OPTIMAL UTILITY NETWORK INVESTMENT

M E N du Preez
(Managing Director,
Pr.Eng, SMSAIEE)

D J Vrey
(Senior Engineer, Pr.Eng)

Abstract. Capital investment by electricity utilities is being reconsidered as such investment has a major influence on financial margins and network reliability. Utility owners want to maximise financial margins whilst electricity regulators are very much concerned about tariffs to end users and network reliability. An approach to achieve optimal investment within requirements of regulatory authorities and expectations of shareholders is challenging and the subject of recent research and publications. Investment for network expansion, renewal and reliability needs to be analysed carefully to achieve the stated objective.

Keyword Index – asset management, optimal capital investment, network expansion planning, electricity network renewal

1 Introduction and Background

Following the electricity market liberalisation, the unbundling of electricity utilities and privatisation there is a growing pressure on utilities to improve efficiencies and to rethink expenditure on network assets.

New initiatives in the United Kingdom and New Zealand suggest that a unified approach to optimal network asset management holds some promises. This thinking gave rise to the following definition:

Asset Management is a set of disciplines, methods, procedures and tools to optimise the life cycle costs, performance and risk exposures of the company's physical assets.

This approach to network asset management is advanced and promises major benefits to utilities in the developed world and also to normalised utilities in developing countries. Developing utilities in the initial stages of their investment cycle may not be too concerned with some of the sophisticated aspects implied by the definition above but the fundamentals addressed in the remainder of this paper remains paramount for the huge investment task they are faced with.

In Africa, some countries have progressed well with unbundling the electricity sector and to introduce market liberalisation such as vertical separation, horizontal separation and opening up the market for trading. Countries leading this new trend are Ghana, Nigeria, Uganda, South Africa and Namibia to mention a few. Many other countries have started the process and are well under way towards a more liberal configuration of the electricity sector.

Electricity utilities are asset intensive by nature and many feel that asset management is the correct approach when deciding on the methodology to invest in the network assets.

Fundamental to asset management is managing the trade-off between risk and return.

Asset management is a business approach aimed at maximising network performance and profitability whilst minimising capital expenditure, operational expenditure and the risk of power outages. This implies managing the utility such that key targets align with realities of network asset investment requirements.

The above can only be achieved if business processes and information systems that support the mentioned business objectives are deployed. This approach should result in a long-term capital expenditure plan clearly showing annual investment requirements within an environment where regulatory requirements are met but also where shareholder value is maximised.

To summarise, asset management is about:

- Maximising network performance and return whilst minimizing risk and expenditure,
- Managing the utility such that key targets align with asset investment requirements, and
- Generating a capital investment program that is regularly updated through the support of modern information systems.

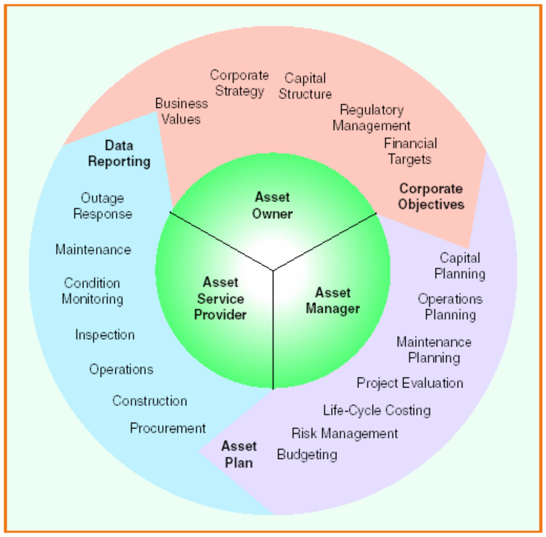

Figure 1: Asset management is based on three functions (asset owner, asset manager, and asset service provider), a single process, and many decisions [1]

Important to note the three functions that utility assets are based on namely asset owner, asset manager and the service provider area. Figures 1 and 2 depict the different aspects addressed by each role player. Note in Figure 2 the different areas requiring asset investment activities such as strategy, portfolios, planning, maintenance etc.

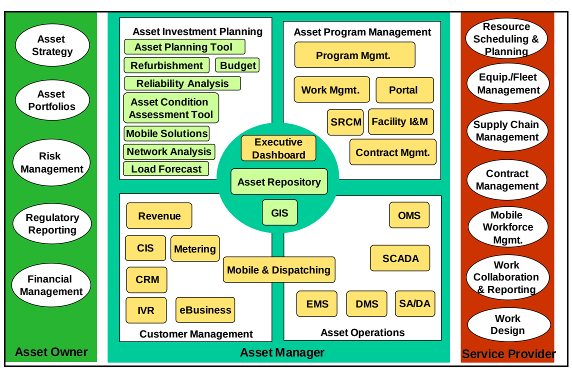

Figure 2: What is asset management?

2 Investing for Network Expansion

One of the objectives of power system planners is to determine an investment schedule for the construction of electrical infrastructure to ensure the economic and reliable supply to the predicted demand.

The steps involved in network expansion planning (see Figure 3) in order to provide electricity capability to a utility supply area include the following:

- A load forecast for the entire utility supply area. This result is the foundation of the planning process. The load forecast is preceded by strategic input studies performed by demographers and economists,
- Alternative networks are identified and tested that can serve the load and that comply with basic technical requirements under steady state conditions such as voltage profiles and loading levels. Fault levels are also evaluated and in special cases stability and reliability constraints are taken into account, and
- An annual based 20-year capital program is compiled to cater for the expected network expansion.

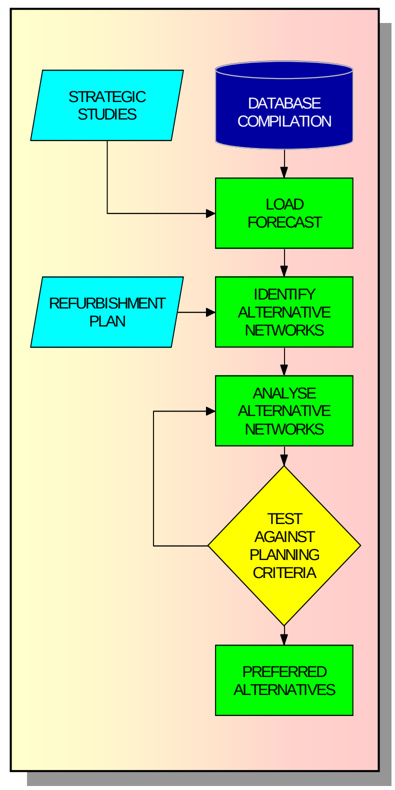

Figure 3: The basic process of network expansion planning.

2.1 *Load Forecasting*

Electric load forecasting is a crucial input to obtain an optimal long-term development plan.

Geographically based load forecasting (GLF) is regarded as the most suitable method where land-use forecasts combined with sound econometric principles are used to establish long term electricity demand, loading is not just summated onto a substation but determined geographically at the customers where this demand originates.

Figure 4 is a graphical depiction of this process and it shows how forecasting in the bottom layer per small area is summated upwards per load zone and eventually per substation or feeder as required.

Figure 5 shows what the loading on substation level eventually looks like. Network development results in load zone transfers between substations and feeders - hence the step changes in loading.

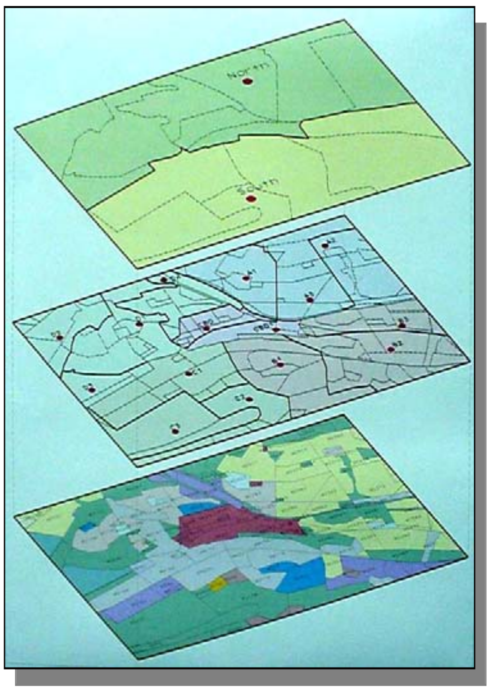

Figure 4: Geo-spatially based load forecasting

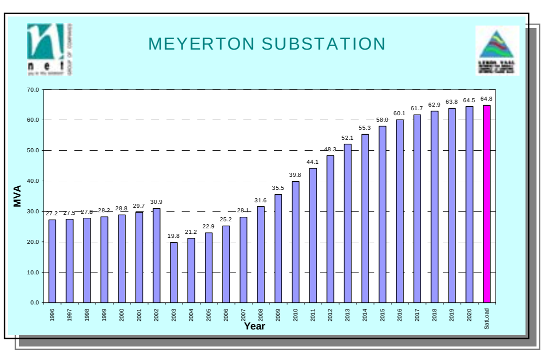

Figure 5: Forecasted annual loading per substation

2.2 Confirm loading levels and voltage profiles

In order to be sure that the networks will be able to supply the load within thermal capabilities and at acceptable voltages it is necessary to do comprehensive network analysis for confirmation. Network strengthening is necessary where the analysis shows deficiencies. Capital projects for the network reinforcement and expansion are identified and included into the capital investment program.

2.3 Planning Process

The planning process involves iteration between zoning in the load forecast, network analysis and adjustments to the capital investment program until the networks can supply the loads within the required technical standards on a just-in-time basis.

3 Investing for Network Renewal

It should be realised that having identified and resolved network expansion it is still necessary to also address capital investment for network renewal. A first priority is to normalise the existing or old portions of the networks such that they can deliver their design capacities at an acceptable level of quality. A process of available data collection, field audits, analysis of interruptions, ranking of deficiencies, costing, prioritisation and project formulation is followed to achieve this.

This process entails the collection and processing of an extensive amount of technical data and software tools normally come in handy to achieve this. The software is used to capture both the nameplate and condition data of the equipment. Evaluation is done through score sheets and these scores eventually lead to ranking and renewal prioritisation. Projects are identified, formulated with cost calculations and ordered into the capital investment program.

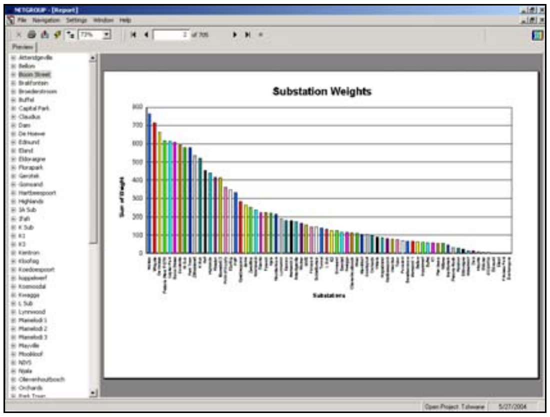

Figure 6: Renewal prioritisation results

4 Reliability Considerations

4.1 General

It is becoming common for Electricity Utility Regulators to enforce network performance targets. The principle is to not only regulate the price of electricity but also the quality. An aspect that was not answered in sections 2 and 3 above is the risk or probability that the networks will fail and the consequent electricity interruptions to the customers.

Reliability targets normally aim at the frequency and duration of power outages. It is important that the capital investment program results in a network that will comply with set reliability standards and reliability analysis is used to confirm this.

4.2 Composite System Reliability

Single or multiple load level Transmission and Sub-Transmission system adequacy assessment is performed through a contingency enumeration process. Contingency studies are normally performed incorporating an ac-loadflow algorithm.

System adequacy indices are quantified through the following analysis:

- Deterministic contingencies,
- Load curtailment, voltage and overload violations,
- Voltage collapse, network cascading, network islanding,
- Probabilistic assessment of system violations,
- Frequency, duration and severity of events,
- Probabilistic load curtailment assessment, and
- Expected unserved energy (EUE) and customer impact.

4.3 Distribution Reliability

Approximately 80% of all interruptions experienced by customers are due to faults on the Distribution system. One of the most challenging aspects of Distribution System planning is the optimization of the system in terms of outage performance or reliability. This is achieved through the application of a number of analytical techniques and methods.

These Analytical methods include:

- Calculate historical failure rates,
- Model chosen feeders,
- Calibrate model with physical inspection data,
- Determine baseline reliability performance,
- Assess reliability goals and targets,
- Identify applicable mitigation strategies,
- Conduct parametric studies, using a predictive model through Monte-Carlo simulation, and
- Select viable mitigation strategies.

Distribution performance indices as usually specified by regulators include:

SAIDI, SAIFI, CAIDI, CAFI, ASAI, CTAIDI, ASIFI, ASIDI and MAIFI

4.4 Substation Reliability Assessment

The reliability of a substation can be measured by the frequency and duration of station related outage events. These outages include:

Failure of the sub-system supplying the station, faults on the substation equipment, failure of a breaker to clear a fault or the false tripping of a breaker, operational failures as well as scheduled and unscheduled maintenance.

Substation reliability assessment provides for:

- Comparing substation configuration alternatives,
- Evaluate the sensitivity of substation performance to various system conditions such as: equipment outage statistics, equipment rating and load level,
- Determining the impact of equipment maintenance on reliability, and
- Comparison of substation configuration and breaker arrangement.

5 Financial Considerations

Financial modelling of the utility, including the envisaged capital investment program is important to confirm the long-term viability of the utility.

The financial model covers the following:

- Capital expenditure and long-term loan repayment,
- Income from sales by applying the tariff structure to customer category consumption levels,
- Expenses such as operating and maintenance costs,
- All income and expenses are projected into the future,
- Indicators such as cash flow, internal rate of return and net present value, and
- Aspects such as surplus, taxation, non-technical losses and social-economic implications.

Such a model is useful to calculate different scenarios and to highlight the factors that influence the financial well being of the utility. The utility can then be managed towards the strategic long-term goals. Common financial indicators such as internal rate of return and cash flow are calculated.

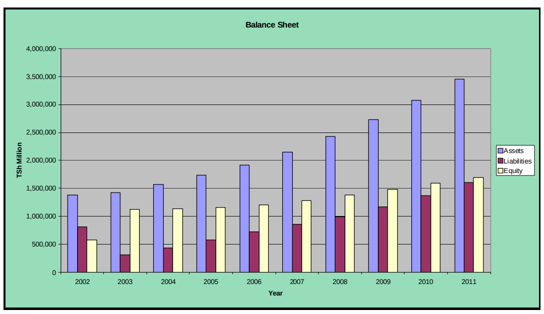

Figure 7: Balance Sheet

6 Information Systems

The business processes described above rely on quality information systems. Decisions about capital investment rely heavily on good data. The best way to make reliable information available to decision makers is through information systems. It should be realised that the discussions as reflected above imply that systems are in place that records aspects such as maintenance of equipment, the failure of equipment, the loading on systems and other critical asset investment related information. The following systems are specifically implied:

- Asset register,
- AM/FM/GIS,
- SCADA, and
- Maintenance management system.

Recently the whole matter of system integration and the difficulties associated with legacy systems have been realised. Exploiting technologies such as the integration bus and the common information model (CIM) makes the whole task of asset management and capital investment decisions simpler.

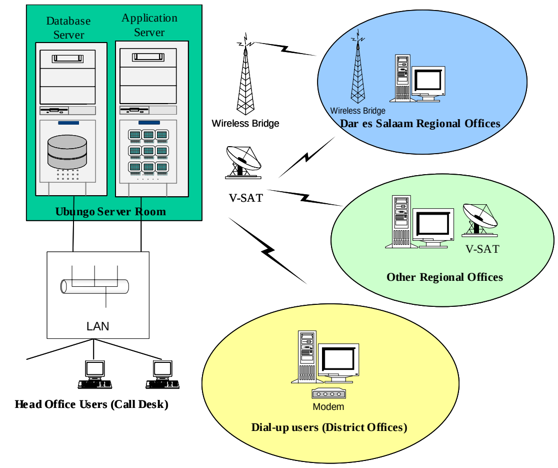

Figure 8: Typical IT systems

7 Final Capital Investment Program

7.1 *Finalising Projects*

All the projects necessary for network expansion, renewal, reliability improvements and efficiency improvements need to be consolidated into a single and phased capital investment program. These projects should then be packaged and phased into practical units so that customers still enjoy electricity supply while construction continuous.

7.2 *Costing of Projects*

The costing of capital projects is done by using standard equipment costs, contained in an equipment library. Exploiting software is very helpful to lighten the burden of costing the capital projects. By defining standard project modules or building blocks such as line feeder bays, transformer bays and standard transmission line costs per kilometre the automation of the costing exercise is possible.

7.3 *Final Investment Program*

Once all the projects have been phased, packaged and priced it is important to confirm that the capital program contains practical annual capital investment programs that can be implemented within the resources available to the utility. Although the financial viability has been proved at this stage, the following factors need to be considered as well:

- Balanced annual project work load,

- Avoid excessive project workload in initial stages,
- Outages due to construction activities should be reasonable,
- Acceptable network reliability must be maintained during construction, and
- The market must be able to supply the required services e.g. manufacturing, construction and project management.

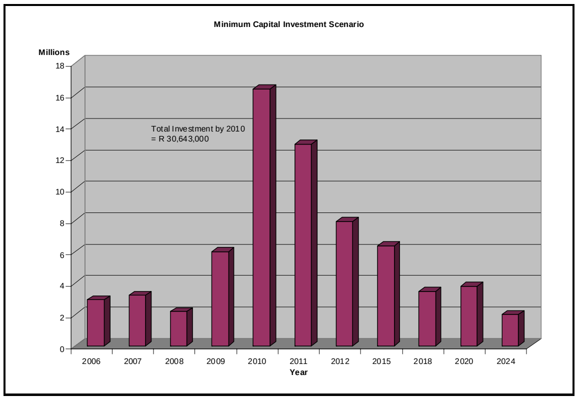

Figure 9: Capital investment program showing annual expenditure

Year	Project description		Project Cost
2006	Add 1 x 11kV CB panel, move Cable.	R	186,340.00
2006	Add 2 x 3.5km, 300mm² 1C Cu XLPE 66kV Cables.	R	-
2006	2 x 66kV Feeder Bays and Busbar Extension.	R	2,740,249.77
2006	New Distribution Network Development - Worcester Dam.	R	-
2006	Add 1 x 11kV CB panel, add 2.0km 35ABC OH 11kV Al L	R	967,840.00
2007	Add 0.4km 70mm² Cu XLPE 11kV Cable.	R	160,000.00
2007	Add 2.2km 240mm² Cu XLPE 11kV Cable.	R	1,262,800.00
2007	New 11kV Substation and 9 x 11kV CB panels.	R	-
2007	Add 2 x 11kV CB panels at Roodewal Substation.	R	480,680.00
2007	Add 1.8km 240mm² Cu XLPE 11kV Cable.	R	1,033,200.00
2007	Upgrade 0.77km to 185mm² Al XLPE 11kV Cable.	R	344,190.00
2007	Add 1.5km 240mm² Cu XLPE 11kV Cable.	R	861,000.00
2007	Add 2 x 0.55km 240mm² Cu XLPE 11kV Cables.	R	631,400.00
2007	New 11kV Substation and 13 x 11kV CB panels.	R	-
2008	Upgrade 1.48km to 185mm² Cu XLPE 11kV Cable.	R	778,480.00
2008	Upgrade 1.84km to 185mm² Cu XLPE 11kV Cable.	R	967,840.00
2008	Upgrade 1.05km to 240mm² Cu XLPE 11kV Cable.	R	598,108.00
2008	Upgrade 1.1km to 185mm² Al XLPE 11kV Cable.	R	491,700.00
2008	Add 0.2km 35mm OH 11kV Line.	R	60,000.00

Table 1: Example of capital investment program

8 Conclusion

Previously utility capital investment was based on concepts such as least cost planning, value based planning or simply on an as required basis. This paper reflects the modern approach based on the concept of asset management. This entails a more holistic approach where the asset investment requirements are more closely aligned with key business objectives. Important is to formalise and implement business processes backed by information systems to achieve the capital investment that works the best for the utility and that still meets regulatory requirements.

9 REFERENCES

1. Brown Richard E and Humphrey Bruce G Asset Management for Transmission and Distribution, IEEE Power and Energy Magazine, May/June 2005.

10 BIOGRAPHY

Marius du Preez is an electrical engineer by profession with 20 years practical experience. His experience in utilities varies from Generation and Transmission to Distribution.

Marius graduated from the University of Pretoria with bachelors, honors, and masters degrees in electrical engineering. He did his practical training with Eskom Transmission Operations. He is a co-founder of NETGroup Solutions and established various business units in NETGroup.

His experience in NETGroup includes: network planning, design, project management as well as the conceptualisation and development of various engineering software tools. Other skills are: financial modelling and tariff design, utility restructuring, market rules, reliability analysis, and all aspects of power system analysis.

Marius is currently the managing director of NETGroup South Africa.