SOUTH AFRICAN REVENUE PROTECTION ASSOCIATION

6.

REVENUE PROTECTION IN INDUSTRIALAND LARGE COMMERCIAL INSTALLATIONS IN KENYA

PAPER PREPARED BY EZRA K. NDENDERU

1. PREAMBLE

High System Losses have been identified as one of the greatest challenges facing the Kenya Power Lighting Company (KPLC)- Kenya's sole Power Distribution and Transmission utility. At the end of June 2006 Total System Losses stood at 19.6% broken down as follows:

Type of Loss	Percent of Purchased units
Transmission Losses (220 and 132 KV)	3.9%
Estimated distribution Technical Losses	10.8%
Estimated distribution Non-Technical (Commercial) Losses	**4.9%**
Total System Losses	19.6 %

With this state of affairs an ambitious target of reducing total System Losses by 1.5 % by 30th June 2007was set. To realise this target a new strategy was formulated at the beginning of the year 2006/2007. Improved Loss Reduction in Industrial and Large commercial Installations was one of the key pillars of this strategy. This paper highlights the efforts, challenges and gains made in addressing losses in this crucial customer segment for the last one year.

2. EXISTING LARGE INSTALLATIONS LOSS REDUCTION STRATEGY

KPLC's customers are divided in two broad segments, namely the Ordinary Customers comprising of domestic and small commercial customers consuming less than 7,000 units per month and the Large Power Customers made up of Industrial and Large Commercial customers consuming above 7,000 units per month.

The importance of the Large Power Customers to KPLC's business is evident from the table below.

Customer Category	Number Of Customers	Consumption (Gwh)	Percentage Of Consumption
Ordinary	861,776	141.06	36.14 %
Large Power	3,949	249.24	63.86 %
TOTAL	**865,725**	**390.30**	**100%**

Although the Large Power customers comprise less than 0.5% of the total customers they account for more than 63% of the sales.

Due to this reason the following strategies were employed in a bid to maximise revenue collection and minimise losses in the Large Power accounts;

- Only electronic meters with high security serialised seals were used in these accounts.
- The accounts were placed in their own itineraries and were not read by ordinary meter readers. Staff of at least Technician level were responsible for reading, anomaly resolution as well as meter installation, removal and replacement.
- Exception Reports on suspect accounts are generated by the billing system every cycle and the same have to be resolved before the next cycle.
- Field teams comprising of at least technician staff regularly swept these accounts to ensure that there was no theft or any other loss.
- A special centralised Inspectorate Unit was in place to routinely check these accounts and validate the findings of the field teams.

These measures have led to a collection rate of over 99 % of billing and debt age of 1.1months for the Large Power accounts.

3. NEW APPROACH

Despite the above success the following shortcomings were noted;

- There was almost no input from Engineers in charge of Customer Service in the day-to-day operations of the Large Power accounts. Their subordinates had an almost free reign in this regard.
- Lack of proper segregation of duties.
- Lack of proper technical training.
- Lack of adequate test equipment.

A number of interventions were effected to address these shortcomings. These were;

- **Delegation of Authority**: The responsibility for the Large Power accounts was transferred upwards making the Regional Customer Engineers directly accountable for Large Power electricity theft.
- **HT Metered Accounts**: The Regional Engineers were made personally responsible for the reading and inspection of accounts serving the largest customers. These were the accounts metered at voltages of 11KV and above.
- **Procurement of Test Equipment**: To ensure the full testing of Large Power installations the following test equipment were procured;
  - **Portable Class 0.1 Working Standards**: These equipment enabled field teams to conduct meter accuracy on site quickly and efficiently. CT and VT wiring could also be easily confirmed.
  - **Primary Injection Set**: This was installed at the Meter Central Laboratory and was used to fully test all CTs before installation. This guaranteed that all CTs used were in good working order and operating within their class accuracy.
  - **Portable CT Tester**: Suspect CTs could now be tested and proved on site.
- **Staff Training**: Thorough training focussing on Commercial Loss Reduction was then conducted starting with the Customer Service Engineers and then Customer Service staff of Technician level and above. The training covered;

- **Polyphase energy meter operation**.
- **CT and VT Theory**: Topics such as operation of CTs and VTs, CT classes, magnetisation characteristics and common CT and VT wiring mistakes were discussed.
- **Electricity Theft/Loss Detection and Prevention**: Staff were taken through **"The Revenue (Metering) Chain**" i.e. the link from the CTs and VTs to the meter through to billing and revenue collection. The vulnerability of all the links of this chain to electricity theft/loss and mitigation was discussed.
- **Use of New Equipment**: Staff also had an opportunity to learn about the new equipment and the use of the same in electricity theft/loss detection.

At the end of the training sessions a total of 151 staff were trained. This included all the Engineers and staff in the Large Power Section. Also included were Revenue Protection staff who normally did not deal with the Large Power customers. The idea behind this was to have a large pool of competent staff so as to allow proper segregation of duties and avoid over-reliance on a select group of staff for Large Power work.

- **Securing of HT metered Supplies**: In order to reduce unauthorised access to metering equipment it was resolved that all HT meter rooms be locked. Prior to this customers had unfettered access to the meters.
- **Upgrading of CT Metered Ordinary Accounts:** It had already been observed that ordinary disconnections clerks had problems disconnecting CT metered ordinary accounts. The clerks would often disconnect the meter by removing potential fuses instead of disconnecting the supply. Inspections for such accounts were also suspect. To counter this, all Ordinary CT metered accounts were placed in their own itineraries and upgraded to Large Power status thus bringing them to the purview of the Large Power staff.
- **New Inspection Procedures**: New inspections sheets were designed to cover all already identified electricity loss/theft risks. Guidelines clarifying all aspects of these sheets were prepared.

The guidelines made staff aware of what was being tested, how to test it and why the test was being done. Brief guidelines on the use of the new equipment were also prepared with an aim of drawing staff's attention to key equipment features and test procedures.

4. LOSS REDUCTION CAMPAIGN

The campaign for Large Power Wiring Verification and Meter Testing was launched in January 2007 after the completion of staff training. HT metered accounts were to be tested first followed by LV metered accounts consuming over 100,000 units a month. Large Power LV accounts with monthly consumptions of between 7,000 and 100,000 units were to be tested last with the testing of CT metered ordinary accounts with monthly consumptions of less than 7,000 preceding them. This was so because it was felt that CT metered accounts were bound to have more losses due to not getting enough attention in the past.

The main emphasis of the campaign was the quality of the inspection rather than the number of inspections done. Field teams were expected to fully complete the elaborate inspection sheets even where this meant having to shut down the installations to verify some aspects.

After the testing the Regional Customer Service Engineers signed declaration forms averring that the installations had been fully tested and were free of theft. As a control measure the inspection forms were reviewed by a Central Office Inspectorate which also sampled tested accounts.

5. GAINS ,LESSONS LEARNT AND WAY FORWARD

Although the campaign is still in its early stages a total loss reduction of 1.17% had been realised by the end of May 2007. This reduction cannot be attributed to the new Large Power inspections alone as there were other campaigns for ordinary accounts running in tandem. However some significant recoveries of unbilled units do show that this campaign has played a key role in this loss reduction.

About 3.4 % of the accounts inspected have been found to have defects that contribute to losses. Fallback activities to rectify the defects and to recover lost revenues are carried out as soon as the defects are discovered. These recoveries have been substantial with two of the ten sub-regions recording more gains from the recovery of unbilled units from just a single Large Power account than they had recovered from all their scheduled ordinary accounts inspections. (An example of the loss calculations for one of these accounts is included in the appendix)

Perhaps the greatest lesson learnt from the campaign is that no group of supplies or customer segment can be said to be safe from electricity theft or loss and that it pays to always keep on looking for ways to minimise this loss or theft. Training was found to be of paramount importance and a major motivator. Staff, once trained, on the new equipment were very eager to use them. It is crucial to form a team that is passionate about the reduction of electricity theft. The free exchange of information on electricity theft/loss amongst this team is critical in the reduction of electricity theft/loss.

In order to reduce losses even further, it has been proposed that AMR (Automated Meter Reading) be implemented for the Large Power accounts. Although this will improve meter reading and billing accuracy and reduce tamper opportunities, the inspection campaigns will still need to be carried out to ensure the reduction of losses to a minimum.

6. CONCLUSION

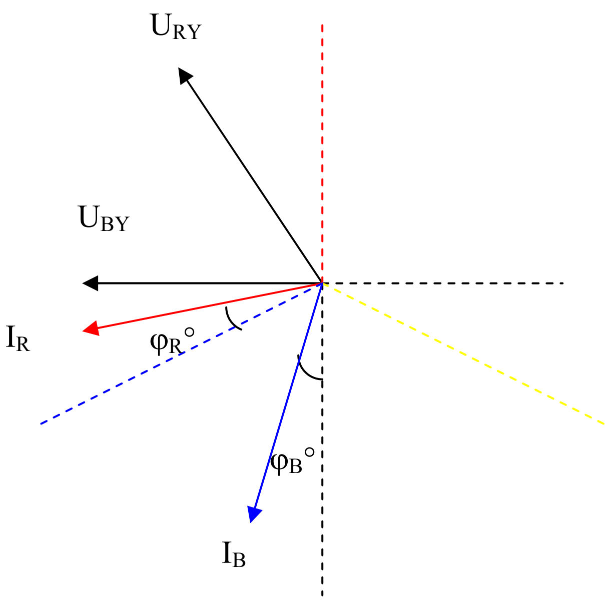
Due to its initial success, the renewed Large Power campaign has already been made one of the routine campaigns in non-technical loss reduction. However this campaign will be constantly reviewed and improved through feedback from the ground and benchmarking with others so as to ensure that the target of zero commercial losses in eventually realised.

APPENDIX

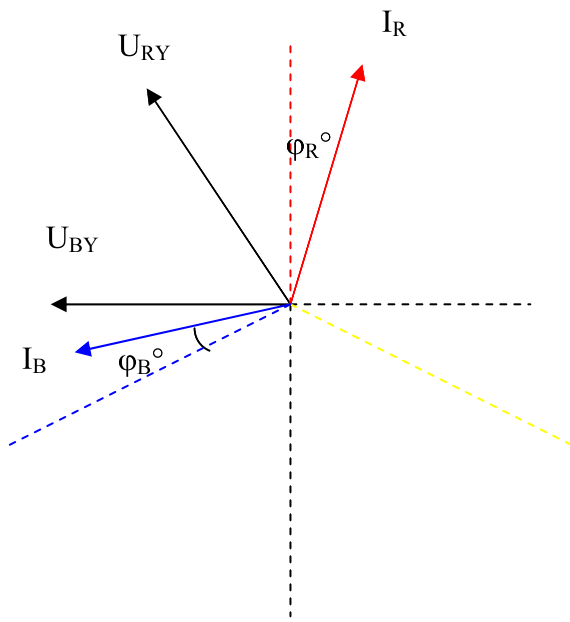
CASE STUDY: RECOVERY OF UNBILLED UNITS

BACKGROUND:
Inspections conducted at a large food processing plant revealed that there the energy meter was wrongly wired causing KPLC to lose revenue. The wiring problem was quickly identified by observing the vector diagram displayed on the Class 0.1 Working Standard.
This not only helped in the rectification of the defect but also in the calculation of the exact units lost. The following is a derivation of an expression for losses that have been incurred at the plant due to this problem.

Observed Vector Diagram



Expected Vector Diagram



For 3-Phase 3-Wire connected meters Active, Reactive and Apparent Power are given by the following Complex expressions (in Polar Notation):

$$P_R = Re\,(V_{RY}.I_R^*)$$
$$P_B = Re\,(V_{BY}.I_B^*)$$
$$P_T = P_R + P_B$$

$$Q_R = Im\,(V_{RY}.I_R^*)$$
$$Q_B = Im\,(V_{BY}.I_B^*)$$
$$Q_T = Q_R + Q_B$$

$S_T = \sqrt{(P_T^2 + Q_T^2)}$

Where

P_R and P_B are the Active Powers measured by the metering elements connected to the red and blue phases respectively.

P_T is the Total Active Power measured by the meter.

I_R^* and I_B^* are the complex conjugates of the red and blue phase currents

Q_R and Q_B are the Reactive Powers measured by the metering elements connected to the red and blue phases respectively.

Q_T is the Total Apparent Power measured by the meter.

S_T is the Total Apparent Power measured by the meter.

From the Observed Vector Diagram above the voltage and current phasors are;

$$\begin{aligned}
V_{RY} &= V_{ry}\angle 120° \text{ V} \\
V_{BY} &= V_{by}\angle 180° \text{ V} \\
I_R &= I_r\angle 210 - \varphi_R° \text{ A} \\
\therefore I_R^* &= I_r\angle \varphi_R - 210° \text{ A} \\
I_B &= I_b\angle 270 - \varphi_B° \text{ A} \\
\therefore I_B^* &= I_b\angle \varphi_B - 270° \text{ A}
\end{aligned}$$

Now

$$\begin{aligned}
P_R &= \mathrm{Re}\,(V_{RY}.I_R^*) \\
&= \mathrm{Re}\,(V_{ry}\angle 120° \times I_r\angle \varphi_R - 210°) \\
&= \mathrm{Re}\,(V_{ry}\, I_r\, \angle 120° + \varphi_R - 210°) \\
&= \mathrm{Re}\,(V_{ry}\, I_r\, \angle \varphi_R - 90°)
\end{aligned}$$

Expressing in rectangular notation

$$\begin{aligned}
P_R &= \mathrm{Re}\,[V_{ry}\, I_r\, (\mathrm{Cos}\,(\varphi_R - 90°) + j\mathrm{Sin}\,(\varphi_R - 90°)] \\
&= V_{ry}\, I_r\, [\mathrm{Cos}\,(\varphi_R - 90°)] \\
&= V_{ry}\, I_r\, [\mathrm{Cos}\varphi_R\, \mathrm{Cos}90° + \mathrm{Sin}\varphi_R\, \mathrm{Sin}90°]
\end{aligned}$$

$$\boxed{P_R = V_{ry}\, I_r \mathrm{Sin}\varphi_R}$$

$$\begin{aligned}
P_B &= \mathrm{Re}\,(V_{BY}.I_B^*) \\
&= \mathrm{Re}\,(V_{by}\angle 180° \times I_b\angle \varphi_B - 270°) \\
&= \mathrm{Re}\,(V_{by}\, I_b\angle \varphi_B - 90°)
\end{aligned}$$

Expressing in rectangular notation

$\mathbf{P_B} = \mathbf{Re}\ [V_{by}\ Ib_r\ (Cos\ (\varphi_B\ -90°)\ +jSin\ (\varphi_B\ -90°)]$

$\mathbf{P_B} = V_{rb}\ I_b\ [Cos\ (\varphi_B\ -90°)]$

$= V_{by}\ I_b\ [Cos\varphi_B\ Cos90° + Sin\varphi_B\ Sin90°]$

$$\mathbf{P_B} = V_{by}\ I_b Sin\varphi_B$$

PT = PR+PB

$= V_{ry}\ I_r Sin\varphi_R + V_{by}\ I_b Sin\varphi_B$

Assuming balanced loads

$V_{ry} = V_{by} = V_L, \quad I_{ry} = I_{by} = I_L$ and $\varphi_{ry} = \varphi_{by} = \varphi$

$$\therefore \mathbf{P_T} = 2V_L\ I_L Sin\varphi$$

It can be shown by similar analysis that,

$$\mathbf{Q_T} = -2V_L\ I_L Cos\varphi$$ and

$$\mathbf{S_T} = 2V_L\ I_L$$

Unbilled Units Calculation

Lost Energy Units are given by:

$E_L = E_A - E_M$

Where E_L = Lost units, E_A= Actual units consumed, E_M = Units recorded by meter.

The actual Active power is given by

$P_A = \sqrt{3} V_L I_L Cos\varphi$

While the measured Active Power is

$P_M = \mathbf{P_T} = 2V_L\ I_L Sin\varphi$

$P_A / P_M = (\sqrt{3} V_L I_L Cos\varphi) / 2V_L\ I_L Sin\varphi$

$P_A = \sqrt{3} P_M / (2Tan\varphi)$

$P_L = P_A - P_M$

$P_L = (\sqrt{3}/(2\tan\varphi)-1)\ P_M$

Since energy is directly proportional to power then

$E_L = (\sqrt{3}/(2\tan\varphi)-1)\ E_M$

$$\mathbf{E_L = (\sqrt{3}/(2\tan(\cos^{-1}P.F.)-1)\ E_M}$$

Where P.F. is the actual power factor of the load and is given by the expression

$PF_{Actual} = \cos(\sin^{-1}(\sqrt{3}PF_M/2))$

PF_M = Measured Power Factor

By substitution EL can also be given by the expression

$$\mathbf{E_L = (\sqrt{3}/(2\tan(\sin^{-1}(\sqrt{3}PF_M/2)))-1)}$$

Using the above formula the unbilled units were calculated and found to be 544,527 KWh for a period of six months. The customer has been taken through the findings and has promised to pay the same once debited.