EVALUATION AND EFFECTIVE MANAGEMENT OF NON-TECHNICAL LOSSES IN POWER NETWORKS

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Abstract: Market-driven power economies and deregulated electricity industry environment have stimulated the minimization of technical and non-technical losses (NTL) even though they do not constitute major operational or quality of supply problems. Their negative impact on the economics of utilities operations is often passed down as costs to consumers. NTL need to be addressed to determine the overall performance of power networks, as these losses are expected to be more dominant at the sub-transmission (132kV-33kV) and reticulation (22kV and 11kV) levels of the electricity supply industry value chain. In some national grid operations, NTL are estimated to account for up to 30% in revenue losses to electric utilities, and overhead expenditure in added maintenance costs. This paper discusses a method for NTL evaluation and an effective management approach to loss minimization and revenue collection.

1. INTRODUCTION

Investigations have been undertaken to assess the impact of technical losses in generation, transmission and distribution networks, and the overall performance of power networks [1-5]. Non-technical losses (NTL) are widely acknowledged by electricity distribution utilities worldwide, and in some national grid operations, they are estimated to account for up to 30% of revenue losses to utilities. This is largely due to non-payment for services, unauthorised line tapping and overhead expenditure in added maintenance costs for line or equipment damage.

Technical and NTL require continuous, efficient control supervision by utilities to ascertain the factors responsible for them, and consequently how to minimise them. NTL appear to have never been adequately studied, and to date, no published data of NTL in the South African Electricity Supply Industry (ESI) is known to the author. This study is a critical analysis of NTL in electric power networks; it identifies and describes the sources of NTL, with the key question: To what extent does NTL account for loss of revenue to public and private electric utilities (e.g. annual GWh lost expressed as a percentage of total GWh produced). It further addresses the costs associated with NTL, their overall economic impact, and how NTL may be reduced to an acceptable level.

2. NON-TECHNICAL LOSSES

Substantial losses are incurred in the processing, delivery and utilisation of electricity. These losses are both technical and non-technical, but need to be minimized to optimise returns on investment. Technical losses include: generation losses (due to turbine efficiency), and losses due to the current flowing in the electrical network such as line losses, copper and iron losses of transformers [5]. Losses represent a considerable operating cost, estimated to add 6 to 8 percent to the cost of electricity and some 25 percent to the cost of delivery [2].

The accurate estimation of electrical losses enables the supply authority to determine with greater accuracy the operating costs for maintaining supply consumers. This in turn enables a more accurate estimate of the system lifetime costs, over the expected life of the installation [3].

In most developing countries, transmission and distribution (T&D) losses account for a large portion of non-technical loss. This implies that the utilities may have to concentrate on non-technical loss reduction prior to reducing technical loss [6]. Non-technical losses (NTL) can be attributed to and include the following:

- Non-payment of electricity bills
- Unauthorized line tapping and diversion
- Losses due to faulty meters and equipment
- Inadequate or faulty metering
- Poor revenue collection techniques
- Inadequacies and inaccuracies of meter reading
- Inaccurate customer electricity billing
- Loss/damage of equipment/hardware, e.g. protective equipment, meters, cables/conductors and switchgear
- Inaccurate estimation of non-metered supplies, e.g. public lighting, agricultural consumption, rail traction
- Inefficiency of business and technology management systems

The types of non-technical losses identified are dominant in lower levels of distribution (reticulation) networks, and lead to loss of revenue. The South African ESI like many counterparts in developing countries has been largely a government monopoly hence the cost of these losses is often arbitrarily passed on to end-users (consumers) as higher electricity costs. NTL are usually construed as a loss of revenue by the utility, and both these losses need to be reduced to their optimal level.

When NTL decrease to an acceptable level, steps should then be taken to reduce the technical losses by rehabilitation of the existing networks and construction of new additions. The sources of NTL require new and innovative methods for estimation, analysis and minimization when compared with technical losses.

3. TECHNICAL AND NTL ESTIMATION

Using South Africa's power grid as a case study, a review of the evaluation procedure for technical losses in transmission and distribution (T&D) system is carried out, and a method for NTL estimation is presented. The total system loss is given by the difference between the energy generated or delivered and the energy sold. Normally the energy used in power station or substation auxiliaries is deducted from the losses to get a true reflection of the system losses.

Energy loss is given by:

$$E_{Loss} = E_{Delivered} - E_{Sold} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$C_{Loss} = U_{Cost} \times E_{Loss} + M_{Cost} \quad \ldots\ldots\ldots\ldots (2)$$

$$C_{NTL} = C_{Loss} - C_{TLoss} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$C_{NTL} = U_{Cost} \times E_{Loss} + M_{Cost} - C_{TLoss} \quad \ldots (4)$$

where,

C_{Loss} = Revenue loss due to technical/additional losses
U_{Cost} = Unit cost of electricity
M_{Cost} = Maintenance and additional operation costs.
C_{NTL} = Non-technical loss cost component, while
C_{TLoss} = Technical loss cost component.

The NTL has an energy component directly related to the power network losses, and a second component due to non-energy related revenue loss, accounted for by additional maintenance costs, and direct revenue loss. The first component is computed as in equation (4), but the second component is obtained for additional operation and maintenance costs associated with NTL data.

For technical loss estimation, the annual cost of I^2R loss in Rand per mm^2 of conductor cross-section per mm length, can be estimated. For cost of cable,

$$C_{cable} = \alpha A + \beta \quad \text{Rand/unit length}$$

where α is in Rand/mm^2 /mm length for three-phases, A is conductor cross-sectional area/phase (mm^2), and β is for the rest of the three-phase cable

Structural charge, S is given by

$$S = L(\alpha A + \beta)\frac{r}{100} \quad \text{Rand/annum}$$

Cost of technical losses, W is given by:

$$W = 3 \times \frac{I^2 \cdot \rho \cdot L}{1000 \cdot A} \times 24 \times 365 \times \frac{p}{100} \quad \text{Rand /annum}$$

where I is phase current (amps), L is total length (mm), ρ is resistivity of conductor material (Ω-mm), p is the cost of energy in cent/kWh, and r is the combined % rate of interest and depreciation of the line conductors.

From estimates of technical losses, it is easy to estimate the impact of NTL on revenue and electricity pricing. Therefore small reductions in network losses will amount to significant financial savings to utilities as well as customers.

4. STRUCTURAL REFORM AND ESI

Electrical power utilities in developed and developing economies, which are largely government monopolies, are being compelled to restructure due to globalisation, changing public perception, environmental, regulatory and economic competitiveness in this sector. Restructuring and privatisation (entailing government divestiture) often precedes this, followed by deregulation. This market liberalization and industry privatisation trend is not limited to the electricity industry, but also applies to the communications, petroleum, defence and other industries.

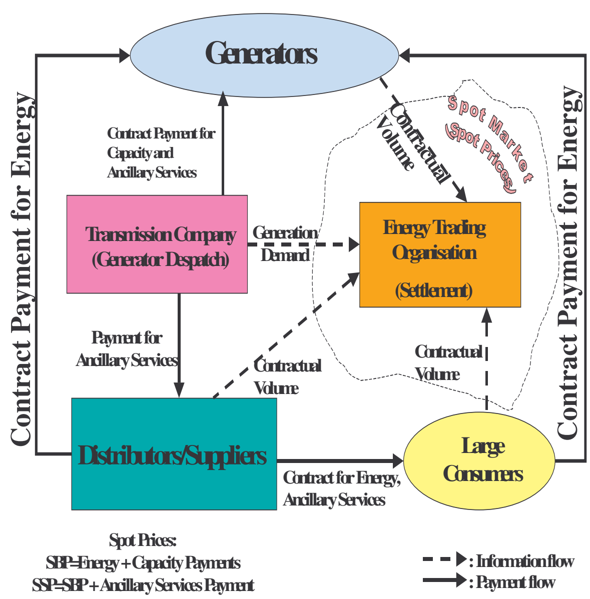

Figure 1 Proposed Electricity Market Structure

Fundamentally, the objectives for ESI restructuring and privatisation should be to:

- Sustain future economic and technological growth.

- Deliver adequate social benefits to the populace.
- Ensure a secure and reliable supply of electricity.
- Encourage efficiency through competition and regulation in all segments of the electricity industry.

Worldwide experience shows that successful privatisation and deregulation of the electricity industry is achieved when it is unbundled into generation, transmission and distribution sections, with each section operating as a business enterprise on its own merit with distinct functions and responsibilities [7]. The restructuring of the ESI means breaking up the often vertically integrated structures into generation, transmission and distribution operations. The focus of this approach is to maximise revenue to be derived from restructuring and privatisation, and ensure wider public involvement in the industry. The operation of each of these sections as separate business entities often involves measures to minimize costs, provide good quality service, enhanced operational efficiency, maximize profits and provide a high rate of return on investment (ROI).

5. OPERATING ELECTRIC POWER NETWORKS AS BUSINESS ENTITIES

Consumers/regulators are demanding price transparency and elimination or disclosure of cross subsidies among different users. Consumers want competition in the electric industry so they can get lower prices. Marketers want the electric industry restructured so they can make money, either by getting a higher price for the output of generators they own or to which they have access, or just by opening up a new market. [8] These two seemingly opposing forces must be adequately managed and regulated to achieve optimal performance of electric power networks.

The business and technical systems performance of network operators will determine the overall return on investment (ROI), hence economic and business measures have to be adopted. Maximum efficiency minimizes the cost of kWh to the customer and the cost to the company for delivering that kWh, with rising or changing fuel, labour, and maintenance costs. Recently, the UK electricity regulator opted to remove price controls from the ESI, because of the realization of competition in the industry. Economic operation of power networks will necessitate a reduction in technical and NTL.

6. NTL AND SOUTH AFRICA'S POWER GRID

An accurate assessment of the NTL problem is critical to prescribe appropriate solutions. As a basic constraint, the cost of implementing solutions should not exceed the cost of NTL in revenue to electric utilities. Factors affecting NTL include:

(i.) Socio-economic: unemployment, rural and urban poverty, financial insecurity, illiteracy and lack of broad-based private/community sector ownership.

(ii.) Professionalism: This is poor in many business enterprises, as well as weak commercial skills

(iii.) Organizational behaviour: This is often poor leading to negative attitude to customer service.

(iv.) Technical Tools: Insufficient cost-effective technical resources to tackle these problems.

The strategies to be adopted for NTL reduction include development of optimum business models, new capabilities for managing power networks as business entities, and a shift in public attitude. These can be divided into focused areas.

6.1 Business/Management Focus

This involves:

- Development of optimum business models for enhanced management of processes

- Development of business capabilities:
  - Structures and controls to reduce errors
  - Improve segregation of duties/accountability
  - Reduce possibilities for fraud
  - Eliminate inaccurate financial reporting and reconciliation
  - Effective system recording, documentation and journal entries for energy data, operational and additional maintenance costs due to NTL.
  - Standardization of reporting techniques and energy-balancing tools.
  - Accuracy of management reporting and the processing of pre-paid transactions.
  - Energy data and revenue audits

- Staff training, work ethics, professionalism and good customer service to support these business capabilities.

- Development of efficient community-based revenue collection techniques, bulk meter installations for – small power consumers.

6.2 Technology Focus

This involves technology management and deployment, in areas such as:

- Operating more power substations on supervisory control (SCADA)
- Protection, metering and control (PMC) functional integration and automation
- Standardization of measurement techniques.
- Pre-paid metering, to reduce NTL within the pre-paid environment
- Energy monitoring and data acquisition techniques

- Electronic and cashless financial transaction in the electricity supply industry
- Testing, maintenance and elimination of faulty meters, and out-dated equipment.
- Detection of metering tempering

6.3 Public Sector Focus

This includes:

- Extensive private sector and community participation in ownership of power network and infrastructure
- Public safety issues
- Minimization of fraud at work and theft of cash in transit to protect revenue

7. CONCLUSION

To evaluate the impact of system losses, the magnitude of these losses needs to be determined. As shown, the total system losses can easily be determined from equations (1,2). The losses are then divided into technical and non-technical losses. The next step is to assess the continuing cost of losses, usually in annual terms. This cost should reflect the cost of production (i.e. generating capacity), fuel consumption and reflect the cost of capacity/delivery in transmission and distribution networks. These losses should be recognized as real and substantial costs on the supply of electricity and should be managed like other costs.

Losses can be reduced by local network development and implementing the strategies proposed in this paper. By using this option you not only reduce the generation and system capacity but also reduce the cost of delivery of energy, which is the biggest contributor to the final cost of energy. This option also improves system efficiency and reduces cost of electricity to consumers.

The benefits of NTL estimation/minimization include:

- Provide vital database information on the risk factor associated with our power network to power system planners and maintenance units, and thus improve on security and quality of supply.
- It translates into direct economic benefits with enhanced revenue for distribution companies and municipalities.
- Potentially reduce electricity prices and boost economic competitiveness in local industrial sector, and improve electric power affordability by low-income earners.

NTL minimization is a concrete economic and business tool to optimise the overall performance of our power networks.

8. ACKNOWLEDGEMENT

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