NON-TECHNICAL LOSSES IN POWER NETWORKS
ANALYSIS AND IMPACT ASSESSMENT

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Abstract–Electric utilities operating as government monopoly institutions in rigid grid structures, have in the past paid little attention to assessing and analyzing technical and non-technical losses because they did not constitute major operational or quality of supply problems. Since their impact is economic, costs involved were often passed down to consumers. In market-driven economies and deregulated electricity industry environments, the minimization of these losses has assumed greater importance. In South Africa, non-technical losses need to be addressed to determine the overall performance of transmission and distribution networks, as these losses are expected to be more dominant at the subtransmission (132kV-33kV) and reticulation (22kV and 11kV) levels of the electricity supply industry value chain. Non-technical losses appeared to have never been thoroughly studied. In some national grid operations, it is estimated to account for up to 30% of revenue losses to utilities, and overhead expenditure in added maintenance costs. The goal of privatization and deregulation of South Africa’s electricity supply industry and introduction of competition is to provide end-users with lower energy prices and good quality of supply. Hence stakeholders are demanding greater transparency in electricity pricing by regional electricity distributors (RED). This paper provides an overview of non-technical losses in South Africa’s power grid, and presents strategies for loss minimization, revenue collection and stimulus for further NTL research investigation with active industry participation.

Key words: Non-technical losses (NTL), loss minimization.

I. INTRODUCTION

Research 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) appear to have never been adequately studied and in some national grid operations, it may account for up to 30% of revenue losses to utilities due to overhead expenditure in added maintenance costs. To date, no existing data of non-technical losses in South Africa’s Power System is known to the author.

This paper undertakes an introductory study/review of non-technical losses in electric power networks. It identifies and describes the sources of non-technical losses, with this key question in view: To what extent does non-technical losses account for loss of revenue to power utilities and municipalities (e.g. annual GWh lost expressed as a percentage of total GWh produced by Eskom)? It further attempts to address this and other issues, such as: the costs associated with NTL, their overall economic impact, and how NTL may be minimized or eradicated?

II. NON-TECHNICAL LOSSES

The processing and delivery of electricity involves substantial losses, which need to be minimized to maximize revenue. These losses are both technical and non-technical (NTL). 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]. Technical and non-technical losses in networks are an economic loss. 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].

Non-technical losses (NTL) can be attributed to and include the following:

- Equipment loss and vandalization - loss and damage of hardware, such as meters, protective equipment, cables/conductors and switchgear
- Unauthorized line tapping
- Losses due to faulty meters and equipment
- Inadequate metering and poor revenue collection techniques
- Inadequacies and inaccuracies of meter reading
- Inaccurate customer billing
- Inaccurate estimation of non-metered supplies, such as public lighting, and
- Performance (inefficiency) of business/technology management systems

Most of these types of losses are dominant in lower levels of distribution (reticulation) networks, and lead to loss of...
revenue. 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. The sources of NTL require new and innovative methods for estimation, analysis and minimization when compared with technical losses.

III. POWER SYSTEM INVESTMENT PLANNING

Power system development planning entails load growth identification by magnitude and location over a period of interest, and matching generation is secured. This is followed by the possibility of local generation with fuel transportation compared with remote generation and electrical transport.

The technical problem of transmission is considered and a decision made on the choice of ac or dc. The management of a power-supply authority demands consideration of these factors if the most attractive return is to be secured on the investment.

The basics of investment planning for power networks involves:

(a.) Fixed (Capital) Costs
- Switchgear
- Equipment - generators, transformers, protection devices, etc.
- Land
- Infrastructure (building)
- Loans/interests/insurance
- Labor (construction)

(b.) Variable (Operational) Costs
- Fuel costs
- Worker’s salaries
- Maintenance
- Transportation

Before a numerical evaluation of NTL is carried out, a background on the changing electricity industry environment should be mentioned, and how market forces are shaping a radically different world.

IV. STRUCTURAL REFORM AND OPERATION OF THE ELECTRICITY SUPPLY INDUSTRY

Globalization, changing public perception, environmental, regulatory and economic challenges are compelling electric utilities and government-owned monopoly institutions to restructure, both in developed and developing economies. This is often preceded by privatization (which often entails government divestiture), and then deregulation (or re-regulation).

This market liberalization and industry privatization trend is not limited to the electricity industry, but also applies to the communications, petroleum, defense and other industries. Governments are also under pressure to raise funds to pay debt, fund social services, balance budgets, and carry out economic reform [6]. Electric utilities are required to supply low cost power to customers, provide better service and ensure high environmental and health safety.

As a rule, the fundamental objectives for privatization and restructuring of the electricity supply industry (ESI) must 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 privatization 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/responsibilities [7]. Restructuring of the electricity industry means breaking up the often vertically integrated structures into generation, transmission and distribution operations.

This approach will maximize revenue to be derived from privatization, 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, maximize profits and provide a high rate of return on investment (ROI).

V. 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/regulated to achieve optimal performance of electric power networks.

The business/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, labor, 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 entails two components, namely: minimum cost of power production called economic dispatch and minimum loss for delivery of generated power to the loads.

VI. NTL AND SOUTH AFRICA’S POWER GRID

An accurate diagnosis of the NTL problem is critical to prescribe suitable solution. 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 often poor in many business enterprises, as well as weak business skills
(iii.) Organizational behavior: This is often poor leading to inappropriate 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:

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 to support these business capabilities, as well as work ethics, professionalism and good customer service.
- Development of efficient community-based revenue collection techniques, bulk meter installations for small power consumers.

Technology Focus: This involves technologies 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 acquisition in the electricity supply industry
- Testing, maintenance and elimination of faulty meters, and out-dated equipment.
- Detection of metering tempering

Public Sector Focus: This involves:
- Extensive private sector/community participation in ownership of power network/infrastructure
- Public safety issues
- Minimization of fraud at work and theft of monies in transit to protect revenue

VII. 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:

\[ E_{Loss} = E_{Delivered} - E_{Sold} \]  
\[ C_{Loss} = U_{Cost} \times E_{Loss} + M_{Cost} \]  
\[ C_{NTL} = C_{Loss} - C_{TLoss} \]  
\[ C_{NTL} = U_{Cost} \times E_{Loss} + M_{Cost} - C_{TLoss} \]

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

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 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/maintenance costs associated with NTL data.
For technical loss estimation, the annual cost of $I^2R$ loss in Rand per mm² of conductor cross-section per mm length, can be estimated.

Structural charge, $S$ is given by

$$S = L(\alpha A + \beta) \frac{I^2}{100} \text{ Rand/annum}$$

Cost of technical losses, $W$ is given by:

$$W = 3 \times I^2 \times \rho \times L \times 24 \times 365 \times \frac{P}{1000} \text{ Rand /annum}$$

where, $I$ = Phase current (Amps), $L$ = Total length (mm), $\rho$ is resistivity of conductor material (Ω-mm), $P$ is cost of energy in cent/kWh, and $r$ is combined % rate of interest and depreciation of the line conductors.

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

VIII. 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. 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 cost of production (in terms of 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 advanced 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 expected 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 reducing electricity prices, and boost economic competitiveness in local industrial sector, and improve affordability by the poor

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

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