ELECTRICITY SUPPLY BASICS
TO MEET THE CHALLENGES OF DISTRIBUTION

Trevor Gaunt
Department of Electrical Engineering, University of Cape Town

1 Introduction

I had a low voltage incident at home earlier this month. The lamps glowed a dull orange and my computer made clucking noises of disapproval. The condition lasted for about eight minutes. Now, without looking any further, I want you to write down in the box below, or on a separate sheet, the first thing you think of when an incident like this is described.

We will return to this matter later, but first we need to consider some broader aspects of electricity distribution in South Africa today.

2 A short history

About a hundred years ago the young electricity departments in some municipalities in South Africa were already providing electricity to their communities, as a service but also to raise revenues to fund other services. They had seen the potential for business in this new technology. At the same time, some private firms were also building their markets, with the mines and industry being key customers.

There were many problems. Much of the electrical equipment had to come from far away and lead times were long. The new technologies of materials, protection and network planning required new skills and there was not a lot of local experience. The country was recovering from internal conflict and its effects on the economy, but the exploitation of natural resources offered promising development. Government was undergoing quite a lot of change, old allegiances were no longer appropriate and further changes were soon to come in the structure of the electricity supply industry.

It is said that history repeats itself. In many ways the situation now is similar to that nearly a hundred years ago. South African utilities now are facing reorganisation, required to make new alliances, coping with advanced technologies with too few skilled people, offering valued services to their customers and still making a business of it.

Others at this meeting will address the aspects of reorganisation and alliances. I would like to turn to the other topics: technologies, skills, services and business.

3 Advanced technologies

Quickly write in the next box the technology issue that is most important for you in your organisation at present.

Equipment failure

Is your problem equipment failure? The environment for electrical systems is no less severe today than a hundred years ago. Lightning stresses the insulation of lines and transformers, despite the greater understanding of shielding, earthing and the application of surge arresters. Resource constraints and the pressure to

"sweat the assets" require systems to be operated closer to their limits. However, manufacturers have to design and build the equipment to much smaller tolerances than in the past, to be competitive in today's open tenders. Purchasers specifying their minimum requirements cannot expect manufacturers to provide extra capacity at no cost. If equipment is failing too often, the problem may be in the specification or purchasing procedures, not with the manufacturer.

Earthing

Not all the technologies are the responsibility of manufacturers. Earthing is a mature technology, but was the subject of a paper at the AMEU Convention in 1993 [1]. At that stage South Africa was already embarking on the national electrification programme that has so successfully given millions of new customers access to modern energy supply. Utilities faced several pressures - a variety of earthing practices were already in use on existing systems, new approaches in response to cost pressures were changing the details of distribution system design, and new regulations and guidelines were being developed. The problem was to ensure that the correct match was reached between the different components to ensure safe operation of the systems and safety of the public. During the years since that paper, I have been concerned to see that many utilities and staff have still not mastered the basic principles of system earthing:

- Earthing the system neutral provides a reference point for the insulation of the phase conductors.
- Bonding two normally non-current-carrying components reduces the potential between them to safe levels, even when current is flowing through the bond, and reduces the risk to someone touching both components at once.
- System protection should respond to the conditions that indicate there is a fault from phase to earth, disconnecting the supply and removing the possible danger.
- It is not technically possible to prevent every foreseeable dangerous condition by a combination of earthing and protection, but a satisfactory position is reached when the risks to the public and operators are reduced as far as practicable.
- Mixing different earthing and bonding methods together in one system usually produces dangerous conditions.

This last point is particularly relevant with South African utilities adjusting to reorganisation that has brought previously separate networks and staff together in new organisations. Write in the following box whether the condition of the earthing of the systems under your control is acceptable or unacceptable to you.

The earthing of single wire earth return distribution systems is different from protective earthing in that the earth connection is an active part of the SWER circuit under normal conditions. However, the principle of limiting the voltage between two components also applies.

Maintenance

As already mentioned, most utilities (throughout the world) are working their systems harder, to reduce the asset base on which the accountants calculate the financial returns. At the same time the pressure to reduce operating costs leads to a reduction in maintenance. Time based maintenance is giving way to condition based maintenance. But this introduces two new requirements:

- knowing the present condition of the equipment, and
- knowing at what stage the equipment needs attention.

With the age and variety of equipment on the system steadily increasing, and an apparent shortage of suitably skilled maintenance staff, the problems will get worse. Appropriate training and an understanding of the new theories of maintenance management are needed.

Distribution automation

One of the ways to improve the financial return on assets is to increase the flexibility of the distribution systems. Instead of building robust systems, with lots of redundancy and spare capacity, distribution automation techniques are applied to increase the flexibility of operations. Switching can quickly rearrange networks, rebalancing loads,

shedding least important loads when required and making the most effective use of the 'heavy' equipment. Distributed automation comprises data acquisition and management, computing and communication. Intelligent metering and protection are opening up new opportunities, but issues in system integration, security, data quality and applications need to be addressed.

These new approaches to maintenance and distribution automation are at least as novel and important as high voltage insulation and machine reliability were a hundred years ago, and the utility engineers still have to master the new technologies.

4 Skills development

Skills shortages, new skills, improved understanding - a consistent theme. A modern utility requires people with a wide range of skills or abilities:

- to lay a cable quickly and without damage, with reliable joints and terminations,
- to identify a wood pole that is so rotten that it must be replaced
- to maintain a modern switch or protection and control panel
- to plan a network so that it meets all the operating demands, but incurs the minimum cost,
- to manage the utility as a business.

In the past, many electricity departments had the facilities and staff needed to provide suitable training in-house. Now there is a wide range of external organisations offering training. At one end, university education provides "training" in problem solving based on knowledge of engineering science. In response to a widespread need for upgrading the knowledge and qualifications of engineers in employment, UCT now offers part-time courses leading to the Masters degree. Manufacturers, suppliers and training companies offer a broad range of courses for improving specific skills for manual workers, artisans and technicians. Even the improvement of the workforce's literacy can improve productivity and reduce losses.

Modern technologies are available to assist the employees in all the tasks identified above, but even then, appropriate training and better understanding can significantly improve the effectiveness of the new technologies.

Employees are valuable assets. But inadequately skilled employees are costly. However, probably for historical reasons, many municipalities are reluctant to utilise the facilities of external training organisations. For what percentage of the employees in your company is provision made for skills improvement?

5 Services

Returning to the low voltage incident described at the start of the paper, we have touched on several of the ideas that may have come to mind as the first thing of which you thought. Was there a fault, had a neutral become disconnected, did the protection operate correctly, did an unsafe condition exist? Or maybe you thought about the expectations of customers, the standards for quality of supply or the liability for damages. All are relevant. Customers and the public during the hundred years of service provided by municipalities have come to expect reliable, safe, efficient, high quality supplies of electricity. Can these standards be maintained in the future?

Quality of supply

An evaluation of the National Electrification Programme, carried out by the University of Cape Town during last year [2], reported the following regarding the quality of supply and service standard:

In most cases, the distributors have not needed to make significant modifications to the projects, indicating that the construction quality was adequate. However, there have been very high failure rates for the prepayment meters. Also, the design standards have been changed substantially or vary widely between the distributors, indicating that the initial designs generally, and designs in some projects, may have been unduly conservative. On the other hand, most staff were unaware of the performance of many of the … systems designed using very low values of average demand, and so the systems may not be adequate.

and

Some communities resisted the introduction of 20 A capacity limits on the supply. … However, the suitability of this standard became apparent as the low consumption levels and associated poor financial viability of the electrification programme were confirmed by experience.

Obvious questions arise: Are the design parameters used by your organisation and the quality of supply delivered both consistent with the needs of your customers, without being 'unduly conservative' in the use of expensive resources? Are you sufficiently confident of your response to write it in the next box?

Purpose of electrification

A hundred years ago electricity was supplied for economic reasons. It was less expensive or more efficient and convenient than other forms of energy, so that it contributed directly to the financial productivity of a customer. Later, economists and policy makers realised that here were benefits of electrification for the development of the broader community. The benefits did not accrue directly to the customers or get taken into consideration in electrification planning by the utility. Some benefits were not strictly financial, and techniques were developed to evaluate the economic rate of return of stimulating development. Electrification for the purpose of socio-economic development was implemented widely in the 1970s and 1980s. The National Electrification Plan was conceived in this context during the late 1980s.

However, electrification may also be used to reach another objective: poverty alleviation. Poor people cannot afford much electricity, even if the electrification connection is provided very cheaply or free. And they don't initially have the skills and resources to use the electricity productively. Therefore the purpose of electrification is neither economic nor socio-economic development. It has been proposed that the poorest households be given a consumption subsidy, to meet objectives of social development.

This conceptual framework is new and outside the policies of international finance institutions, who resist proposals for subsidies because of the distortion of the economic mechanisms.

Basic Electricity Support Tariff

The University of Cape Town was appointed by Eskom and the Department of Minerals and Energy in October 2001 to carry out research into a proposed tariff to subsidise the electricity consumption of poor customers.

Technical, social, financial, economic, environmental, health and institutional factors were researched, and key issues identified.

The research report [3] included the following findings:

- Research into poverty alleviation and tariffs cannot be carried out effectively without a good knowledge of the load parameters. The national load research programme, collecting household load data for about ten years with support from several municipalities, provided a comprehensive model of loads against which to test various tariff alternatives and the impact on feeder overloading and generation capacity.
- Electrification has significant social impact, but the benefits are constrained by lack of access to the network, lack of appropriate appliances for those connected and a poor understanding of tariffs.
- Tariffs for consumption subsidies can be targeted to the poor, or applied as a broad-based (applicable to all connected households), increasing block rate tariff. Targeted tariffs are not as effective in reaching all the households, but have lower leakage of benefits to those outside the target group - the non-poor.
- Most of the poorest people in the country are in rural areas and many are not yet electrified. A broad-based subsidy tariff will require significant financial transfers from utilities with a low proportion of poor households, in a national sense, to the utilities serving the rural customers.
- A targeted tariff should limit the demand of customers to 8 or 10 A and the first block of energy should be supplied at a heavily subsidised rate.

Further energy purchases during the month will be at the same rate as for other households. Most metering and vending systems are capable of implementing such a tariff.

In the next box write down whether the proposed tariff is important to you organisation and, if so, which is the key issue for your organisation?

In my opinion, if it is to be adopted for poverty alleviation, a special tariff will have to be a self-targeted, demand-limiting tariff, with customers electing to have it. For utilities not already offering a range of household or domestic tariffs, the basic electricity support tariff will require a change in the concept of providing services to customers.

6 Business

What business are you in?

Businesses must address several needs at the same time if they are to survive. Some business models show management at the centre of an organisation, directing the financial, technical, human resources, procurement and sales sectors of the business.

Another model has at the core of the business a technology or process that delivers efficiently and effectively something the customers want. A solid understanding is needed of that core business. Surrounding and supporting the core there are units addressing the financial, human resources and regulatory requirements of business. All the activities are co-ordinated by management. The advantage of this model is that without a core, the other units have no function, but the core cannot stand alone. This indicates that there is no room for conflict between management and engineering, nor with any other unit.

Electricity utilities supply a fundamental service to industry and business, as well as to the residents of the service area. South Africa's abundant and relatively cheap supplies of energy give local businesses a competitive advantage. Without this advantage, we would all be worse off. So our core business is electrical technology, but the impact is national economic sustainability.

7 Conclusion

No mention of load flow, insulation co-ordination, voltage drop calculations, probability techniques or distributed generation? Certainly, they are important, but the basics of electricity distribution engineering are technology, skills, services and business. The answers in the boxes indicate the important topics in your situation.

8 Acknowledgements

I appreciate the support of the University of Cape Town in its promotion of knowledge development and dissemination, and of all those organisations that by supplying students, funding and problems support the research and teaching activities in the Department of Electrical Engineering. They all contributed to the formulation of the ideas presented here.

9 References

[1] DJ Irving, CT Gaunt : How safe is South African earthing practice? 53rd Association of Municipality Electricity Undertakings Convention, Durban, September 1993.

[2] M Borchers et al: *National Electrification Programme Evaluation: Summary Report,* University of Cape Town, 2001.

[3] University of Cape Town: *Options for a Basic Electricity Support Tariff.* Research project 400903, February 2002.

The author:
Prof C T Gaunt, Department of Electrical Engineering, University of Cape Town, Private Bag, Rondebosch, 7701 South Africa. ctg@eng.uct.ac.za

Trevor Gaunt's working experience has included equipment manufacturing, system protection, network analysis and planning, project management, organisation and tariff studies, and now at UCT teaching and research. He leads the UCT team researching the Options for a Basic Electricity Supply Tariff. He presented papers to the AMEU Technical Meeting in 1988 and Conventions in 1991 and 1993.