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Non-technical loss mitigation lessons for Africa from global experiences

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SUMMARY

Non-technical losses (NTL) may be primarily defined as theft or fraud; measurement, accounting or information errors; unmetered supplies and the time difference between meter readings and the period of calculation. The focus in this paper is on theft and fraud due to the fact that illegal connections and bypassing of meters are ubiquitous in many countries in Africa (and indeed in other parts of the world). The contents of this paper are taken from that produced by the authors for CIRED work group CC-2015-2 on the reduction on technical and non-technical losses. This work group has, amongst other things, performed an extensive survey of the state of the art of the reduction of NTL from around the world. This paper reproduces some of the results of that literature survey and other parts of the work group’s output, and uses those results to illustrate which types of NTL mitigation are generally most effective under which circumstances.

The paper then proposes the most suitable measures for sub-Saharan African conditions, based on the above input information and subject to the particular circumstances of each utility (these vary widely across the region). This is based on the fact that smart meters are in most cases not rolled out, and the capability and resources (funds) may not be there to do so. Also, the supporting regulatory incentives and business processes are absent in many cases. The main recommendation for Distribution System Operators (DSOs) in Sub-Saharan Africa is that they should engage their governments to resolve the societal issues behind electricity theft, since technology cannot sustainably reduce NTL on its own. However, the scale of electricity networks in the region means that technology has a significant role to play in improving business efficiency, provided that the societal issues are adequately addressed.

The aim of this paper is to stimulate discussion and should not be seen as a set of all-encompassing recommendations necessarily applicable to all DSOs in the region.

KEYWORDS

Non-technical losses, public safety, electricity theft, illegal connection, smart meter.

1. INTRODUCTION

Non-technical losses (NTL) may be primarily defined as theft or fraud; measurement, accounting or information errors; unmetered supplies and the time difference between meter readings and the period of calculation. All categories of NTL are listed in Figure 1.

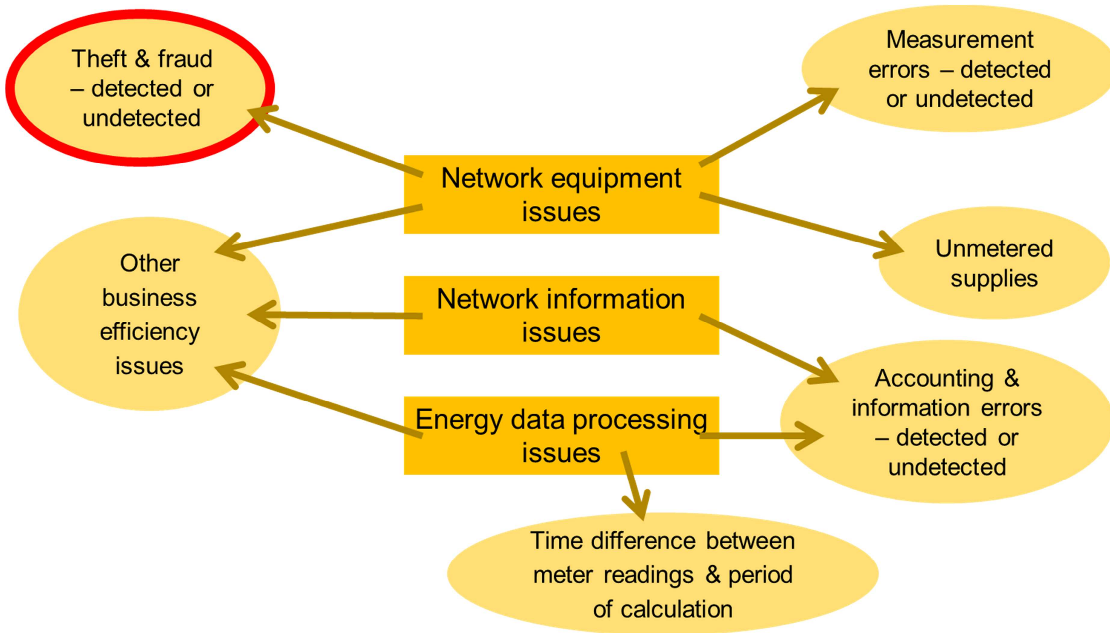

Fig 1: Types of non-technical losses

The focus in this paper is on theft and fraud due to the fact that illegal connections and bypassing of meters are ubiquitous in many countries in Africa (and indeed in other parts of the world). The work presented here is part of that produced by the authors for CIRED work group CC-2015-2 on the reduction on technical and non-technical losses. Mr Toravel is the convenor of that work group. This work group has, amongst other things, performed an extensive survey of the state of the art of the reduction of NTL from around the world. This paper reproduces some of the results of that literature survey, and uses those results to illustrate which types of NTL mitigation are generally most effective under which circumstances. This includes a description of what NTL are, particularly the problem of theft and fraud.

The paper then proposes the most suitable measures for sub-Saharan African conditions, based on the above input information and subject to the particular circumstances of each utility (these vary widely across the region). This is based on the fact that smart meters are in most cases not rolled out, and the capability and resources may not be there to do so. Also, the supporting regulatory incentives and business processes are absent in many cases. (Eskom and other utilities in South Africa are an obvious exception to much of this.) The paper ends with conclusions and recommendations.

The aim of this paper is to stimulate discussion and should not be seen as a set of all-encompassing recommendations necessarily applicable to all DSOs in the region.

The full list of references is included in the CIRED report on the topic due to be published in July 2017, and is not included here due to the length of the list. A selection of references used for each section of this paper is, however, included.

2. TYPES OF NTL

2.1 Theft and fraud

The literature indicates that theft and fraud make up the largest component of NTL, and may take the following forms:

- Illegal connections to the distribution network – these connections are not immediately known to the utility and hence are not metered. These connections are usually to the low voltage (LV) network, but some rare cases of attempts to connect to the medium voltage (MV) network, often with disastrous consequences, have been reported in South Africa.
- Illegal re-connections – where a customer reconnects their supply when they have been disconnected, again the utility may not be metering and charging for this energy. This may occur on the LV or MV network.
- Bypassing or other tampering with the meter to either avoid paying for electricity or to reduce the amount that is billed. An example of this is given in [1]. A variation of this is where the meter is bypassed for only certain loads, e.g. geysers.

Examples of illegal connections to the LV network are shown in Fig 2. Actions such as those shown can have serious safety implications. For example, bypassing certain meters includes bypassing the residual current device (RCD), leaving the installation unprotected [1]. Illegal connections to the network likewise have inadequate protection and live parts may be exposed. These exposed live parts are also often concealed, resulting in innocent people (often children) being electrocuted.

The additional power flows due to illegal connections may also lead to network equipment being over-stressed, this may lead to overheating or even explosion of this equipment (such as transformers), which may cause injury to people.

Fig 2: Examples of illegal connections to a street pole (left) and illegal wires partly concealed in vegetation (right)

2.2 Other types of NTL

All other types of NTL may be broadly defined as business inefficiencies or uncertainties. Measurement errors occur in the metering equipment and can result in the energy usage being under (or over) read, resulting in less energy being recorded than is actually being used. Accounting and information errors are errors or inefficiencies in business processes. Unmetered supplies are either supplies not metered in error or cases where the energy usage of certain customers is estimated rather than measured or where certain customers are purposefully not charged. In a similar way, some supplies may be correctly measured, but not correctly contracted, with the same result of customers not being charged.

Time difference between meter readings and period of calculation refers to energy usage estimations that have to be made when losses are calculated for a defined period (e.g. a month or a year) but the meter readings for the end date (e.g. 31st Dec 24h00) or for the start date (e.g. 1st Jan 00h00) are not available.

Meters may also malfunction for several reasons, due to internal component fault or external environment hazard, although overall this is a rare occurrence. Tampering may also appear as meter malfunction.

Literature used to compile this section includes [1-8].

3. MITIGATION MEASURES USED AROUND THE WORLD

3.1 Main principles

The main principles identified from the literature may be categorized as shown in Table 1.

Table 1: Summary of NTL mitigation measures

Dimension	Global	Local
External to the DSO	Regulation	Customer
Internal to the DSO	Measurements & IT systems	Field force

The principles are now defined.

<u>External</u>
1. Regulation:
   - The regulatory framework must be adequate to incentivize loss reduction in a realistic way with e.g. setting of realistic loss targets and bonuses.
   - Electrification of previously un-electrified areas (where illegal connections are known to be rife) has also had good results as many customers now pay for electricity usage.
   - Privatising state-owned utilities has as a general rule shown to improve business efficiency, but has also have the opposite effect in some cases.
2. Customer:
   - Good relationships with customers are also important, as this allows for the speedy resolution of problems and hence lower risk of customers taking matters into their own hands. Large power users are especially important in this respect since they often have the largest incentive for theft.
   - Customer education is an important component of any intervention, as it not only makes the customer aware of the legal or financial implications of electricity theft, but also educates them with respect to the safety risks.
   - Increasing the vending footprint, so that it is as easy and convenient as possible for prepaid customers to buy electricity, and so doing reducing the temptation for them to bypass their meters.

Internal

1. Measurements and IT systems:
    - Accurate measurement of NTL is crucial, as this allows not only detection of the presence of NTL but also the amount and location of losses, allowing prioritization of areas for mitigation. One way of implementing this is by using central check/observer/supervisory meters (also known as energy balancing).
    - Improving utility business efficiency generally, e.g. implementation of advanced IT systems, is also very important, as this reduces the risk of metering or billing errors. Improving maintenance and inspection falls under the same category.
    - Improving technology and network design can make NTL less likely.
    - Several data analysis methods are available, but these are only as good as the utility systems that support them. Only a few of these methods have been successfully used in the field.
    - Smart meters have significant potential for NTL identification, location and reduction, on their own or as part of a wider system, and are already being used to good effect in several countries. The meters may either be placed in the customer's premises or out of reach of the customer with just a customer interface unit in the premises (split meter).
2. Field force:
    - Dedicated NTL reduction teams are used in several countries to detect and address fraud.
    - When implementing mitigation measures, the largest users of electricity should be tackled first, for the reasons mentioned above, and large customers found to engage in theft should be "named and shamed" and prosecuted, even if politically connected.

3.2 NTL mitigation using data mining and smart meters

Data mining can be used as a tool for optimizing inspections in the field, by steering them to specific areas or locations suspected of fraud, rather than sending teams on blanket inspections. Inspection locations can also be ranked by importance. It is a continuous process that involves statistical modelling, with the models updated with results from the field.

Note that installing smart meters is not required to perform data mining, as long as an adequate amount of input information is provided, e.g. metering and billing records for a sufficiently long period. Smart meters provide more information than if such meters are not installed, improving the analytics – smart meters can therefore drastically improve the effectiveness of a data mining solution, by detecting events such as attempted tampering. However, data mining is not limited to smart networks.

Energy balancing can be performed (depending on the amount of meters deployed in the network analyzed) by simple differences between the energy inflows and outflows in a specific area. The sum of the energy recorded by each customer meter should add up to the energy outflow recorded at the secondary substation – minus calculated technical losses (TL). If not, then some form of NTL (and/or higher TL) is present and should be investigated.

3.3 Mitigation of theft and fraud

The advanced techniques covered in the preceding sections can be used to detect theft and fraud, as shown in Table 2. The response to suspected detected theft and fraud would vary, depending on the conditions at the specific location, e.g. whether it is safe or not to investigate. These methods can also improve TL models with a better LV representation (network connection, load etc.). Data mining and energy balances are two complementary methods that can be applied considering the type of NTL.

Table 2: Mitigation approach depending on type of NTL

Category of NTL	Origin of NTL[1]	Approach[2]
Theft / fraud	Bypass / meter tamper (recent)	Energy balance (P or E difference) or Datamining (P or E drop)
	Bypass / meter tamper (old)	Energy balance (P or E difference)
	Illegal direct connection (no meter)	Energy balance (P or E difference)
Other NTL	Meter uncertainty (recent)	Energy balance (P or E difference) or Datamining (P or E drop)
	Meter uncertainty (old)	Energy balance (P or E difference)
	IT uncertainty (recent)	Energy balance (P or E difference) or Datamining (P or E drop)
	IT uncertainty (old) including GIS errors	Energy balance (P or E difference)

[1] "Recent" and "old" refer to whether NTL were present before or after the approach was applied.
[2] P = power, E = energy.

3.4 Other measures

Equipment-related measures

- Tamper-proof meter boxes and tamper-proof numbered seals.
- Reduction of the average number of consumers per transformer.
- Reducing the length of LV feeders.
- Split meters and meters located in the distribution box of the transformer point.
- Prepaid meters.
- Replace transformers with lower power ratings and improved protection.
- Upgrading of electricity meters.
- Smart card technology (to minimize the theft of energy).Statistical monitoring of energy consumption.

Utility process-related measures

- Energy audits/targeted inspections.
- Providing adequate means of testing meters.
- Schedule for checking meters and replacing defective meters.
- Updating records to remove errors.
- Liaison with all appropriate stakeholders.
- Providing internal training and awareness.

Law enforcement-related measures

- Investigate parties who applied for a connection but didn't complete the process.
- Enacting strict laws and improving their enforcement.
- Strictly apply all reasonable safety measures as soon as an illegal connection is detected.

Use of as many measures simultaneously as possible is encouraged, e.g. technical measures such as implementation of smart meters and legal measures such as prosecuting offenders. However, the cost of mitigation measures should be compared to the cost of the losses themselves – if the measures cost more to implement than the cost of the reduced losses then there is no incentive to implement them.

Literature used to compile this section includes [3-5, 7, 9-24].

4. PROPOSED NTL MITIGATION MEASURES FOR SUB-SAHARAN AFRICA

4.1 Scenarios considered

Distribution system operators (DSOs) may be grouped as shown in Table 3. The cost-to-benefit ratio of each action is ranked for each scenario, the results are shown in Table 4. The ranking is qualitative, and may vary depending on the unique circumstances of each DSO.

Table 3: Grouping of DSO scenarios

Dimension	With opportunity for smart meter deployment	Without opportunity for smart meter deployment
Developed countries	Scenario 1 (Sc 1)	Scenario 2 (Sc 2)
Developing countries	Scenario 3 (Sc 3)	Scenario 4 (Sc 4)

Table 4: Actions ranked in terms of cost-to-benefit ratio (financial impact) for the above different scenarios – H (highest benefit), M (moderate benefit), L (smallest benefit)

	Action	Sc 1	Sc 2	Sc 3	Sc 4
External to DSO	Electrification of previously un-electrified areas, where illegal connections are known to be rife	M	M	H	H
	Good relationships with customers	H	H	H	H
	Engage regulatory authorities to adequately incentivize loss reduction and put appropriate regulation and laws in place	H	H	H	M
	Customer education and awareness	H	H	M	M
Internal to DSO[1]	Accurate measurement, detection and location of NTL	H	M	M	L
	Implementation of smart meters and corresponding support systems	H	M	M	L
	Implementation of prepaid meters[2]	L	L	M[3]	M[3]
	Improving utility business efficiency generally	H	H	H	H
	Improving technology and network design to make NTL less likely	H	H	M	M
	Dedicated NTL reduction teams, including adequate legal and logistical backup	H	M	M	L
	Tackle the largest users of electricity first, including prosecution, publicity and other related measures	H	H	H	H
	Data analysis to support all of the above, including data collection process and data quality validation	H	M	M	L

[1] Colours refer to improvements in metering, operating efficiency and analytics.
[2] This may also be considered as an aspect of "Improving technology and network design" and could involve split meters.
[3] Impact depends on various factors, including socio-economic.

4.2 Recommendations for Sub-Saharan Africa

Since most Sub-Saharan African countries fall into scenario 4, the actions expecting to result in the greatest reductions in NTL may be broadly termed social avenues, i.e. actions that do not rely extensively on complex technology, as well as any actions that improve the efficiency of how the DSO operates (these do not need to be technological). It is interesting to note that these types of actions tend to produce positive results in all scenarios, but that other actions tend to have less of an impact in scenario 4 DSOs.

Note that the impact of actions also depends on the level of losses experienced before implementation of the actions – the higher the losses prior to implementation, the higher the impact of mitigation actions is likely to be. This should also be considered when evaluating mitigation actions. Finally, the more actions that can be applied simultaneously (within reason) the better. Also, each action can have different ways of being implemented.

South African DSOs may be classified as either scenario 1 or 3, depending on whether one classifies the country as developed or developing. Considering the social problems with respect to electricity theft [25-29], scenario 3 is more likely. This means that it is easier to incentivise DSOs to reduce losses than in scenario 4, because the possibility of smart meters means that losses can be more accurately measured. However, social pressures such as community resistance to measures such as implementation of smart and/or split meters makes this very difficult. In essence, technology cannot be used to solve social problems, and so the problem of electricity theft and fraud becomes a societal one, rather than a DSO issue (even though the DSO has to deal with the loss of revenue and is hence in a very difficult position).

Specific recommendations are therefore for DSOs to engage with government to address the societal issues behind electricity theft in its various forms and to actively cooperate with law enforcement agencies to prosecute offenders. International experience indicates that the largest users of electricity, i.e. commercial rather than residential users, should be tackled first. Technology can be used to support the above.

5. CONCLUSIONS AND RECOMMENDATIONS

Smart technologies are in principle well suited to tackling NTL. However, the business processes need to be present within DSOs to support these technologies and the regulatory and general socio-economic conditions in the country need to be able to support them. It is therefore very important that DSOs engage in activities such as fostering good customer relationships, conducting regular community engagements and cooperating with law enforcement agencies.

DSOs should also engage their governments, even if they are private entities, to resolve the societal issues behind electricity theft. This is probably the most important lesson for DSOs in Sub-Saharan Africa, since experience has shown that technology cannot sustainably reduce NTL on its own. Until these issues have been satisfactorily resolved, DSOs will continue to operate in a very difficult environment.

However, the scale of electricity networks in the region means that technology has a significant role to play in improving business efficiency, provided that the societal issues are adequately addressed. Examples are the use of smart meters and power and energy balancing. Applications are not limited to revenue protection and include proactive detection and rectification of supply interruptions and safety hazards.

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