal and ultra-violet inspections
- non-destructive inspection of conductors and earth wires
- earth resistance measurement
- vegetation management inspections
- instrumentation inspection of foundations and anchor bolts

All these patrols and measurements produce a lot of data based on the findings of the crew men and the measurements. The problem is to store all that data in an efficient way so that during the next patrol the findings and measurements of the past are easily accessible. Indeed, the maintenance department must have an overview of the installations and the problems that are linked to a specific tower. To provide such information to use GIS technology is very useful.

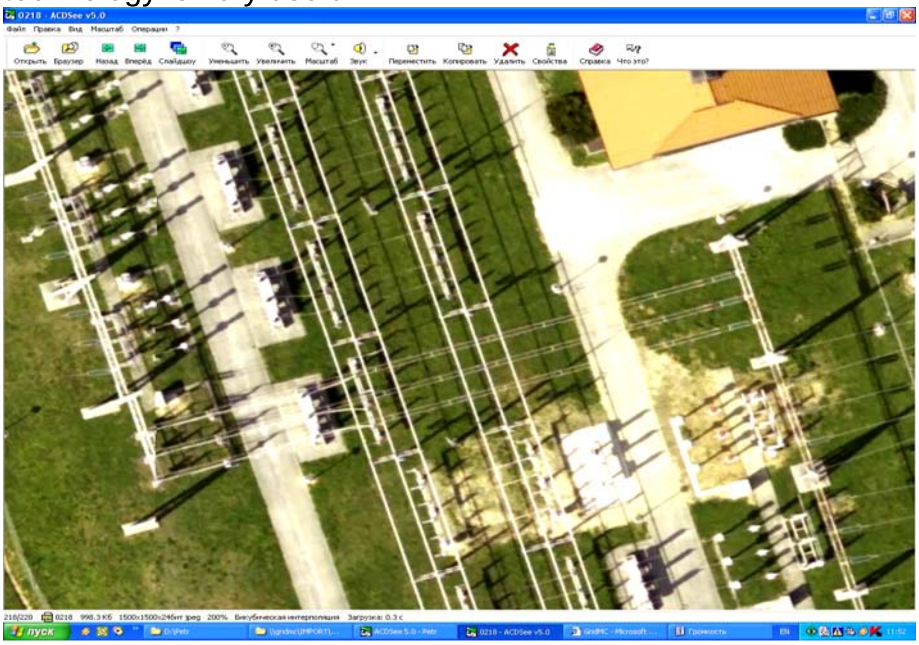


Figure 24 An example of an orthophoto of a 110kV substation held in a GIS (source Cigre B2/D2-109)

Information system packages (ISP), which includes GIS components can also be developed using standard software such as SQL, J2EE, EJB, XML, HTTP or HTML. Data import and export is ensured via software interface for integration with external software systems. The information basis of the package is mainly formed by importing of data from LIDAR surveys of power lines and substations .and is processed with the application of specialized imported software. Examples are shown below.
The interactive capture and modification of data captured in the system by way of ground or air survey methods, is also provided for. Digital data accumulated in the ISP can be used directly by utility staff and management for calculation and analytical evaluations. Parameters such as meteorological conditions or grid operation mode can also be ingested by means of interfaces with existing packages such as PLS-CADD. This approach permits rapid analysis and the identification of the causes for outages. The system may, in addition, be used in the forecasting of network response to conditions such as high wind, heavy snow or anomalous temperatures. (Ref B2/D2 109, 2006). It is considered most important to ensure that the database used for asset management, contain all the relevant information and specifications of the total transmission system’s equipment.

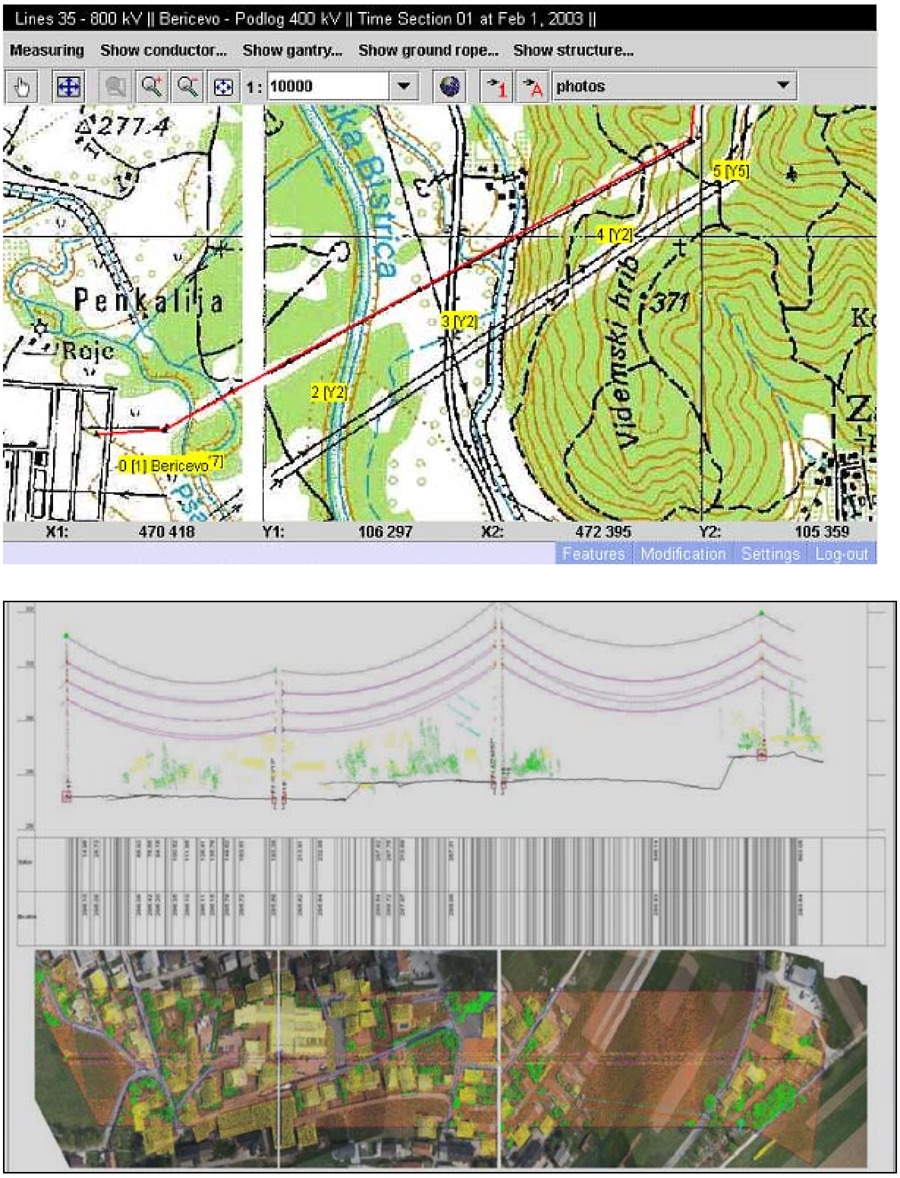


Figure 25 Examples of ground and vegetation surfaces obtained from an ALS survey as well as a profile modelled with PLS-CADD. (source OPTEN, 2008)

Once the data of the installation is stored in a GIS system it is possible to link the findings of the crew men to a specific tower or a specific line segment. This can be done by handheld computers, used by the line men, who transfer the findings to the GIS system. So, in preparing the next patrol one has automatically all the data that is necessary. This is also an aid to determine the global workload of the crew what and what material will be necessary.

Because the GPS coordinates are stored in the GIS it makes it more easy to find a specific tower or number of towers for the line men (under condition they use a GPS-system). This can mean an advantage in time. Also in preparing maintenance work, as the dimensions of the towers are stored in the GIS, it is tool to determine what safety measurements are to be taken during the maintenance work.
If a GIS system exists, a more accurate way of working can be used.

6.4. Inspection methods

A variety of new techniques have been demonstrated in recent times for the inspection of existing lines. Conventional inspection methods were carried out by vehicle (or even on foot) and in those cases, the results of the inspections were recorded on paper. This information could only be analyzed with great effort and the instruction to the repair crews were done manually. This method has been superseded in many utilities, which not only use electronic data logging equipment, but also use helicopters to speed up the inspection process. The transfer of the inspection data to GIS not only permits a variety of analysis methods, but also speeds up the cascading of information to the repair staff.

Another advantage of the GIS, if it is combined with handheld computers, is that the manager can have a better view of where his line crew has been. Lines are wide spread over the country and it not always easy to verify if a tower has really been visited. By the use of a handheld computer with a positioning system in it (GPS), the coordinates of tower that where visited and the route traveled by the inspector can be automatically logged by the GPS system and the towers that where inspected can be visualized.

In some case when a line switches out in response to a fault (lightning, fire...), the approximate distance of the fault is calculated. If that distance is known, a GIS system can very rapidity show on what line segment or nearby which tower the fault has occurred. In such cases, where the repair crew has to react quickly or the field crew has to inspect the cause of the fault, this information is quite useful. It also enables the field staff to inspect the exact site of the line fault and determine (or confirm) the actual cause of the fault. This results in the application of the correct remedy to prevent further occurrences of the fault type.

Once the main data exist in a GIS system it is not always necessary to buy expensive software to manipulate the data. Sometimes it is better to develop specific software in the company than to buy what is on the market. Such in house developments are useful to analyze the existing data and are not always very time consuming.

At first instance one would not think at that the use of a GIS system for the inspection of overhead lines is useful. Nevertheless, as mentioned above, there are some very useful cases where GIS can contribute such as the use during:

- repair work and safety measurements
- trimming of vegetation
- control of line crew
- fault location
- statistical analyses of trends

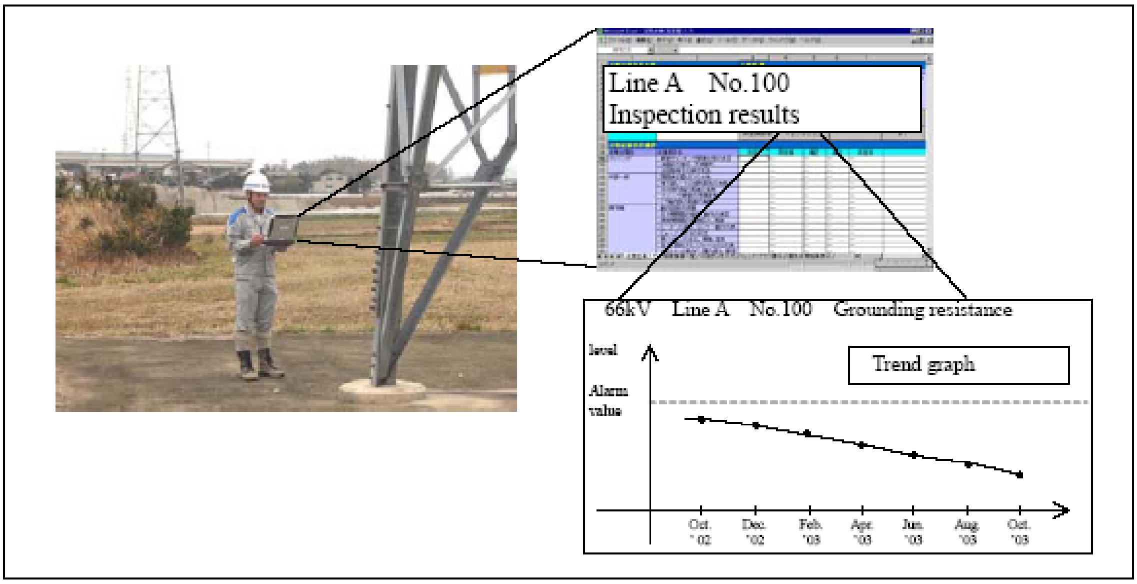


Figure 26- Both in the case of ground and aerial patrols, GPS assisted GIS tools are available to capture data fast and accurately.(source Cigre B2/D2-105, Eskom,2008)

In most cases, helicopter inspections tend to bridge the gap between basic helicopter patrols with no data recording and full LIDAR mapping surveys which may be costly and only required at very wide intervals (10 years?) or when lines are being upgraded or up-rated. Most of these methods employ a mix of camera and video methods, and in some cases, laser scanning. In most cases, manned helicopters are used but in one example an unmanned helicopter was used.

Some examples include:-
CN Transelectrica in Romania (ref. CIGRE paper B2/D2-108) has used a multi-spectral system combining visible, thermal Infrared (IR) and ultraviolet (UV) cameras with emphasis on the inspection of the transmission line hardware components. Using GPS, the geo-referenced locations of each picture may be handled in the GIS system and defect reports generated via their maintenance management system.

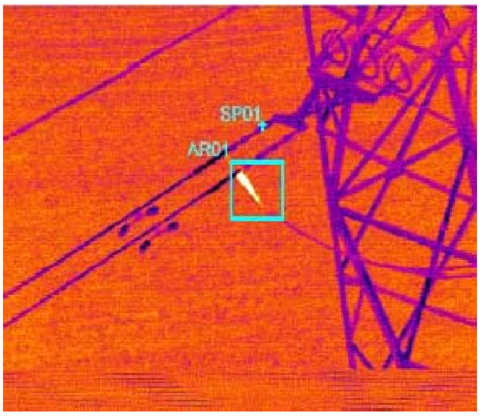


Figure 27. Thermal Infrared (IR) Image left and Ultraviolet (UV) images right recorded from the air. (source Cigre B2/D2-108)

An example from Japan (B2/D2 106) demonstrates the use of unmanned helicopters as a cost-effective means for carrying out inspections with camera and video. Images are time and location tagged for potential GIS use. (In addition, they are also looking at stereo methods for the calculation of clearances from vegetation using the unmanned helicopter).

Figure 28. Unmanned inspection using a remote controlled helicopter
(source Cigre B2/D2- 106)

Vegetation management

The use of a GIS system during the trimming of trees can be very advantageous. In the normal way of working difficulties are detected during a line patrol. When a problem is detected one of the major difficulties is to estimate the distance of the tree to the line. This can be done quite accurately by a land surveyor but such a process is time consuming and is in most cases only done for specific cases. Usually it is the experience of the patroller that is used to determine if the distance between a tree and the line is critically and if so by how many meters the tree must be cut. Measurement tools are not often used. Handheld laser rangefinders are sometimes used.
In France, RTE (Ref. CIGRE Paper B2/D2-102) explore the possibility of using existing GIS data together with their vegetation management software (VMS). However, the authors note that the lack of availability of reliable DTM data and structure locations on much of the network limit the ability to undertake this work in an accurate manner, but that the GIS tools are available. They envisage a system where GIS could model the variable statutory clearance zones within line spans and detect vegetation infringements based on span vegetation report data transferred to the GIS.
In Portugal, Labelec (Ref. CIGRE Paper B2/D2-107) demonstrates the use of a low-cost laser scanner and video camera for corridor/ROW checking and vegetation monitoring. This system permits updates of the GIS database for clearance management and provides a crude 3D model of the line route

including structure locations and sags. As with other line/corridor inspection methods, it attempts to provide GIS-ready data without the need for full-scale LiDAR surveys.

6.5. Real time Condition monitoring

During the operation of a transmission system, it is important to know the conditions under which the line is operating. Knowing the temperature of the conductor or the atmospheric conditions prevailing in the vicinity of the line will enable the system operator to safely approach the limits of the system, without exceeding it. In cases where these values are not known, the system is often operated at sub-optimal loads. In the following sections, some of these real-time systems will be described.

Real- time temperature monitoring.

In a number of cases, utilities monitor the temperature of the transmission line conductors. This is often done by using by observing atmospheric conditions in the vicinity of the line and calculating conductor temperature. In the case below, use is made with high level of accuracy by temperature sensors that are placed on the conductor of the line. Between 4 and 10 of these sensors (Fig. 29) are used per 100km and the worst parts of the line in terms of temperature are chosen for installation of the sensors. Communications of the data is done via cell phone (GPRS/GSM) technology and a website displays both current and real-time data of parameters such as temperature and current (Fig.30). The device is powered by capacity distraction from live OHL conductor. Conductor temperature can be measured (depending on utility’s requirements) within either a range of - 40^0 C to $+125^0$ C, or from - 15^0C to $+150^0$C. Conductor current can be measured within a range of 250 A to 2000 A. The device is equipped with a Global Positioning System (GPS) signals receiver. Consequently, temperature and current measurements contain the precise time of observation as well as X,Y,Z coordinates of the location of the device, The accuracy of course, depends on type of GPS receiver used.

Figure 29. The installation of temperature sensors on the conductor (source Opten 2008)

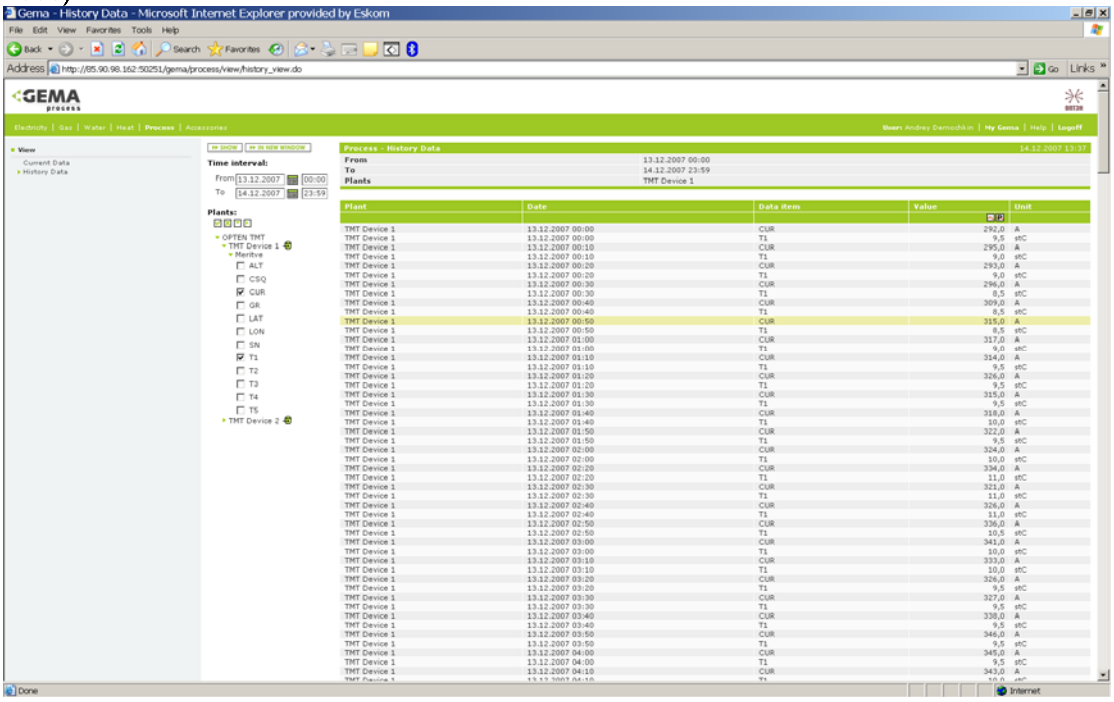


Figure 30. An example of a real-time monitoring system in Russia (source OPTEN, 2007)

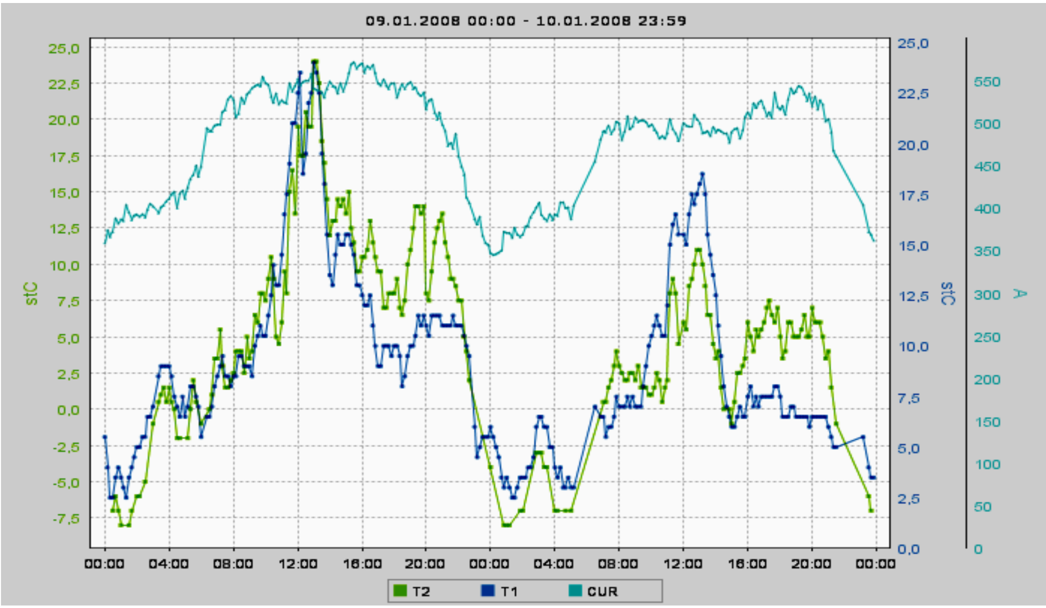


Figure 31. Example of real-time conductor temperature and current flow data.

Real-time ice information tracking

Ice storms can have catastrophic consequences for Transmission lines. As a result real-time systems have been developed to inform the utility of the onset of ice storms. One such system is the SYGIVRE system in use by Hydro Quebec. The system detects the storm by means of icing-rate meters and temperature probes. The icing-rate meter has a linear response to the mass of the ice and provides a quick means of detecting ice build-up. Air temperature is used to determine the type of build-up. Other sensors detecting wind speed, relative humidity, tension and electric fields are placed at geo-referenced locations. The data is transmitted to the host computer at the system control centre via satellite, microwave or telephone lines and stored on an Oracle database. An interface ensures compatibility between the metrological data and the power control system. The data is delivered to power system controllers, researchers, maintenance crews, public relations staff and other users. This data is used during and after a storm as well as in analysis of past events. The Figure 32 below show an example of areas where freezing rain and in-cloud icing were detected by the system.

Figure 32 The real time ice tracking system in use in Canada (Source Hydro-quebec, 2007)

Because all the data of the system is stored in the database it is quite easy to determine the sag of the line at the maximum temperature. This is done by calculation. Once these results are known the GIS brings forward the vegetation and compare the height of the vegetation with the clearing distance. This can be done automatically. There are even programs that are simulating the growth speed of the vegetation.
When this is done all the critical parts of the lines are detected and in respect with the clearing distances, right of way management and the company policy the system can propose at what height a specific tree must be cut.
That is quite an advantage for the line inspection crew. They can directly tell to the person who is cutting the tree at what height the tree must be cut. So the use of the GIS makes the control of the vegetation more effective and accurate.

Table of clearances to objects MS Excel

Bericevo - Podlog 400 kV

Structure numbers	Span length, m	Facility name	Conductor and ground wire names	Distance from left structure, m	Measured clearance, m at survey temperature of 19 deg.C			Note
					left phase	middle phase	right phase	
1-2	320	RIVER	490/65	74.17	12.31	12.47	12.87	
				140.97	12.48	12.46	12.54	
		VEGETATION	490/65	113.57	4.58	4.56	5.03	
				283.36	9.76	12.34	9.19	
2-3	336.05	RIVER	490/65	181.71	14.62	14.5	14.64	
		TREE	490/65	77.63	12.57	18.01	26.49	
				82.21	11.37	15.81	23.6	
				283.2	39.13	48.93	58.87	
		VEGETATION	490/65	154	5.28	6.61	7.25	
				206.85	9.55	8.03	9.59	
				332.26	40.15	31.24	22.62	
3-4	406.83	ETL	490/65	20.81	12.92	12.53	11.87	
		RIVER	490/65	128	24.08	24.79	26.22	
				250.34	38.97	38.14	37.66	
		ROAD	490/65	78.85	21.31	21.21	21.39	
		TREE	490/65	112.12	39.43	31.46	25.31	
		VEGETATION	490/65	123.56	12.66	11.19	14.76	
				147.73	22.35	15.7	13.72	
				180.37	37.05	44.7	53.39	
				217.96	31.03	30.77	30.97	
				380.64	5.76	6.13	3.59	

Figure 33 Example of line clearance data that is available from the GIS (source Opten 2008)

Real-time Fire tracking systems

In cases where fires present a major problem for utility owners, use may be made of satellite fire tracking to warn the system operator as well as field staff of the danger of fires approaching power lines. The system that will be described below was developed jointly between Eskom and the South African Council for Scientific and Industrial research (CSIR).

Advanced Fire Information System

The Advanced Fire Information System (AFIS) has been developed as a service module of the Wide Area Monitoring Information System (WAMIS), which aims to deliver fire information products to researchers, Fire Protection Agencies and Disaster managers all over Southern Africa in support of effective decision-making in the monitoring of natural and manmade fires. AFIS is the first near real time operational satellite fire monitoring system in Southern Africa and was initially developed using the MODIS satellites, Aqua and Terra, described below.

Utilization of multiple satellites

The perfect fire detection satellite capable of identifying very small fires over large areas regularly does not exist yet. The only option is to make use of current satellites that have near and mid infra red spectral bands in order to detect fires. Polar orbiting satellites have the advantage of detecting small fires, but with a very low overpass frequency, while geostationary satellites have the advantage of frequent views over large areas (every 15 minutes with MSG), but with a very low resolution, i.e. can only detect big fires. In order to make use of the advantage of higher resolution imagery (MODIS) and frequent views from MSG the two satellite sensors have been combined within AFIS.

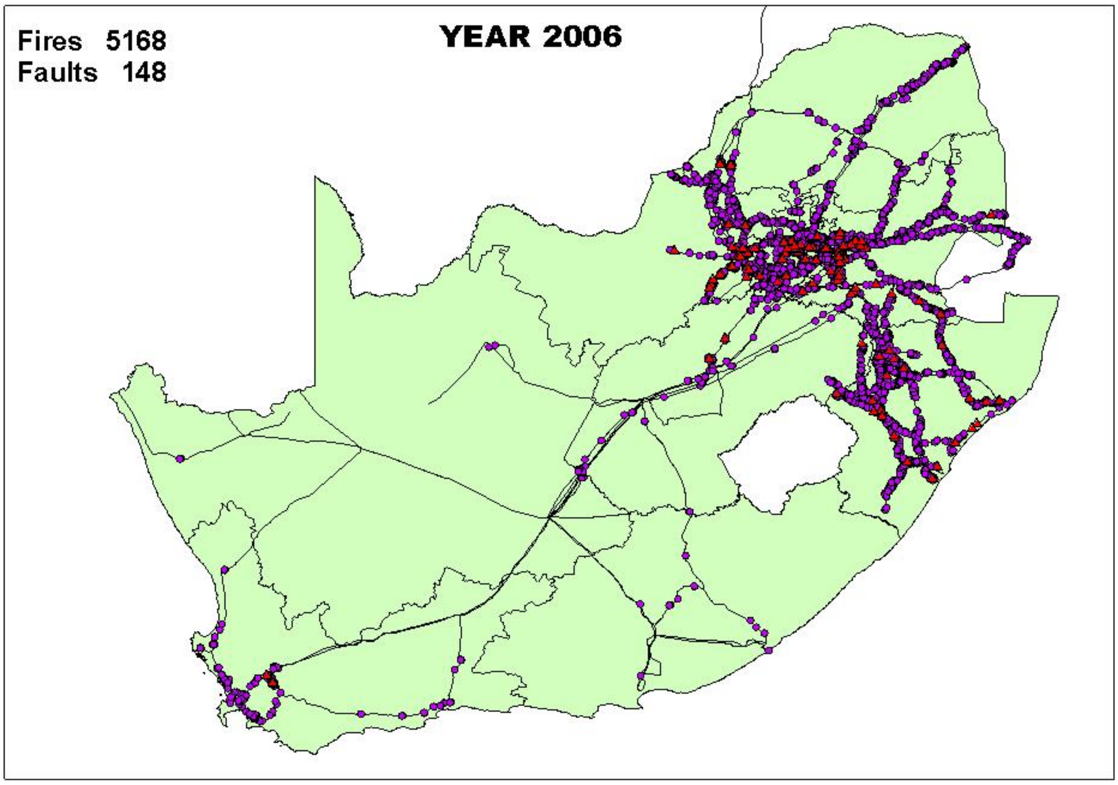


Figure 34 Fires observed adjacent to transmission lines and line faults during 2006 in South Africa (source Eskom,2007**)**

Polar Orbiters (MODIS)

The two MODIS satellites are polar orbiting, moving around the North and South Poles every 98 minutes while the earth is turning from west to east. Terra scans the Southern African region between 10 – 11:30 am while Aqua scans in the afternoons between 14:00 – 15:30 pm (South African time). Each satellite also scans the region at night (Terra at 22:00 pm and Aqua at 03:00 am). Validation results indicate that in many biomes the minimum flaming (~800-1000K) fire size typically detectable at 50% probability with MODIS is on the order of 100m² (Giglio, L. et al. 2000).

Geostationary (MSG)

MSG is a geostationary satellite that scans the African continent every 15 minutes in a south to north direction. The biggest limitation is its coarse resolution which limits the detection of small fires. Validation of the minimum detectable fire size for MSG in Southern Africa is currently being researched. Validation in the USA on similar satellites have shown detectable sizes in the region of 500m², but scan angles, biome, sun position, land surface temperature, cloud cover, amount of smoke and wind direction will be the final determining factor (Prins et al. 2001).

System Description

Collaboration between the CSIR SAC and NASA enabled the installation of the MODIS Rapid Response software within the SAC MODIS direct broadcast processing system. The main component of the MODIS Rapid Response code from the University of Maryland and Goddard Space Flight Centre (GSFC) is the enhanced contextual fire detection algorithm for MODIS (Giglio 2003). The new algorithm can detect fires roughly half the minimum size that could be detected with the original algorithm while having an overall false alarm rate 10–100 times smaller. The system generates an ASCII text file containing information regarding the Latitude, Longitude, Brightness Temp, Along scan pixel size, Along track pixel size, Date , Time of acquisition, Satellite (A=Aqua and T=Terra) and Confidence. This text file is automatically sent via to the ArcIMS and ArcSDE server where it will be displayed in real time.

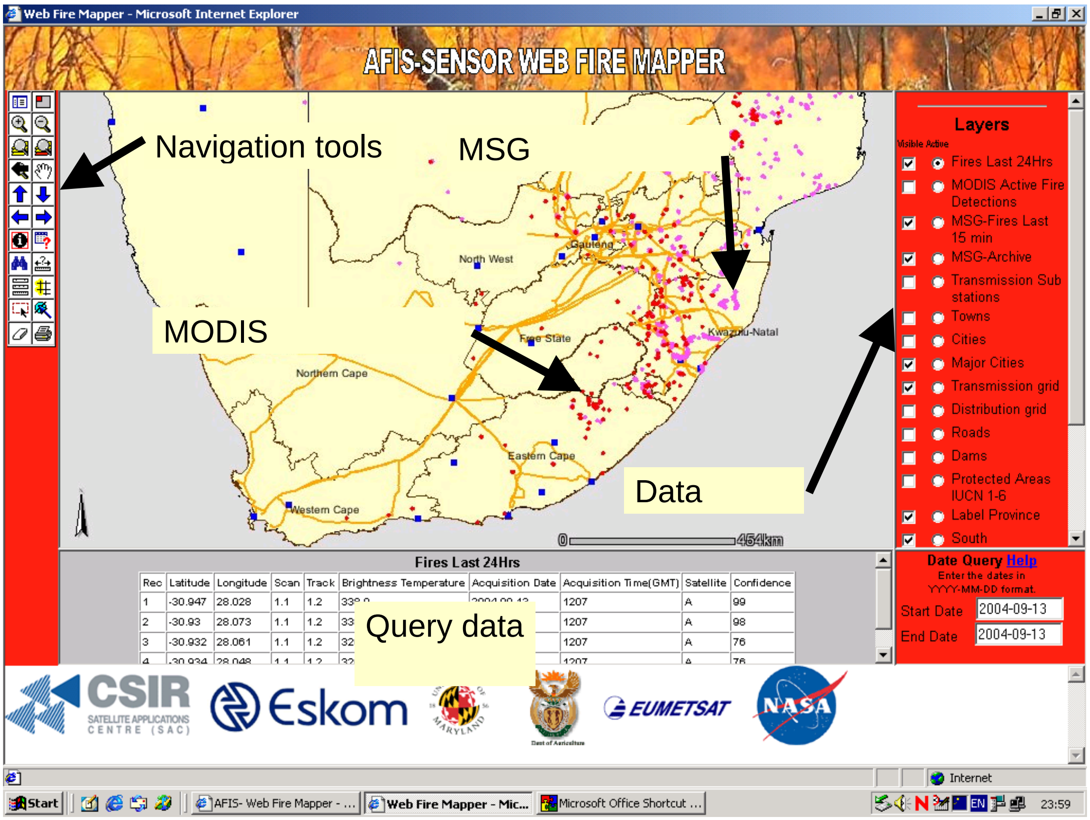


Figure 35 An example of a satellite fire tracking system in use by Eskom (source Eskom, 2007**)**

Email and SMS messaging service

An email and cell phone text message (SMS) system have been developed to provide rapid alert to fires without having to first view the web server. With the use of C++, software routines were developed to enable the identification of fires close to pre defined points, lines or polygons. As soon as a fire is

detected within a pre defined zone an alert is triggered through these C++ routines. An email message is automatically generated which is in turn converted to an SMS message.
AFIS scans a 2.5 km buffer a long side all transmission lines searching for fires every 15 minutes. As soon as a fire is detected by either of the MODIS or MSG satellites an SMS message is generated indicating fire location and distance to the power line. This information is send to the regional ESKOM manager responsible for that portion of the line. At the same time the message is also sent to the National Control centre.
Researchers more interested in the frequency and distribution of fires in specific areas can register to receive a daily email. The email will contain a referenced image and a list of all fires detected within the defined area. Information such as date, time, location (lat/long), detected temperature and confidence of each fire will be included in the list. Researchers in Angola, Mozambique, Lesotho, Swaziland, Botswana and Zimbabwe have been monitoring fire prone areas since beginning of July 2004.

Figure 36 A typical sms message about a fire .56 km from tower 1249 on the Apollo- Cohora Basso No1 line observed at 10:54 UTC(Source Eskom, 2007)

Figure 37. The latest web enabled cell phones permit access to the latest weather information . In this example the cyclone Flavio is seen over Mozambique.(source Eskom, 2007)

Lightning detection systems

The detection of lightning in real-time in the vicinity of power lines is not a new concept. The technology, however, has improved over time and a number of these systems are available to the utility. The system described below is in operation in Europe.

Lightning strokes to conductors of overhead lines can be a reason for disturbances and in certain cases can even lead to outages. Most of such strokes normally are cleared by the automatic re-closure system (ARC) of the line. This system together with earth wires is designed to provide sufficient protection against outages due to lightning.

Reliable knowledge about the keraunic levels of a region (the occurrence and distribution of lightning events) is important for the line designer and in extreme cases, line routes may be planned to avoid such areas. The average and maximum current expected from lightning also influences the design of the protection system of a line. This information is readily available from GIS as will be shown below.

During the operation and maintenance of the line, real-time lightning detections systems are used both by the dispatcher as well as by field staff during post fault investigations.

Description of Lightning detection systems

A number of lightning detection systems exist with different goals. One is to forecast dangerous situations for utilities, farmers, general public, and weather forecast. Another one is e.g. to verify if damages were caused by lightning or have other reasons (typical: for assurance companies). Another is for statistics (number, location, density, lightning current, tendency, etc.) Some of these systems are initiated or supported by utilities. One such example is the ALDIS system in Austria.
This system may accessed at http://www.aldis.at/info/index.html

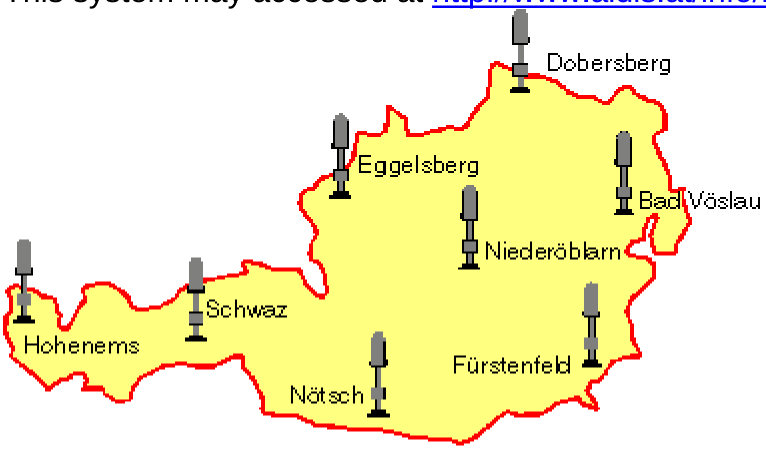


Figure 38Map with position of sensors in Austria (source http://www.aldis.at/info/index.html, 2007**)**

Table 2. Number of lightning strokes in Austria 1992 – 2007 as from:http://www.aldis.at/statistik/main.php?PHPSESSID=6b5d9229de8082a0dc9c8bd65467d5de

	Region in Austria									
year	WIEN	NOE	OOE	BGLD	STMK	SBG	KTN	TI+OT	VBG	TOTAL
1992	194	19.094	9.304	4.071	29.013	12.878	13.265	14.771	2.328	104.918
1993	296	40.701	28.291	7.979	59.656	22.614	31.293	28.155	3.384	222.369
1994	244	22.766	12.395	5.233	41.881	15.343	27.712	25.715	3.190	154.479
1995	426	23.892	10.467	5.560	34.423	12.295	24.294	17.992	2.120	131.469
1996	373	21.262	14.153	6.014	32.690	11.853	14.756	16.665	1.835	119.601
1997	241	20.043	12.299	5.164	39.761	10.380	23.893	10.793	962	123.536
1998	664	28.340	16.032	10.521	55.805	15.110	30.567	21.770	1.349	180.158
1999	256	20.592	10.261	3.770	28.270	7.786	17.771	10.252	1.224	100.182
2000	707	34.074	21.522	7.849	54.673	18.993	29.079	23.286	3.745	193.928
2001	368	24.456	16.986	5.973	29.022	10.055	17.263	14.538	1.897	120.558

2002	613	39.506	27.328	8.642	41.864	14.148	21.588	24.241	3.874	181.804
2003	1.196	32.510	23.636	7.620	53.095	20.555	41.241	28.483	3.419	211.755
2004	476	20.249	17.600	4.834	36.050	9.813	17.941	12.596	2.942	122.501
2005	317	36.400	31.584	3.996	58.585	12.289	18.923	14.318	1.577	177.989
2006	501	50.672	38.662	8.305	72.777	28.975	43.715	37.073	3.300	283.980
2007	1.142	57.538	38.412	8.143	54.400	26.224	33.530	26.023	2.175	247.587

This table shows the number of lightning strikes recorded since 1992 for various regions in Austria

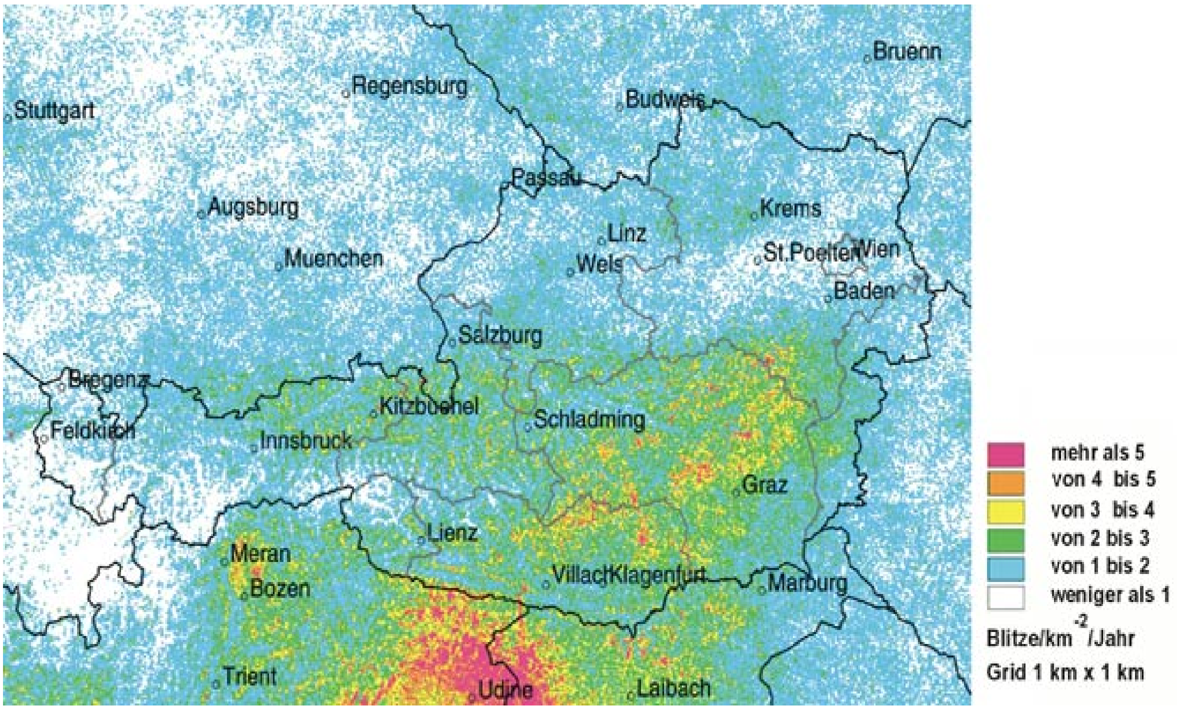


Figure 39 Map: density of lightning strokes (average number of lightning strikes 1992 – 2007 per km2 per year)

EUCLID (on European level)

Many European countries contribute to the EUCLID system – see map below.

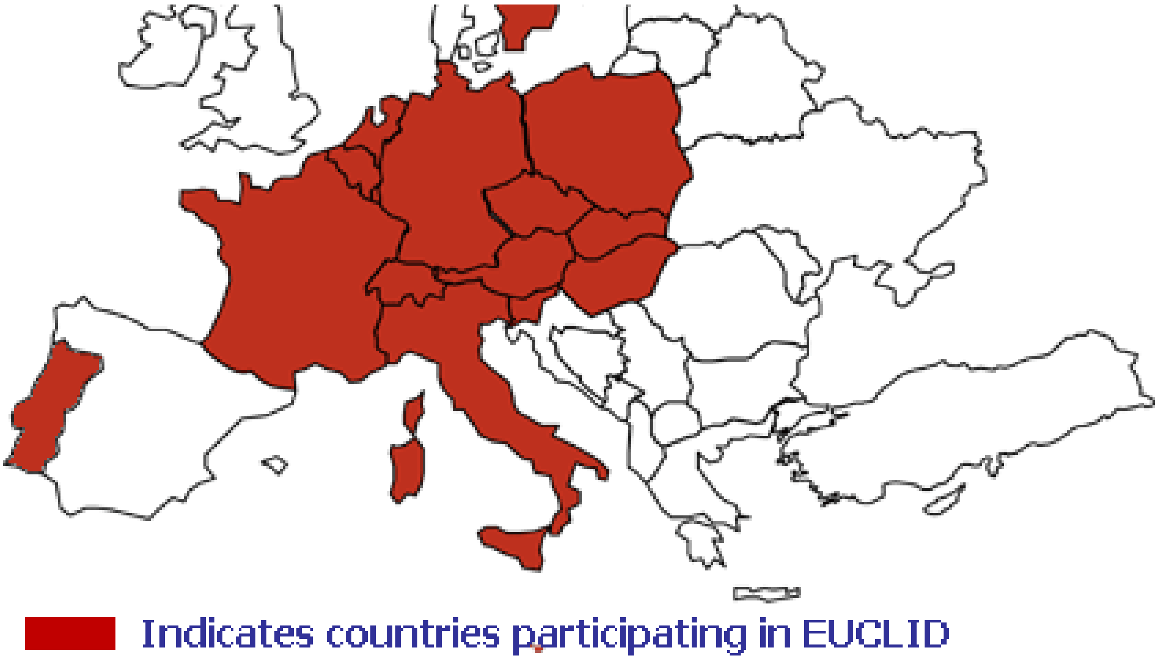


Figure 40 Participants in the EUCLID system (source http://www.euclid.org/what_is.html)

EUCLID (European Cooperation for Lightning Detection) is collaboration among national lightning detecting networks with the aim to identify and detect lightning all over the European area. The countries involved are Germany, Austria, Hungary, Czech Republic, Slovenia, Holland, Belgium, Luxembourg, Italy, Poland, Slovakia, Norway, Finland, Denmark, Sweden and France. At the moment the complete network consists of 75 sensors, in these 13 countries, contributing to the detection of lightning. .The information coverage ranges from the Gulf of Biscay to Warsaw and from Sicily to the North of Norway. There is no other project like EUCLID in the world, with so many lightning people connected together and compiles lightning information in Europe for a mutual area of interest in common ideas and results.

The EUCLID network provides lightning data for Europe with homogenous quality in terms of detection efficiency and location accuracy.
Individual participating networks receive real-time access to the complete EUCLID data and use this data to serve clients for national lightning data. Each network retains its national independence and provides lightning data for individual user applications in their own country as well.
The core operational applications for EUCLID include meteorology, hydrology, electric power utilities, communications, insurance, forestry, defence and aviation.

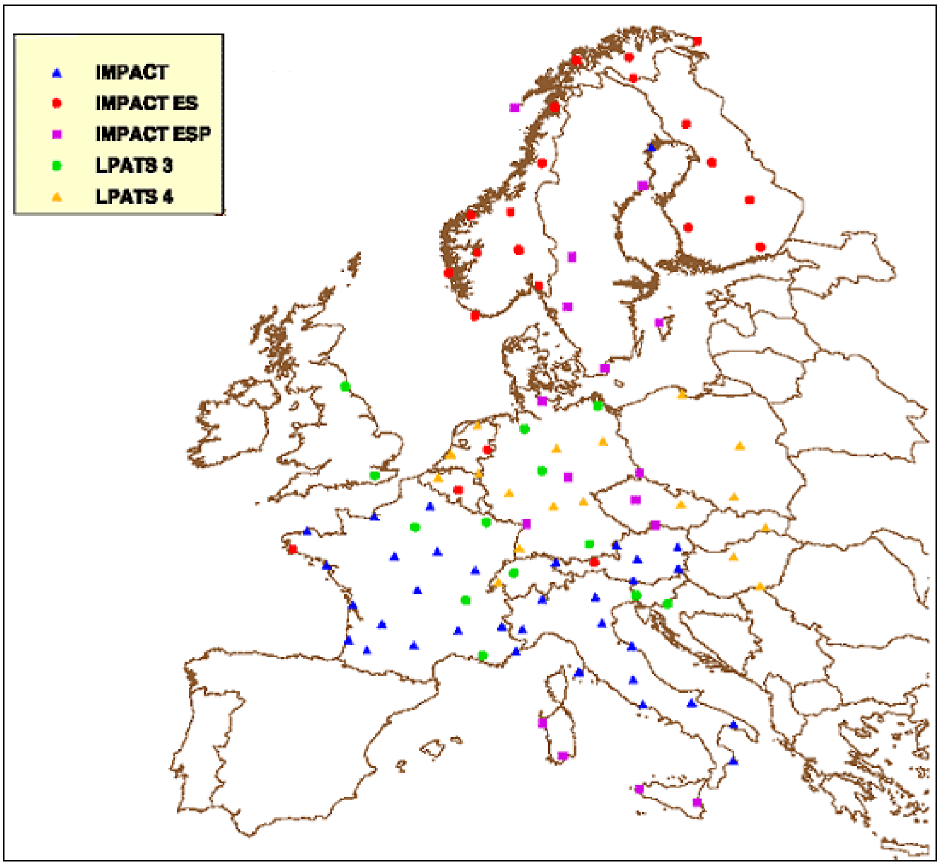


Figure 41 Position of sensors for EUCLID (source http://www.euclid.org/what_is.html

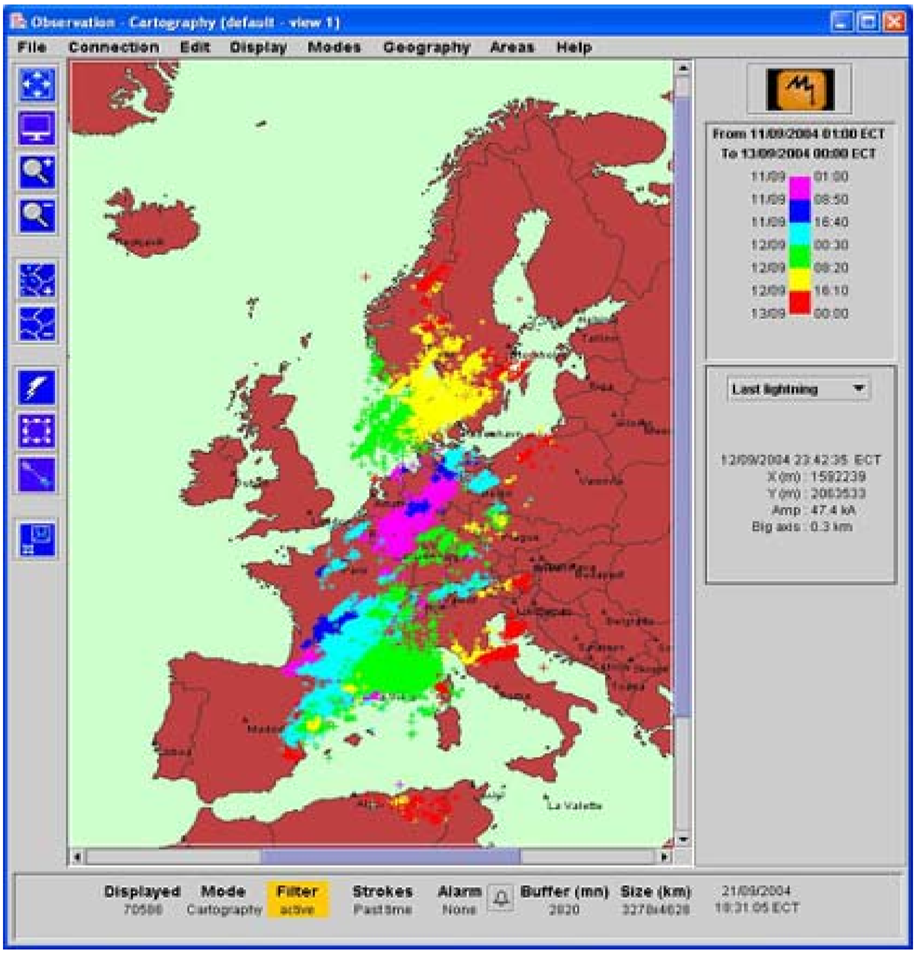


Figure 42Example for EUCLID: Lightning thunderstorm over Europe on 12th September 2004 (source http://www.euclid.org/what_is.html)

6.6. Benefits of using GIS in operation and maintenance

The advantages of GIS in this phase of the life cycle are many and the benefits that the utility may gain vast.

The determination of the condition of the asset (line and servitude) is improved by the introduction of electronic data capture, both on the ground as well as from the air. This is particularly important when dealing with ageing infrastructure and real-time knowledge of the condition of plant is crucial in the decisions taken during operation and maintenance.

The knowledge of the condition of the asset and its surrounds, both from the electronic capture of data, as well as from real-time monitoring systems described in this chapter, is crucial to the utility in making fast and effective operational and economic decisions. Real-time monitoring systems also permit the utility to safely operate the system close to its design limits, thereby optimising its use.

Where the utility is faced with staff with sub-optimal qualifications or experience, as well as increased requirements of regulatory bodies, a reliable information system becomes indispensable. The electronic storage of the data not only speeds up the dispatch of repair and maintenance staff, but also permits the organisation to analyze the data and determine trends. In Chapter

8 it will be shown that vast improvements in efficiency can be realised trough an integrated information system.

6.7. Conclusions and recommendations

In an age where the efficient and effective management of the assets of the utility is crucial to its continued and profitable existence, sound, timeous and reliable knowledge (through GIS) about the multiple aspects that influence the operation and maintenance of a transmission system is no longer a convenience but imperative for the manager of the utility.

7. DECOMMISIONING OR RE-USE OF POWER LINE ROW

7.1. Introduction

The lifetime of a line and its reliability are defined in regulations and project specifications (e.g. for CENELEC-countries in the standard EN 50341, chapter 3.2). In cases where it is feasible a line may be refurbished to extend its life.

7.2. Activities in decommissioning

If a line is taken out of service for technical or economic reasons in some countries it is to be dismantled. This is, in some countries based on legal requirements, and may differ from country to country. The work for decommissioning concerns mainly the following aspects.

- authorization process where necessary
- dismantling work (dismantling of towers, conductors, foundation, earthing systems)
- access roads, land and vegetation management of disturbances of vegetation including bush clearing/tree clearing
- farming operation/disturbance on agriculture
- disturbance of landowners and neighbouring people (noise, pollution)
- disturbance of wildlife and birds during the works
- reuse and disposal of the line’s components
- Re-cultivation, reforestation and replanting on the former line’s corridor.
- Where the right of way exists in perpetuity this servitude may be reused for a new line project. This would typically require a new EIA and permit

In principle the same aspects are to be followed as during the erection of a line. This is fully discussed in chapter 4. The main difference is the much shorter time needed for dismantling and the (normally) easier authorization procedure, if any needed.

The structures, conductors, insulators, fittings, can mostly be reused as scrap material. Considerations of doing this may be found in O’Luin C et al, (2004). The components of an overhead line that are normally not recovered are

- Foundations (which are removed below a certain depth from the ground level – depending on the legal situation, typically between 0,5m and 1,5m). Anchor, grillage and pile foundations often remain.
- Earthing/grounding systems: Depending on the kind of agriculture and the kind of cultivation as well as depending on the demands from landowners and authorities, the systems may stay in the soil below a certain depth. Typical values are below 50 and 100cm.

Good records of these components can easily be stored on a GIS for later reference.

7.3. GIS applications for dismantling work

In general the same aspects related to safety and security apply as for the construction work. The knowledge about the actual situation on site is necessary to prepare a serious tendering and to guarantee a reliable process. GIS can provide actual data about relevant existing aspects such as:

- new developments/settlements in the vicinity of the line
- railways, highways, roads
- power lines - overhead and underground
- telecommunication lines - overhead and underground
- access to the towers for small and heavy vehicles
- embedded pipes, channels, etc.
- clearances to be kept from any facility
- updated list of landowners
- condition of the structure to be dismantled (age, mechanical aspects, defects, etc.)

GIS and administrative aspects

The decommissioning process with respect to the servitude can benefit from the use of GIS. All the landowner information (cadastre, topography, name and address) is normally kept in a GIS

GIS for documentation of non-recovered parts of the OHL

It is typical practice not to recover certain parts of the foundation and earthing systems. The EIA or other relevant permissions and regulations define the actual practice.
Good records of the position of the structures being dismantled will aide any future land development process. It is suggested that these records be kept in a GIS for later. The advantage of this proposal will ensure easy access and will prevent the loss of records associated with other forms of data storage (such as paper copies) due to reorganisations, change of staff, etc.

GIS and economic considerations

The financial implications of the dismantling process needs to be recorded in the asset register of the utility. For these purposes some date as length, age, number of towers, etc. are required. This data is normally found in the GIS of the utility. Automatic signals from the GIS to the financial system will ensure that this process is carried out. This integrated approach is discussed more fully in chapter 8.

7.4. Benefits in using GIS

The benefits of GIS during the decommissioning of a power line are similar to those experienced during the permitting phase as it permits the user to consolidate a number of data sets in a visual representation. One of the main advantages, however, lies in the fact that data about the project may be stored in a safe way that will be usable to later generations of staff and in this way stretches the utility's corporate memory.

7.5. Conclusion and recommendations

If GIS is considered where the whole lifecycle from planning to operating and maintenance, the decommissioning process will benefit greatly from the data kept in a GIS. Original considerations kept during authorization and construction my greatly benefit and inform the decommissioning process if it was available.
The GIS will enable this information to span generations of staff inside the utility.

8. ENTERPRISE-WIDE GIS

8.1. Introduction

In the chapters of this document the various phases of the life cycle of a power line was used to describe activities typically found in each case as well as applications and benefits derived from the use of GIS. This may have created the impression of a fragmented approach.
The converse is actually true and that fact will be illustrated in this chapter. Many authors have indicated that an integrated approach to GIS is the ideal way to manage transmission lines from "cradle to grave" where maximum benefits may be derived if the GIS is integrated across the entire business and with links to typically non- geographic referenced systems such as financial or logistics. This approach is referred to as "enterprise GIS" and some of its characteristics will be discussed below.

8.2. Description of enterprise GIS

Van der Merwe (2007) states that the objective of this approach is to leverage GIS technology to deliver business value across the entire business. The approach requires that geospatial data are stored in a corporate repository and applications support a wide range of corporate business processes and interfaces. The system should give both expert and casual users seamless access to mission-critical data in a variety of spatial and non-spatial formats. Numerous businesses started out with fragmented or departmental systems but during 2003-2004 a rapid move towards an enterprise wide approach was observed amongst companies in the electric, gas, pipeline, telecommunications and water utilities (GITA, 2004).
With the recent approach of asset management, the driving of efficiencies in the utility is not only a business imperative but is forced by regulatory institutions throughout the world. Accurate and integrated information systems are crucial for efficient decision making across the entire organisation under these conditions.
In the case of Japan's Kyushu Electric Company and integrated system was implemented across the entire organisation. This system known as the Enterprise Resource Planning (ERP) system is shown in Figure 43

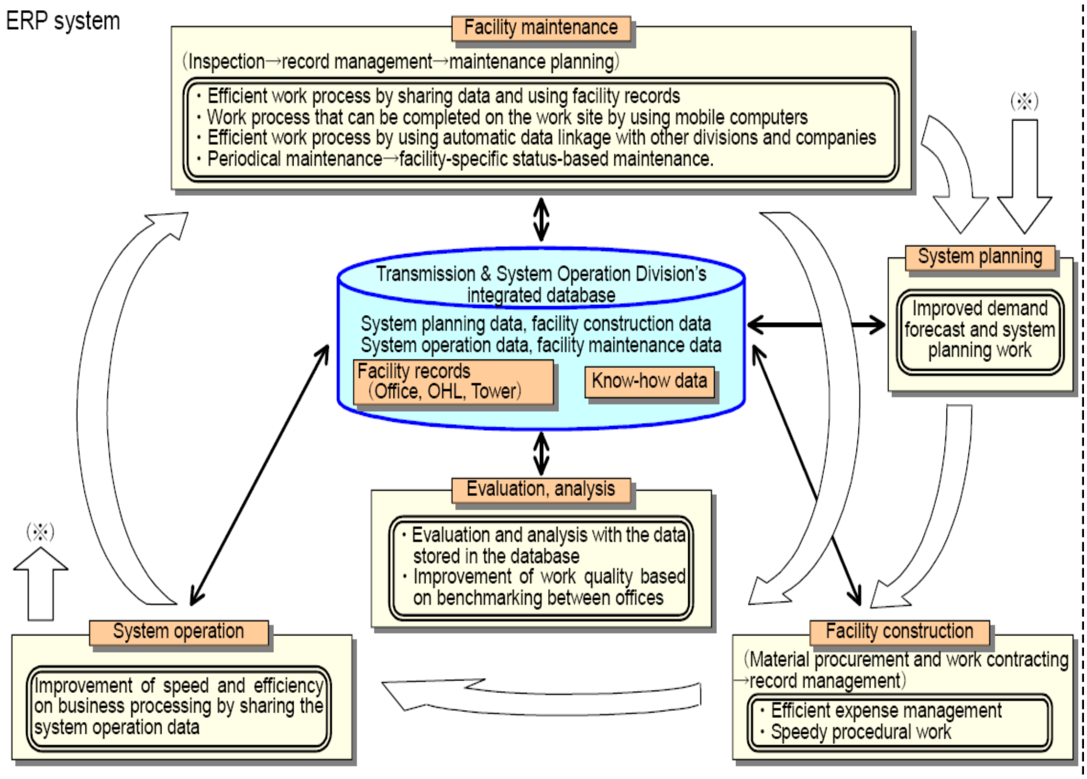


Figure 43. The Enterprise Resource Planning (ERP) system of the Kyushu Electric Company in Japan shown the integration of systems across the entire business (source Cigre B2/D2-105)

The system was developed to manage all activities related to the management of overhead lines and consists of integrated databases that manage all the data relating to this task.
In the first column in Table 3 below, the phases of the life cycle are listed. The second column shows the activities for each phase and the third the functions that are performed for each activity.
This table also shows that integrated process of this information system covers the entire life cycle as was outlined earlier in this document.

Table 3 An outline of the integrated approach followed by the Kyushu Electric company throughout the entire life cycle (source Cigre B2D2-105)

Subsystem	Item	Function
System planning	Demand forecast and analysis	Data collection and analysis of demand records; drawing up and management of substation load forecast lists
	System planning	Selecting locations necessary for facility enhancement; long-term/annual system planning
Facility construction	Work request forms	Drawing up of documents including budgeting lists, accounting lists; management of work request forms
	Work contracting form	Drawing up and management of documents including work design and specs. for procurement and work contract
	Budget and cost	Management of budget, estimate and actual figures; management of difference between budget and actual for every work case, section, office and facility
	Work execution	Management of daily reports and inspection records
	Work take-over	Drawing up and management of work take-over documents
System operation	Maintenance outage	Application and management of maintenance outage for transmission line; drawing up of annual/semiannual/monthly maintenance outage planning
	Data sharing	Data sharing of system operation including load dispatching and weather; drawing up and management of electrical failure records
Facility maintenance	Patrol	Data input, collection, and management of patrol results of transmission lines
	Regular inspection	Data input, collection, and management of regular inspection results of towers.
	Pending items	Data input, collection, and management of pending issues found through patrols and regular inspections
	Failure & disorder	Data input, collection, and management of failures and faulty disorders (case name, description and occurrence data)
	Tree-to-line clearance	Data input, collection, and management of clearance between the tree and the line, as well as land owner information
	Inspection planning	Data input and collection of patrol, regular inspection, and repair work; annual/monthly work planning
	Repair/improvement work planning	Budgeting for every work case at long-term/annual planning; documentation, drawing-up for each work case; entire data collection, adjustment and management
Common items	Facility record management	Uniform management of data including maintenance records, history of failures, pending issues, and tree-to-line clearance, as well as facility-specific information and drawings
	Cost management	Cost analysis by facility, organization, budget/actual, accounting items, work items, or time
	Geographic Information System	Drawing up and management of diagrams commonly used for each work case (e.g. single line diagram, power station/substation/transmission line location map, transmission system diagram)

The example of Electro-Slovenia

An example of the use of an integrated system for transmission line operation and maintenance is the GRIDMC (GRID Monitoring Centre) as implemented by Electro-Slovenia (see CIGRE B2/D2-109 for details).
This system may be used to manage the data on a transmission line following its construction/commissioning in such a way that the large volume of information captured during a LiDAR survey can be distributed across an organisation post-construction. The GRIDMC application has been used by Electro-Slovenia as a means of distributing the key terrain, structure and other asset information in a form that can be readily used as a tool for line maintenance and clearance checking and is compatible with their existing asset management database. The example below shows a visualisation of the route of a 400kV line for which data was captured as part of the implementation.

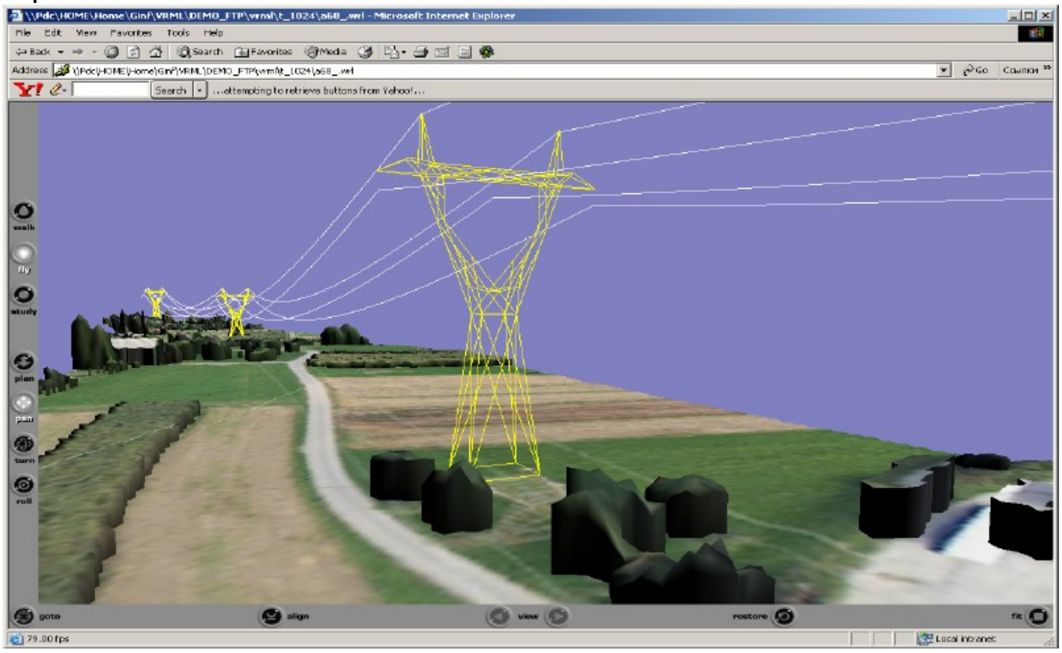


Figure 44: 3D visualisation of 400kV line as used by Electro-Slovenia (source Gigre B2/D2-109)

The capture of large volumes of LiDAR data and imagery from Mobile Mapping Systems for design of new lines may be readily undertaken. However, the more significant issue is how that data is integrated with the as-built design information and deployed by the asset owner after construction. With Electro-Slovenia, GRIDMC demonstrates how these challenges can be overcome and the data utilised to improve system performance and reliability.

8.3. Benefits of enterprise GIS

Some of the obvious benefits that come from and enterprise GIS are:

- Significant reduction in data redundancy
- Improved accuracy and integrity of information
- Efficient and timely sharing of data
- Improved enterprise wide knowledge management and decision support capabilities
- High level of interoperability between GIs and non-GIS applications
- More effective use of GIS skills and resources

- Reduced overall GIS maintenance and support costs

US based utilities are required to demonstrate regulatory compliance through detailed reporting of maintenance activities. GIS plays an important role here. According to one of the authors, very few large utilities in the United States had to motivate the purchase of their GIS system on return on investment (ROI) but rather recognised it as strategic investment by their executives. (L.vd Merwe, pers. comm.)
Improved management of the utilities assets can have huge monitory advantages. In the case of Kyushu Electric Company savings in the cost of maintenance are cited as 10% of their annual ¥18 bil budget. This was mainly achieved by extending the inspection cycle. This was in turn based on their analysis of the condition of the asset derived from the database.
Kyushu Electric Company have also experienced further savings in IT investment of ¥2 bil, which was achieved by implementing the ERP system in their Telecommunications and Civil Engineering departments as well as in their Thermal Generation division.

8.4. Conclusion and discussion

The decision to implement an enterprise GIS must however, be taken with circumspect. The vast improvements experienced by Kyushu Electric Company were not only achieved by the use of an integrated GIS, but was also based on a re-defined work process that was supported by the integrated information system.
Human aspects such as computer literacy of staff as well as the resistance to change should also be considered when contemplating the use of GIS. In the case cited by Kyushu Electric Company, it followed that staff was made redundant through improved efficiencies resulting from the improved work process. Where this happened, staff were not dismissed but rather re-deployed elsewhere in the company.
Numerous sessions were also held with staff to explain new work methods and a help desk was set up to answer questions. An important aspect in the successful implementation of their system was that suggestions for improvement of the system from staff, were mostly readily implemented, thereby giving staff ownership of the system.

9. DISCUSSION AND CONCLUSION

This study attempted to provide an overview on latest GIS technology that is available to the manager of the modern utility manager. Preferential subject 1 deals with ways in which that information is gathered, stored and used by the utility.

The work is organized following the total life cycle of an overhead line and each chapter is devoted to a specific phase in the life cycle. This approach not only ensures that the total subject is covered, but has also become accepted in the asset management discipline as crucial in ensuring that asset is managed in an optimal way. Positive (or negative) decisions made in one section of the life cycle, will influence the other. By way of an example, it can be stated that poor planning in the route of a line, will negatively effect the operation and maintenance of that line. Similarly, poor maintenance practices will make the acquisition of new Rights of Way difficult.

As Engineers, we are primarily focused on the design, building and operation of electrical infrastructure. Without good information to base our decisions on, we will not be successful in this task.

Prior to the advent of the computer age, many earlier design and operational decisions were made by engineers using approximations. This inevitably led to some measure of over-design. This is no longer acceptable and current demands require of the engineer to optimize both the planning, design and operation of the asset. The integrated approach described in this study not only shows the variety and range of geographically based information systems, but also cites cases where utilities have experienced major financial advantages by integration these systems with each other and with the work processes of their employees.

As was stated at the outset, this document does not propose to be another GIS handbook, but rather takes the reader through the various options available in the GIS field and quotes best practices and advantages where possible.

9.1. Acknowledgement.

The convener of TF B2/D2 wishes to thank all the members of this group for their input and participation. He also wishes to thank the reviewers for their comments and guidance.

10. ANNEXURE A: DATA CAPTURING METHODS AND DESIGN PLATFORMS

Introduction.

During the chapters in this document , the focus was on GIS applications. The data-capturing methods are also considered important and will therefore be discussed in this annexure.

10.1. Geo-information requirements (geospatial data)

Relevant developments in geospatial data collection

The past decade has seen remarkable developments in the variety and availability of geospatial data. Where previously Surveying, Photogrammetry and Remote Sensing were considered separate specialised fields, the rapid technological advance of integrated systems combining satellite and inertial positioning with digital sensors (both passive e.g. Photogrammetry or active e.g. LIDAR) has blurred the traditional distinctions. These systems (often referred to as Mobile Mapping Systems or Mobile Multi-Sensor Systems) can rapidly and economically collect large amounts of digital data, all of which is geo-referenced for use in CAD or GIS systems.

Ground Survey (including GPS)

Although airborne data collection (LIDAR, Photogrammetry etc.) has generally superseded ground survey as the primary means of survey for transmission line profiles/corridors, ground survey techniques are still required for geo-referencing airborne methods and for setting-out of transmission line structures. GPS (Global Positioning System) is now the standard method for surveying for infrastructural projects although total stations i.e. theodolites with electronic distance measurement (EDM) still have their uses for infill survey in heavily forested areas and for setting out and monitoring of construction of towers/poles.
Major factors have influenced the widespread adoption of GPS over the past decade for geospatial data collection :-

GPS-compatible co-ordinate reference systems

To work with the inherently high accuracies of GPS, many countries have adopted mapping reference frames based on the GPS system. This has encouraged the use of precise GPS surveying as it has simplified the task of connecting surveys to national networks.

Accurate height models

The availability of accurate height models to relate GPS derived ellipsoidal heights at any location to orthometric heights (and hence to vertical datums) has also been important, particularly so on long linear type projects such as transmission lines.

GPS RTK

The introduction of Real Time Kinematic (RTK) GPS (i.e. base station and rover receivers with radio link) in 1998 removed the need to post-process much GPS data and in effect, allowed GPS to be used for setting-out. Hence, defined centrelines could be followed without the need for line-of-sight, a further key development in the use of GPS for survey/setting out of transmission lines.

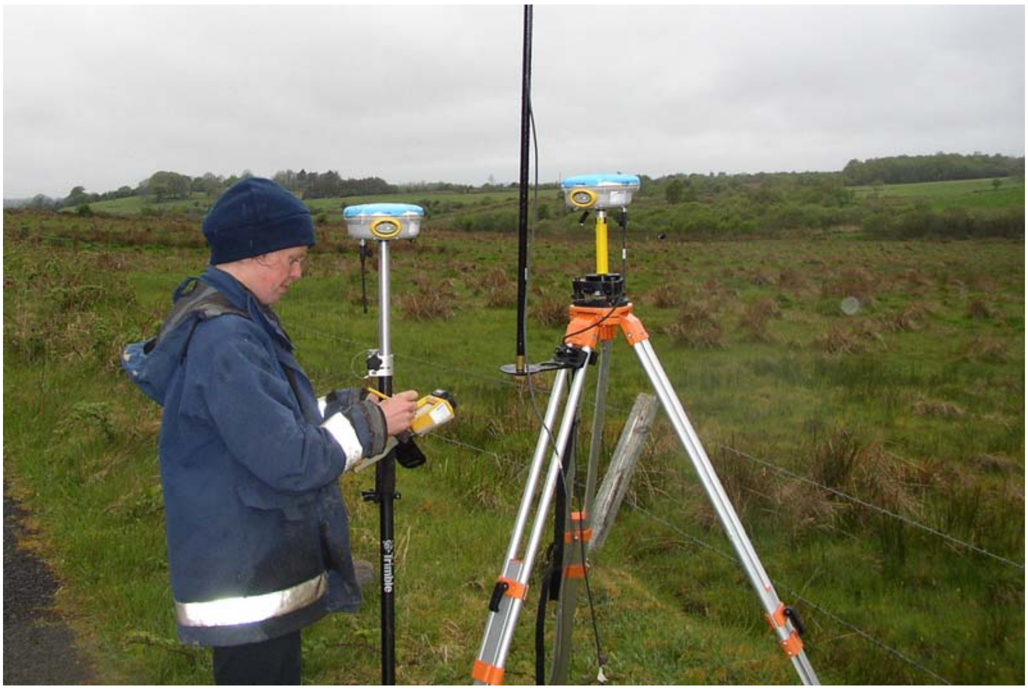


Figure 45 GPS RTK equipment in use for transmission line survey (Source ESB, 2007)

Active Networks (Network RTK)

The introduction of GPS active networks (also known as CORS – Continuously Operating Reference Stations) with differential corrections transmitted via GPRS on GSM mobile phone networks has also been a significant step in the use of GPS. Active network GPS permits single receiver RTK GPS from more than one base station with an increase in reliability through use of these permanent base stations.

Photogrammetric Data

Photogrammetry (aerial survey) was traditionally utilised for the production of large-scale topographic maps. In recent years, the technology has evolved substantially and the provision of digital terrain models (DTM's) and digital orthophotos (geometrically corrected aerial photos) have become key deliverables for engineering design applications including transmission lines. Orthophotos and DTM's form the basis of modern 3D design systems and permit terrain visualisation and fly-throughs etc.

The major developments in photogrammetry have included :-

"**Soft-copy" photogrammetry** : Hard-copy aerial photographs are scanned and processed digitally with no mechanical restitution of image geometry. The process uses PC's with add-ons for stereo viewing etc. which are usually referred to as DPW's (Digital Photogrammetric Workstations). This approach has significantly reduced the associated hardware costs.

Direct geo-referencing : Most aerial survey flying now includes airborne GPS coupled with an IMU (Inertial Measurement Unit) for precise location/orientation of the camera. This can significantly reduce (or in some cases eliminate) the need for ground survey for geo-referencing.

Large-format Digital Cameras : The final element of the fully digital photogrammetric workflow has been the cameras themselves. The past 2-3 years have seen the availability of new large format frame and line-scanner digital cameras which can replace the conventional film cameras. Although at present, these sensors still only number around 10% of the film cameras in use, the situation is rapidly changing.

The vertical accuracy of photogrammetric data is normally directly related to flying height and is generally quoted as such. For design of transmission lines, generally the best available vertical accuracies would be of the order of 10-15cm from flying heights in the range 500-1000m. Recent tests on some of the new large-format digital cameras have shown promising results with in some cases, a significant increase in both horizontal and vertical accuracies.

LIDAR (Airborne Laser Scanning) Data

LIDAR (Light Detection & Ranging), also often referred to as ALS (Airborne Laser Scanning) is a remote sensing technique that may be used to rapidly acquire Digital Terrain Models and which is particularly suited to route corridor applications including transmission lines. LIDAR systems are typically mounted on fixed wing aircraft for higher altitude surveys over wide areas, or helicopters for low altitude surveys such as route corridors (see Fig. 3 below).

The major developments with LIDAR use that have been of benefit for transmission line corridor mapping have included :-

Multi-Sensor Systems : The use of medium-format digital cameras (typically 16-20 MegaPixels) to provide orthoimagery overlays of the corridor. These cameras are light enough and have similar fields of view to the LIDAR sensors which means they can be combined and flown on the same platform.

Pulse Rates : Five years ago, average pulse rates of LIDAR systems were less than 25kHz, while now most exceed 100kHz. This has greatly increased point density on the ground.

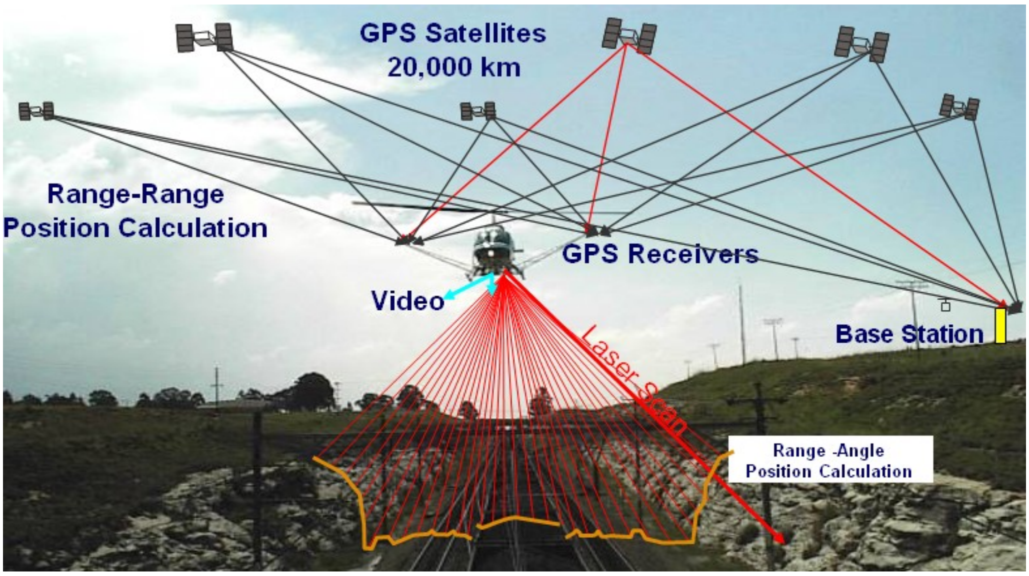


Figure 46 Helicopter platform Mobile Multi-Sensor System set-up

With regard to the accuracy of LIDAR data, providers of LIDAR surveys from altitudes below 500m generally quote height accuracies of the order 5-15cm. It should be noted that such accuracy estimates are normally based on "fundamental" (best case) conditions in open terrain and may not be representative in areas of different ground cover classes or steeply sloping terrain.

10.2. Examples demonstrating technical/economic benefits

Photogrammetric Mapping for Design/Construction

Irish utility consultants ESB International have been using photogrammetric mapping and derived digital terrain profiles for design/construction of transmission lines for over a decade. A 600m corridor width is generally specified for the purpose. For the past 5 years, full 3D Digital Terrain models together with ortho-imagery covering the 600m corridor have been used to permit rapid full design and cost investigations of multiple options and variations. This approach has been highly beneficial in a country with high levels of dispersed settlement and ribbon development along roads.

Figure 47 Proposed construction access routes are marked in yellow (source ESB, 2007)

The vertical accuracy of 0.3-0.5m is generally sufficient to provide a detailed design for planning/permitting purposes. The corridor mapping and orthoimagery allow for qualitative assessment of structure locations e.g. ground conditions, visual impact from dwellings/roads etc. as well as identification and mapping of access routes for construction and stringing (see Figure 47 above).

LiDAR (Airborne Laser Scanning)

Venezuelan utility company CVG EDELCA has been using LiDAR since 2000 for design and construction of new transmission circuits. To date, CVG EDELCA has located 800km of 400kV and 765kV lines. CVG EDELCA recently completed a project using LIDAR for 160km of 765kV line. The survey element of the project was completed in 45 days at a cost of US$150K. This compared with an estimate of US$225K for traditional ground survey. (Ref. CIGRE B2/D2-110 of 2006).

10.3. Additional Remote Sensing Data Sources

Various other forms of remotely sensed data which may be of use in transmission line design include:-

Geo-Referenced Video

Geo-referenced video has found a significant role in the management/inspection of transmission lines. However, when carried on mobile multi-sensor systems, it may also have a role in the design of new transmission lines (e.g. access routes, vegetation cutting, fly-throughs etc).

High Resolution Satellite Imagery

High resolution satellite imagery (e.g. IKONOS, OrbView3, Quickbird) may be of supplemental use in transmission line design where other imagery is not available, also for aspects such as land use, site access and vegetation assessment. This imagery typically has 0.5-1m ground sample distance in panchromatic mode and 2-4m ground sample distance in 4-band (multi-spectral) mode.

Radar Imagery/Digital Elevation Models

IfSAR (Interferometric Synthetic Aperture Radar) can penetrate dense vegetation canopy and may be used for collection of Digital Elevation Models (DEM’s) in tropical environments. DEM’s with vertical accuracies as high as 0.5m may be produced. An example of this is InterMap Technologies NextMap product, although this is presently only available for a limited number of countries.

Geospatial Data Integration for Design/Construction

Developments in Geographic Information Systems (GIS) and terrain visualisation software have occurred as a result of the increased availability of geo-referenced digital imagery and terrain data. In the past, imagery/terrain data were seen as separate from Geographic Information Systems database implementation, where the imagery/terrain data were one step in a process from data collection to GIS database. Modern systems based on the use of Mobile Mapping Systems tend to follow a more complex model of integration in which GPS, Remote Sensing and GIS databases are bound together much more closely.

10.4. Requirements for Mobile Mapping Systems

Most Mobile (Multi-Sensor) Mapping Systems are based around different sensor configurations and many providers use proprietary methods for processing the raw LIDAR data. This can make it difficult to make comparisons between systems and ensure that the resulting data meets specification requirements.

In addition, the technology for filtering and processing of LIDAR data has tended to lag somewhat behind that for LIDAR data collection. Processing of data may take significantly more time than for data collection, between 3 and 20 times depending on the level of processing required. For transmission line design, high levels of processing may be required to provide the required information e.g. bare-earth DTM and correct feature classification of above-ground obstacles including vegetation, buildings, power lines etc. The table below summarises the various levels of LIDAR data processing, levels 4 & 5 being typically those required for transmission line design.

Product Definitions for LIDAR data

Level	Name	Description
1	Basic or “All-Points”	Geo-Referenced LIDAR data, no filtering or analysis : Cheapest/fastest product

2	Low Fidelity or "First-Pass"	Automatic filtering to ground and non-ground points with no other classification
3	High Fidelity or "Cleaned"	Fully edited data set with extensive manual analysis/classification
4	Feature Layers	Further classification for identification of features of interest
5	Fused	Sensor fusion of LIDAR data with information from other sensors e.g. imagery, video etc. Information-rich product with the highest cost

Note : Table summarised from "Product Definitions and Guidelines for use in specifying LIDAR Deliverables", Flood, M., PE&RS Dec.2002.

10.5. Design Platforms

A variety of design platforms are in use for transmission line design. These range from systems based on standard CAD/GIS systems such as AutoCAD (Autodesk), Microstation (Bentley), ArcGIS (ESRI) and others through to more specialised platforms such as PLS-CADD (Power Line Systems), TL-PRO (ITRON) and ALTEXIS (GeoKosmos), most of which offer easy integration with the common CAD/GIS applications as well as the ability to handle geospatial data from multiple sources including LIDAR. These systems frequently offer terrain visualisation, spotting optimisation and materials management amongst others. Some products offer Isoclearance Line feature and danger tree locator.

Data Management during/after Construction

A key issue in the use of Mobile Mapping Systems relates to the management of the large volumes of data that are typical of these projects and how this is maintained during and after construction of the line. When design is complete, the coordinates of the alignment/structures may be exported to GPS/Total Stations for setting-out. Following any design adjustments, the final as-built structure locations will be captured.

The as-built design data will then be transferred to the utility operator and becomes part of their asset base and record information. Ideally, the large volume of information on new lines that may be captured by Mobile Mapping systems (LIDAR, Ortho-imagery etc.) should be retained as part of the asset information after commissioning of the line. However, the management, access and distribution of the large datasets associated with these projects pose many challenges.

Example of Data Management during/after Construction

Examples such as GRIDMC (GRID Monitoring Centre) as implemented by Electro-Slovenia point the way in terms of providing distributed access to geospatial data collected for both existing and newly designed transmission lines.

This system may be used to manage the data on a transmission line following its construction/commissioning in such a way that the large volume of information captured during a LIDAR survey can be distributed across an

organisation post-construction. The GRIDMC application has been used by Electro-Slovenia as a means of distributing the key terrain, structure and other asset information in a form that can be readily used as a tool for line maintenance and clearance checking and is compatible with their existing asset management database.
The capture of large volumes of LIDAR data and imagery from Mobile Mapping Systems for design of new lines may be readily undertaken. However, the more significant issue is how that data is integrated with the as-built design information and deployed by the asset owner after construction. With Electro-Slovenia, GRIDMC demonstrates how these challenges can be overcome and the data utilised to improve system performance and reliability.

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12. LIST OF ABBREVIATIONS

AFIS	Active Fire Information System
ALDIS	Austrian Lightning Detection and Information System
ARC	Auto Re-close
Arc IMS	Arc Internet Mapping Service
Arc-SDE	Arc Spatial Data Engine
CAD	Computer Aided Design
CORS	Continuously Operating Reference Stations
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EIA	Environnemental Impact Assessment
EJB	Enterprise JavaBeans
EMP	Environmental Management Plan
EUCLID	European Cooperation for Lightning Detection
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Global System for Mobile communications (originally from Groupe Spécial Mobile)
HTML	Hyper text markup Language
HTTP	Hypertext Transfer Protocol
IfSAR	Interferometric Synthetic Aperture Radar
ISP	Information system packages
J2EE	Java 2 Platform, Enterprise Edition
LCA	Life Cycle Assessment
LIDAR	Light Detection & Ranging
MODIS	Moderate Resolution Imaging Spectroradiometer
MSG	Meteosat Second Generation
PLS-CADD	Power Line Systems Computer aided Design and drafting
ROW	Right of Way
RTK	Real Time Kinematic
SMS	Short Message Service
SQL	Structured Query Language
WAMIS	Wide Area Monitoring Information System
XML	Extensible Mark-up Language