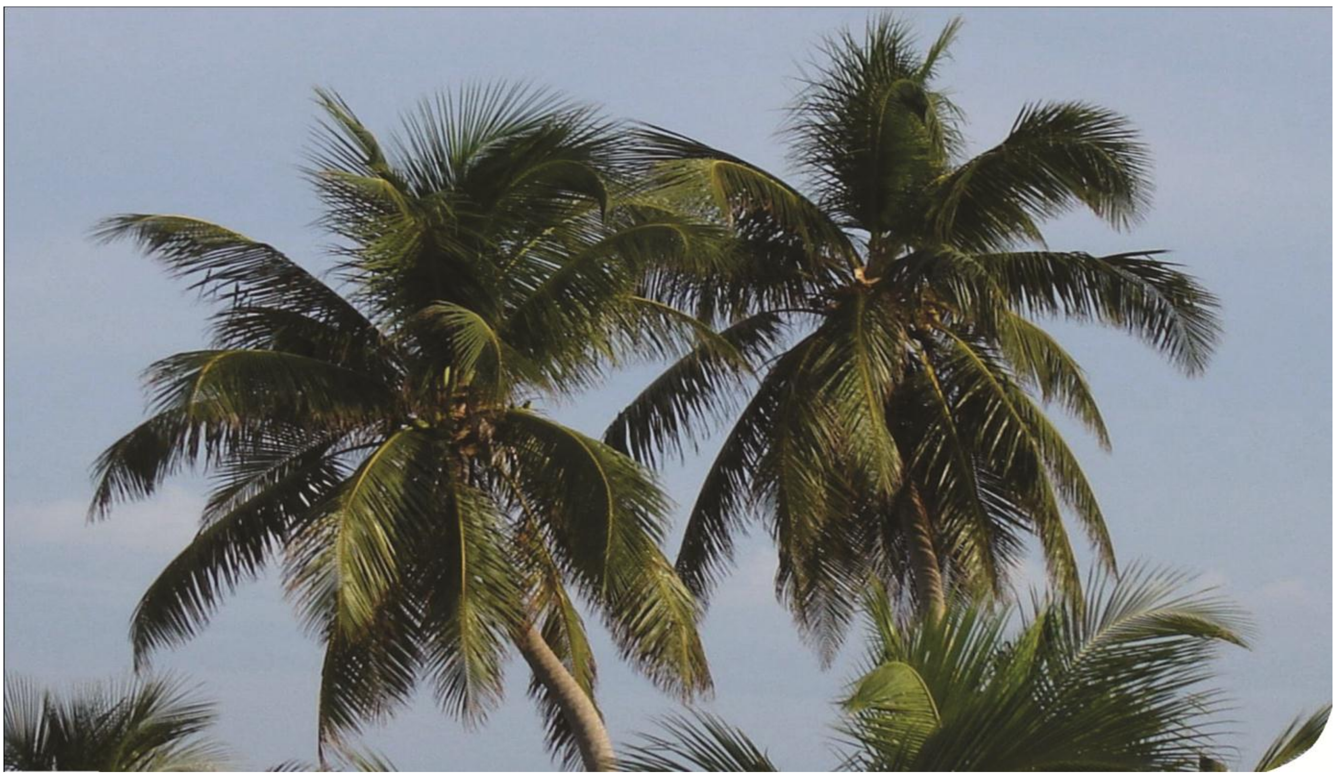
Quantification of the Power System Energy Losses in Southern Pacific Utilities

Consolidated Report



Ordered by

Pacific Islands Forum Secretariat

Prepared by: KEMA International B.V.

May 25, 2012 – Consolidated Report

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1. Executive Summary

In 2011, KEMA International B.V. ("KEMA") was contracted by the Pacific Power Association (PPA) to conduct an energy efficiency study entitled: a study called "Quantification of the Power System Energy Losses in Southern Pacific Utilities" for 10 Southern Pacific islands. This Consolidated Report gives an overview of the major findings of the study.

The ten (10) utility island systems studied were the following:

1. Electric Power Corporation (EPC), Samoa
2. Fiji Electricity Authority (FEA), Fiji
3. Niue Power Corporation (NPC), Niue
4. Nauru Utilities Corporation (NUC), Nauru
5. PNG Power LTD (PPL), Papua New Guinea – Port Moresby system
6. Public Utilities Board (PUB), Kiribati – Tarawa Atoll
7. Solomon Islands Electricity Authority (SIEA), Solomon Islands
8. Te Aponga Uira O Tumu -Te-Varovaro (TAU), Cook Islands
9. Tuvalu Electricity Corporation (TEC), Tuvalu - Funafuti
10. Tonga Power Limited (TPL), Tonga

Project objectives were to:

1. Quantify energy losses in each island power system, paying attention to both technical and non-technical losses, and develop recommendations made to reduce these losses.

2. Subject to data availability, perform an assessment of thermal station fuel efficiency.

3. Prepare a prioritized list of power system equipment needing to be replaced to reduce technical energy losses.

4. If an existing power flow model was not available for the island, prepare a digital circuit model of the power system or distribution system using EASY POWER, an established commercial engineering analysis package.

5. Subject to data availability, prepare an electrical data handbook containing the key electrical characteristics of the power system high-voltage equipment, or review the utility's existing data handbook if one was already available.

KEMA prepared a report for each of the ten island systems with findings and results of the study, including recommendations. In most cases this included cost/benefit analyses of adding one or more new thermal generating units to replace other units in order to reduce losses and enhance efficiency.

For most of the islands KEMA prepared data handbooks and power system grid models using Easy Power software. Exceptions were (1) FEA which already had their grid modeled in ERACS, (2) EPC which had their grid modeled in DigSilent PowerFactory, and (3) PPL which already had their transmission grid modeled in ETAP. In one case (EPC), KEMA was also asked to update the existing Power Factory model with transmission lines and power station units due to be commissioned in 2012/2013. Some utilities had existing data handbooks, in which case KEMA provided recommendations on additional data to add as appropriate.

Subject to data availability, KEMA classified the following types of losses:

- Power station own usage (so-called Station Losses)
- Transmission/distribution system losses which consist of
  - Technical losses
  - Non-technical losses

Non-technical losses also include “losses” due to power deliveries which are not metered and not accounted for, such as:

- Energy usage for water and sewerage activities
- Power delivery for street lights
- Energy usage in utility offices and buildings

Finally, if applicable data was available, KEMA evaluated the levels of generation efficiency by quantifying fuel usage in kWh/Liter.

The table below gives an overview of quantified losses (as % of production).

Utility	Power delivery unaccounted for (streetlights, water & sewerage facilities, offices, etc)[1]	Power Station Auxiliary Loads Served (station losses)	Technical Losses	Non-technical Losses	System Losses: Technical + Non-Technical	Total Losses (including power station, delivery system & power delivery unaccounted for)
NUC	-	2.27%	4.37%	15.77%	20.14%	22.41%
NPC	1.94%	5.19%	4.70%	0.03%	4.73%	11.86%
TAU	1.00%	1.96%	4.41%	2.96%	7.37%	10.33%
TEC	3.51%	8.63%	3.62%	3.53%	7.15%	19.29%
TPL	1.00%	2.96%	3.82%	9.72%	13.54%	17.50%
SIEA	-	2.89%	5.85%	17.05%	22.90%	25.79%
PUB	4.69%	4.81%	5.90%	5.23%	11.13%	20.63%
FEA	0.03%	1.06%	8.01%	0.11%	8.11%	9.20%
EPC	0.90%	1.28%	6.67%	7.56%	14.23%	16.41%
PPL	-	-	2.08%[2]	-	-	28.80%

Table 1: Overview of quantified losses (as % of production)

[1] FEA, PUB, and TEC monitor their utility's own usage. FEA also meters other social usages. The remaining utilities either provided estimates of power deliveries unaccounted for on their system, or did not address this issue. These metered and estimated values are aggregated together, with respect to each utility, under the term "Power delivery unaccounted for".

[2] Includes transmission system losses only, because no loss information was available on the PPL distribution system.

Total losses as percent of production by loss category are given in the graphs below.

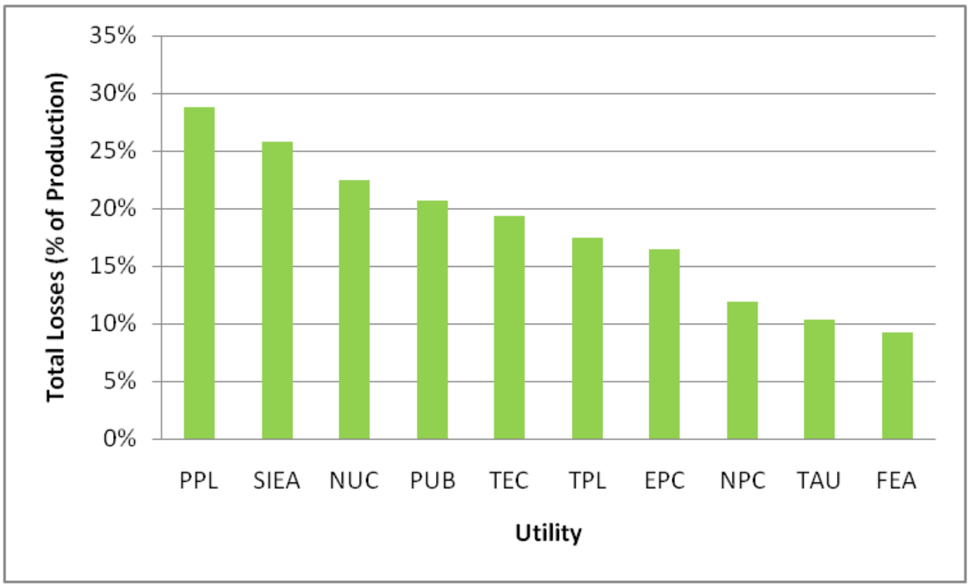

Figure 1: Overview of total losses

It is interesting to note that the utilities with the lowest total losses include the largest island system (FEA) and the smallest island system (TAU). This means utilities of all sizes can achieve low system losses. Economy of scale becomes a factor, however, when considering generation efficiency and overall company costs.

The thermal station loss component (station's own usage) is shown in Figure 2. Data was unavailable for PPL. Hydro plants are excluded.

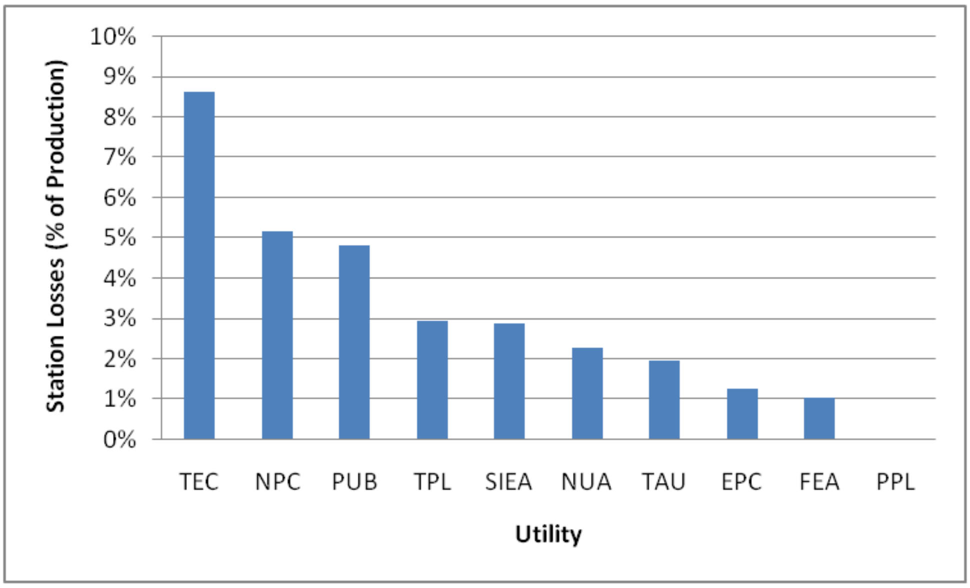

Figure 2: Overview of Station Losses

Thermal station Losses should generally be lower than 5%. Best practices show percentages between 2.5 and 3.5%. Most of the islands studied fell below 3.5%, which is excellent performance. Even so, some opportunities for improvement may exist.

Figure 3 shows the available data for power deliveries unaccounted for.

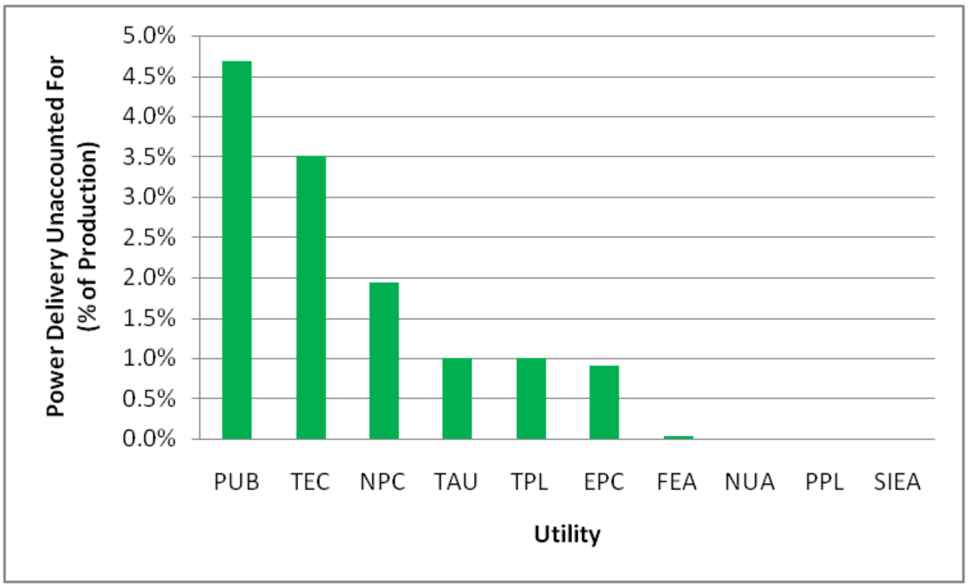

Figure 3: Overview of Power Deliveries Unaccounted For

Power deliveries unaccounted for often represent financial losses for the utility. In some cases, the utility may receive fixed compensation for certain categories of unmetered usage such as street lighting, water and sewarage.

An overall breakdown between Technical and Non-technical losses is shown in Figure 4.

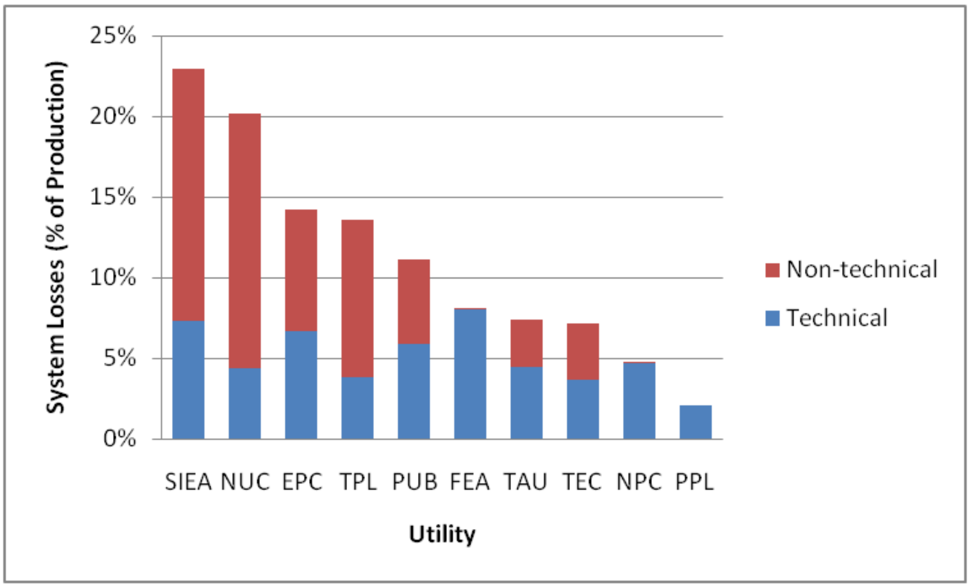

Figure 4: overview of System Losses

It should be noted that Figure 4 excludes Power Station Losses and Power Deliveries Unaccounted For.

Technical losses were calculated using grid data provided by the utilities. In some cases, assumptions were required. Technical loss percentages between 5% and 8% are considered reasonable, but actual values may be higher since some of the data was missing and assumptions had to be made based on previous similar studies. Recommendations to reduce technical losses were included in individual utility company reports. It should be noted that the technical loss data shown for PPL includes only the transmission system, as data for distribution system losses was unavailable.

Non-technical losses were calculated by subtracting the calculated technical losses and estimated unaccounted for usages from the kWh's entering into the grid. If non-technical losses are higher than 2 or 3%, a loss reduction strategy should be developed. For mitigating non-technical losses, recommendations were included in the individual utility company reports.

In regard to thermal station generation efficiency for the southern islands, the following observations are important:

1. For several utilities, generators were de-rated because of severe deterioration of the unit, its coolers, and auxiliaries. This was due to a lack of funding to purchase replacement parts and maintain the units properly. Some generating units were found to be inoperable. These units were used for spare parts to keep the remaining units in operation.
   Revenues of these utilities may not be sufficient to keep the whole fleet of thermal station units in good working order. As a result, in some cases the utility cannot supply full load during forced outage of a generating unit and may have to employ load shedding schemes.

2. Generation efficiency is often not optimal due to the above conditions. In the individual utility reports, economic payback periods are calculated for replacing old generators or purchasing a new one.

3. Although reduction of losses and enhancing generation efficiency will have a positive impact on utility revenues, the major day-to-day concern is keeping the engines and power grid on line.

During the period of the study, KEMA identified utilities where programs were in place (or just started) to improve reliability and efficiency (e.g., EPC assessed their transmission and distribution system through a re-conductoring program, FEA address ongoing issues with faulty meters, and meter tampering and pilferage through inspection programs, and TPL is undergoing a meter replacement program to ensure proper monitoring.)

Individual reports were prepared for each of the ten island utilities. Executive Summaries from the individual reports, which include a summary of investments for implementing loss reduction measures, are presented in Chapters 3 through 11 of this consolidated report.

2. Electric Power Corporation (EPC)

KEMA's analysis of Electric Power Corporation (EPC) power system determined total losses of 16.41% consisting of:

- 1.28% in generator auxiliaries
- 0.90% in street lighting and Magiagi
- Street lighting should be accounted for and billed. If these revenues cannot be collected, street lighting should be considered a financial loss for EPC and not a power system loss.
- 6.67% in technical losses
- 7.56% in non-technical losses
- Technical and non-technical losses total 14.23%.

Recommendations

(The individual report for EPC and its appendices contain detailed loss calculations and an updated Power Factory grid model)

A. Generation

Fuel efficiency of the diesel fired engines is too low with an average value of 3.74% and with some engines even around or under 3%. New Cummins engines have been added and in Fiaga four units of 5 MW will be installed. It is assumed that these new generators will replace older units with low fuel efficiency, although we have not seen decommissioning of old engines in the EPC Corporate Plan 2011-2014. Instead the Corporate Plan indicates that all diesel engines will have had a complete overhaul by December 2011. Fuel efficiency will therefore increase while still the efficiency of older units that will remain available for power supply should have been brought at highest efficiency by optimizing the engines performance during their overhaul in 2011.

Station losses are very low at 1.28%, which does not give much room for further improvement. It should be monitored and controlled that the current low amount of station losses will remain at this level.

The analysis has shown that the power station is operating at low fuel efficiency, but that a substantial amount of new generation will be added, by which fuel efficiency will improve and will stay at a better level in case of economic dispatch of the engines and continuous maintenance at an appropriate level.

On the issue of power station own usage it is clear that the own usage is already very low and it should be taken care of to keep the station losses low, also once new generation has been installed.

B. Transmission and Distribution

Calculation of technical losses of the EPC transmission and distribution system showed to be 6.67% of all energy produced. In 2007 technical losses were at 7.03%. The reduction of technical losses may have been achieved by loss reduction measures as taken by EPC as taken after the 2007 losses study, such as re-conductoring certain feeders and addressing power factor issues in certain grid parts.

When looking at the total capacity of all distribution transformers, which we have estimated, these transformers are loaded at less than 35% of full connected capacity under peak demand. This increases the level of no-load losses. It should be possible to achieve a reduction in annual energy losses by more closely matching the ratings of transformers to peak load at individual locations over a number of years as new transformers are purchased. Based on the number of customers/load connected per transformer it can be determined which distribution transformers are the best candidates to be rotated.

When buying new transformers, EPC should require sufficient data from bidders that can be used for evaluating copper and iron losses. A dollar per kW value should be applied as part of the evaluation by which the total transformer life cycle costs (capital and losses) can be calculated. This approach often shows that a transformer with lower losses, even if somewhat more expensive, can be more cost effective over its lifetime.

A final recommendation is to regularly check electrical connections of clamps, bushings, connectors in the HV and LV systems. This could be done with an infrared camera. It is KEMA’s experience that these types of connections can become hot spots after being in service for years. As such hot spots will bring higher losses.

C. Non-technical Losses

KEMA recommends the following based on findings:

- Make sure that problems with prepayment meters have been resolved satisfactory.

- Randomly check the aged population of electromechanical meters for accuracy and replace meters when appropriate.

- Check generator meters and feeder meters for their class and accuracy. In fact these meters should be revenue class meters. As KEMA understood a meter recalibration program should be started by the end of 2010 to maintain both the necessary accuracy of production as well as of customer meters.

- Perform the monthly meter readings on or around the last day of the month in order to get a more accurate comparison between “energy entering into the feeders” and “energy generated”.

- Assign a senior staff member to be Revenue Assurance Officer, responsible for Loss Reduction Strategies, who plans and initiates loss reduction programs, keeps records of progress, and reports to the General Manager.

- Develop a program for checking old meters.

- Train meter readers to identify tampering, by-passing, broken seals, hook ups.

- Train a customer service staff member to audit metering and billing processes (including quality checks of billing system data such as multiplying factors, tariff categories applied to customers, functioning of red flags in the case of irregularities) and non-technical loss causes found by meter readers, such as meter tampering or by-passing.

- Select targets for inspection, also focusing on commercial customers. When selecting targets for inspection, the potential of the estimated amount of revenue recovery should be a major selection factor. When selecting accounts with highest revenues the recovery potential and hit rates will be the most efficient, particularly when only limited resources will be available.

- Make operations less predictable. EPC's own experience may possibly show that there are sophisticated fraud activities that take advantage of known patterns of Revenue Assurance operations. This should be countered with less predictable operations (e.g. occasional night inspections, computer-generated random daily target lists, and so on). This will help to identify these fraudsters and increase the deterrent effect.

- Prevent repeat fraud activities. Once a fraud is found, measures should be implemented to ensure it will not occur again.

- Prevent and curb internal collusion activities. One important aspect of effective revenue protection operation is to prevent and curb potential internal collusion. Internal collusion seriously undermines the effectiveness of any revenue assurance process. One possible solution is to bring in non-local inspection teams to conduct critical revenue-protection operations, such as large account audits under the direct control of EPC's top management.

- Employ right tactics for each group of customers. It is a fact that different types of customers have different needs for electricity, different usage patterns and different payment capabilities. A successful revenue assurance strategy should take this into account to develop corresponding tactics for each group of customers. In general, customers should be grouped based on their usage patterns and payment capabilities. Establishing typical usage patterns and payment capabilities for each group is a very important task of Revenue Assurance. Results should then be used as the basis for employing right tactics for each group of customers.

3. Fiji Electricity Authority (FEA)

KEMA's analysis of Fiji Electricity Authority (FEA) power system determined total losses of 9.20% consisting of the following:

- 1.06% in power station auxiliaries (station losses), which is a relatively low amount of losses. Typically, station losses are lower than 5%.
- .03% in power delivery unaccounted for
- FEA usage for its own buildings, street lights and water utility are all accounted for and billed.
- 8.01% in technical losses
- 0.11% in non-technical losses
- Technical and non-technical losses total 8.11%.

Recommendations
(The individual report for FEA and its appendices contain detailed cost and benefit information, as well as data that should be added to the FEA system manual)

A. Generation

KEMA recommends a thorough evaluation of the equipment maintenance and dispatch practices at Rakiraki, Deuba, and Sigatoka Power Stations. This step is to ensure that generators are regularly serviced and inspected and that they are consistently dispatched as close to their rated capacity as possible.

Once these power plants have been inspected, FEA should re-evaluate the reliability criteria using the latest recorded peak load to ensure the total installed capacity can handle it for the contingency scenarios discussed in section 3.2. For the current worst-case scenario, where two generator units at Wailoa Power Station trip off-line, the capacity reserve is roughly 3%, which means that the current rated capacity is on the verge of being inadequate.

B. Transmission and Distribution

The technical losses on the FEA transmission system (4.14%) are somewhat high, but this transmission loss level is not unusual for an island with a transmission system as extensive as VLIS.

The technical losses on the FEA distribution system were estimated to be 3.39%, which is relatively low. A typical figure is about 4%. KEMA recommends that FEA develops a power flow model of the VLIS distribution system to allow for more exact power loss analyses.

However, distribution transformer no-load losses appear a bit high. In order to reduce the no-load losses from transformers, KEMA recommends monitoring of VLIS distribution transformer loads and implementing a plan for installing reduced distribution transformer bank capacity in those locations where replacement is needed and light loading condition is identified.

C. Non-Technical Losses

KEMA recommends the following based on findings:

- Consistently train meter readers to look for unusual meters that have had their seals removed or provide other clues that they have been tampered with and report those to management immediately.
- Continue implementing of rigorous inspection programs, particularly in high-consumer density areas, such as cities, where meter-tampering is typically more common. This step is to ensure that the non-technical losses remain at a minimum.
- Regularly audit administrative and billing processes to identify any possible inaccuracies, failures, or irregularities that may not be currently reported. These investigations should be contracted to an outside body to ensure the process is conducted without bias.

4. Niue Power Corporation (NPC)

KEMA's analysis of Niue Power Corporation (NPC) power system determined total losses of 11.86% consisting of the following:

- 5.19% in power station auxiliaries (station losses), which is a high percentage, and there is potential for reducing of these losses.
- 1.94% in street lighting. Street lighting should be accounted for and billed. If revenues cannot be collected the street lighting should be considered a financial loss and not a power system loss).
- 4.70% in technical losses
- .03% in non-technical loss
- Technical and non-technical losses total 4.73%.

Recommendations

(The individual report for NPC contains detailed system loss analyses)

A. Generation

Energy generated by the solar panel systems should be added to the monthly generation statistics.

Fuel efficiency of the relatively new generating units is quite optimal, considering the generators' capacity of 500 kW each. The most efficient situation (4.28 kWh/liter) is reached in the periods when only one generator is running at some 350 to 400 kW and even when two generators are dispatched the efficiency is still 4.13 kWh/liter or higher.

Power station's own usage (5.19%) is high and should be reduced to a percentage below 4%. NPC should perform an energy efficiency survey of the power station premises (lighting and equipment in the buildings, effective usage of auxiliaries in the power station when only one or two engines are running). NPC should then prepare a plan on improving the power station energy efficiency.

Before that the power station log sheets should be extended with logging the energy entering into the feeders in order to be able to calculate the power station own usage (which is energy generated minus energy entering into the feeders at the substation, while also the contribution to the own usage by the PV installations can be determined. Furthermore it must be determined what power usage is involved by some street lights and two houses that are connected to the power station LV system in order to determine the actual power station own usage.

B. Distribution

Since the distribution system is oversized technical losses remain relatively low. However, there still is potential for substantial reduction of technical losses:

- The 750 kVA power transformers are oversized and have high core losses. However, at the current loading condition, replacing them with transformers of reduced capacity would not realize much of saving on losses. With size reduced, core losses are reduced but copper losses will increase since load current through each transformer is of a higher percentage of capacity. The existing transformers are only 3 to 4 years of age, and still have a depreciation period to go, which will make the replacement unattractive unless the 750 kVA transformers can be sold at a price level that compensates the remainder of the capital costs, which is unlikely. Another issue is that if unexpected demand growth will occur by new economic developments the n-1 situation will be affected and an undersized situation would then be the case.

  For these reasons replacement of the power transformers is not recommended.

- The introduction of two shunt reactors would reduce the technical losses substantially (by more than 50%). This would save 75,000 kWh on technical losses, representing a value of NZ$ 27,750.

  Costs for shunt reactors 150 kVAr with taps are estimated, including transportation costs and installation costs) at NZ$ 40,000 per reactor.

  With capital costs at 8% per year the pay-back time will be 3.5 years, based on an NPV calculation.

- When looking at the total capacity of all distribution transformers, these transformers are loaded at less than 20% of full capacity. Loss reduction savings can be achieved by optimizing the ratings over a number of years as new transformers are purchased. Based on customers connected per transformer it could be found out whether distribution transformers can be rotated. Furthermore more appropriate ratings should be considered when buying new distribution transformers.

  Issues like corrosion, bad connections, and oil leakages should be monitored in order to identify those transformers that need maintenance and/or replacement.

- When buying new transformers, the transformer total life cycle costs should be considered when evaluating bids. Hence bidders must also specify copper and iron losses to evaluate cost of operating the transformer using NZ$ value per kW. It often shows that somewhat more expensive transformer can be more cost effective over its lifetime because of lower losses.

C. Non-Technical Losses

KEMA recommends the following based on findings.

- Replacement of the old meter population by new meters, as planned by NPC, is recommended, since aging meters tend to get more inaccurate, and may run out of their accuracy class.

- Include meter readings of the feeder bays in the power station log sheets in order to be able to separate the station losses from the distribution system losses (by deducting "energy entering into the feeders" from "energy generated").

- Include meter readings of the energy delivered by the three grid-connected PV systems into the log sheets.

- Note that the total of "energy entering into the feeders" is the sum of the energy as metered in the feeder bays plus the energy delivered by the solar panel systems.

- Perform the monthly meter readings on or around the last day of the month in order to get a more accurate comparison between "energy entering into the feeders" and "energy sold".

5. Nauru Utilities Corporation (NUC)

KEMA's analysis of the Nauru Utilities Corporation (NUC) power system determined total losses of 22.41% consisting of the following:

- 2.27% in power station auxiliaries (station losses), which is a relatively low amount of losses. Typically, station losses are lower than 5%.
- 4.37% in technical losses
- 15.77% in non-technical losses
- Technical and non-technical losses total 20.14%.

Recommendations

(The individual report for NUC and its appendices contain detailed system loss analyses)

A. Generation

Nauru Power station's own usage (2.27%) is very low and may not have many options for improvement. An energy efficiency audit may reveal areas for improvement. The power station log sheets should include logging the energy entering into the feeders in order to be able to calculate the power station own usage (which is energy generated minus energy entering into the feeders).

In addition, energy generated by the grid-connected PV systems should be added to the monthly generation statistics and correlated by time.

B. Distribution

The technical losses on the NUC distribution system are 4.37%, which is in normal range. A good figure is typically less than 5%.

C. Non-Technical Losses

KEMA recommends the following based on findings:

- Replacement of the old meter population by new meters is recommended, since aging meters tend to get more inaccurate, and may run out of their accuracy class.
- Include meter readings of the feeder bays in the power station log sheets in order to be able to separate the station losses from the distribution system losses (by deducting "energy entering into the feeders" from "energy generated").
- Include meter readings of the energy delivered by the solar panel systems into the log sheets and correlate the recorded times.
- Note that the total of "energy entering into the feeders" is the sum of the energy as metered in the feeder bays plus the energy delivered by the solar panel systems.
- Perform the monthly meter readings on or around the last day of the month in order to get a more accurate comparison between "energy entering into the feeders" and "energy sold".
- Adding metering for water and power usage calculations for street lighting (although not billed) would provide NUC with financial information for future decision-making and cost recovery methods.
- Additional metering for the LV services and plant auxiliary loads would provide more data to more accurately estimate power station usage.
- A program of meter inspection, testing, and maintenance should be implemented as soon as financially possible. Since NUC does not have a meter test facility, this could be contracted to an experienced provider of this type of service.
- Assign a senior staff member to be Revenue Assurance Officer, responsible for Loss Reduction Strategies, and who plans and initiates loss reduction programs, keeps records of progress, and reports to the General Manager.
- Develop a program for checking old meters.
- Train meter readers to identify tampering, by-passing, broken seals, hook ups.

- Train a customer service staff member to audit metering and billing processes (including quality checks of billing system data such as multiplying factors, tariff categories applied to customers, functioning of red flags in the case of irregularities) and non-technical loss causes found by meter readers, such as meter tampering or by-passing.

- Select targets for inspection, also focusing on commercial customers. When selecting targets for inspection, the potential of the estimated amount of revenue recovery should be a major selection factor. When selecting accounts with highest revenues the recovery potential and hit rates will be the most efficient, particularly when only limited resources will be available.

- Make operations less predictable. PUC's own experience may possibly show that there are sophisticated fraud activities that take advantage of known patterns of Revenue Assurance operations. This should be countered with less predictable operations (e.g. occasional night inspections, computer-generated random daily target lists, and so on). This will help to identify these fraudsters and increase the deterrent effect.

- Prevent repeat fraud activities. Once a fraud is found, measures should be implemented to ensure it will not occur again.

- Prevent and curb internal collusion activities. One important aspect of effective revenue protection operation is to prevent and curb potential internal collusion. Internal collusion seriously undermines the effectiveness of any revenue assurance process. One possible solution is to bring in non-local inspection teams to conduct critical revenue-protection operations, such as large account audits under the direct control of PUC's top management.

- Employ right tactics for each group of customers. It is a fact that different types of customers have different needs for electricity, different usage patterns and different payment capabilities. A successful revenue assurance strategy should take this into account to develop corresponding tactics for each group of customers. In general, customers should be grouped based on their usage patterns and payment capabilities. Establishing typical usage patterns and payment capabilities for each group is a very important task of Revenue Assurance. Results should then be used as the basis for employing right tactics for each group of customers.

6. PNG Power Limited (PPL)

KEMA's analysis of PNG Power Limited (PPL) power system shows total losses of 28.80% consisting of the following:

- 2.08% technical losses in the transmission system
- 26.72% in power station's own usage, distribution system losses, non-technical losses, and unbilled usage. Due to lack of information, losses under each of these categories cannot be estimated.

Recommendations:

(The individual report for PPL contains a detailed approach adopted by KEMA, and its appendices contain detailed data requests and memos sent to the utility)

To improve loss estimation results for the Port Moresby system, KEMA recommends:

- Continuing meter monitoring and meter calibration to improve the accuracy of historical data for energy demand, consumption and production.
- Create and maintain historical statistics for distribution feeders.
- Create and maintain a power flow model for the distribution system.
- Keep records of all power equipment from manufacturers, including equipment specifications, nameplate information and test data, along with any loss reports.
- Compare the power flow study results with the test data of the power transformers and adjust parameters to improve the accuracy of calculated transformer losses. KEMA understands that PPL has already put some effort into this area.

7. Public Utilities Board (PUB)

KEMA's analysis of the Public Utilities Board (PUB) power system determined total losses of 20.63% consisting of the following:

- 4.81% in power station auxiliaries (station losses). Typically station losses in power stations of similar sizes are 5%.
- 4.69% in utility's own usage and other social usages
- 5.90% in technical losses
- 5.23% in non-technical losses
- Technical and non-technical losses total 11.13%.

Recommendations:

(The individual report for PUB contains detailed system loss analyses)

A. Generation

From the data provided, the fuel efficiency for Betio and Bikenibeu Power Stations averaged 3.65 kWh/liter in December 2010. This is a bit low and it may be possible to improve it by changing the way the units are dispatched and by keeping the units in optimal operating condition. KEMA recommends that PUB consider looking at opportunities for improving its economics of generation dispatch.

There were several generating units that were out of service and not being maintained as observed at the time of KEMA's visit to Tarawa Atoll. The PUB barely has enough generating capacity to meet its peak demand, which violates availability criteria which are necessary for maintaining at least a reasonable level of reliability. Therefore, KEMA recommends that PUB immediately purchases and installs a pair of new 1200 kW diesel generators to improve dispatch capability, reliability, and generator efficiency.

The Net Present Value (NPV) to install 2 new, 1200 kW, high-efficiency diesel generating units was compared to the NPV of the existing poor generator efficiency. The calculation shows that the cost of purchasing 2 new 1200 kW diesels would save the PUB nearly $7 million over 20 years because of improvements in generator efficiency.

B. Distribution

The technical losses on the PUB distribution system are 5.9%, which is slightly high. A good figure is typically less than 5%.

KEMA recommends that PUB perform infrared inspection of key connections and facilities throughout its system to determine if such hot spots do indeed exist. These inspections will help determine locations of bad connectors that need replacement.

With a system utilization factor of 62.36%, which was calculated for the power flow study, the PUB distribution transformers may be slightly oversized for the loads served. This means higher distribution transformer losses in the form of no-load losses. System utilization factor of 75% or higher is desirable from a system utilization standpoint to maximize efficiency and minimize losses. KEMA recommends that PUB purchase transformers that more closely match the projected loads to be served.

KEMA recommends that a distribution transformer and load power factor study be done for the system on Tarawa Atoll. This will help to determine individual transformer loading and power factor correction requirements, which will help to improve technical losses on the PUB distribution system.

C. Non-Technical Losses

KEMA recommends the following based on findings:

- The meter population may be old and a program of replacement of old or inaccurate meters should be considered.
- The presence of theft, meter tampering, and meter by-passing cannot be documented with the data that PUB was able to provide. However, since non-technical losses are somewhat high for the PUB system, line patrols and meter inspections should be performed on a regular periodic basis to determine the extent of such problems.
- Additional metering should be added to enhance detection and categorization of losses.

8. Solomon Island Electricity Authority (SIEA)

Analysis of the Solomon Island Electricity Authority (SIEA) power system determined total losses of 25.79% consisting of the following:

- 2.89% in power station auxiliaries (so-called station losses), which is a normal amount of losses. Typically, the station losses are lower than 5%.
- There are known non-payment issues with the Solomon Island Water Authority. In the event the water and sewerage services costs are not allocated, they will remain a financial loss for SIEA's power services and cannot be considered a power system loss.
- 5.85% in technical losses
- 17.05% in non technical losses
- Technical and non-technical losses total 22.90%.

Recommendations

(The individual report for SIEA and its appendices contain detailed cost and benefit information)

A. Generation

From the data provided, the fuel efficiency for Lungga and Honiara Power Stations averaged 3.74 kWh/liter for 2010. This figure is somewhat on the low side and it may be possible to further improve it by changing the way the units are dispatched and by keeping the units in optimal operating condition. KEMA recommends that the SIEA consider looking at opportunities for improving its economic dispatch of generation resources.

The power station own usage for SIEA in the Honiara power system was 2.89% of production, which is a reasonable figure. A good figure for auxiliary consumption is typically below 4%, and this figure is below that threshold. Therefore, KEMA has no recommendations in regards to power station usage, other than to say that coolers and other auxiliary loads that comprise power station usage should be well-maintained according to manufacturer recommendations. Furthermore it is recommended to conduct an energy audit in order to identify possible efficiency improvements.

There were two generating units that were out-of-service and obviously not being maintained at the time of KEMA's visit of the Honiara power system. SIEA has sufficient generating capacity to meet its peak demand under an n-1 reliability criterion, but not n-2. Therefore, KEMA recommends that SIEA replace one of the decommissioned 1500 kW diesel generators at the Honiara Power Station to improve dispatch capability, reduce production costs and enhance system reliability. The annual cost calculations show that there would be immediate pay-back in the form of net annual savings.

B. Transmission and Distribution

Technical losses include primary line losses, distribution transformer losses, LV secondary wire losses, and other non-conventional sources such as bad connectors and hot spots. Therefore, KEMA recommends that SIEA perform infrared inspection of key connections and facilities throughout its system to determine if such hot spots do indeed exist.

To improve the loss estimation, KEMA recommends continuing meter monitoring and meter calibration, as well as maintaining historical data. KEMA also recommends keeping record of all power equipment from manufacture including equipment specifications, name plate information and test data.

C. Non-Technical Losses

KEMA recommends the following based on findings:

- Implementation of an asset assessment program focusing on identifying and replacing old or inaccurate meters is recommended.
- Patrolling the lines, and inspecting energy meters on a periodic basis to determine the extent of theft, meter tampering, and meter by-passing.
- Train meter readers should be trained to detect meters that have been tampered with, or other illegal activities. Local police should be present when dealing whenever such a situation occurs to ensure a safe and fair resolution.
- Audit of the administrative and meter reading processes should be conducted by a third party to ensure an unbiased evaluation of the situation, and identify potential discrepancies in numbers, inefficient procedures, or suspicious behavior.

9. Te Aponga Uira O Tumu-Te-Varovaro (TAU)

KEMA's analysis of Te Aponga Uira O Tumu-Te-Varovaro (TAU) power system determined total losses of 10.33% consisting of the following:

- 1.96% in power station auxiliaries (station losses), which is a low amount of losses. Typically, the station losses are lower than 5%.
- 1.00% in street lighting, which should be accounted for and billed. If these revenues cannot be collected, street lighting should be considered a financial loss and not a system loss.
- 4.41% in technical losses
- 2.96% in non-technical loss
- Technical and non-technical losses total 7.37%.

Recommendations

(The individual report for TAU and its appendices contain detailed system loss analyses)

A. Generation

Six of nine generators are de-rated for different reasons and generators 4 and 5 appear to have reached the end of their useful lives.

TAU could consider deferring a new generator by not decommissioning generators 4 and 5 and taking the risk of not being able to maintain these units due to future unavailability of spare parts. However, decommissioning units 4 and 5 and buying a new generator of 2.7 MW (same size of generator 7) will actually have a favorable payback time because of higher fuel efficiency.

Developing a generation expansion plan, whether with fossil fuel fired generation units or with renewable energy sources, is not part of the current study on Supply Side Energy Efficiency. However, KEMA's analysis indicates that fuel savings can lead to a reasonable payback time, assuming that no significant renewable energy capacity is introduced in the next several years. TAU may choose other options, like introducing significant renewable energy capacity in the short term or installing a smaller diesel generator sets.

TAU's largest generating unit size of 2.7 MW is quite high compared with a peak load of 5.3 MW. If the 2.7 MW generator is generating a substantial part of the base load it could run the risk of the entire power system going down if this generator trips, due to frequency/voltage decay or instability of the remaining generators. After the addition of a second 2.7 MW generator it is assumed that under normal conditions both units would supply similar shares of base load. In that case, when either one of the 2.7 MW generators trip, there should be less risk of an underfrequency, undervoltage or stability issue. However, a dynamic simulation should be carried out as part of the generation expansion plan to determine the precise impact of a sudden trip of either of these large generators under different operating scenarios.

Although the power station own usage is only 1.96% of total power generated, an energy efficiency audit could still be undertaken for identifying any further options for energy savings.

B. Distribution

The TAU distribution system is in good condition with pad-mounted substations (ring main units) and where all distribution feeders are laid out with underground cables. This contributes to the fact that power factors as shown in the generator log sheets are quite good (0.96 to 0.98 lagging), which also contributes to the relatively low technical losses in the power system.

Another factor is that the load flow study showed that all feeders and buses are in fact oversized as can be seen in the Power Flow Summary Report (which is part of the Excel file: Cook Islands Loss Worksheet). The distribution system is for this reason also ready to accommodate higher future loads. Even when the demand has doubled the system can still carry the loads. Only ratings of some individual distribution transformers may be too low in certain future growth scenarios.

When looking at the total capacity of all distribution transformers, these transformers are loaded at less than 35% of full connected capacity under peak demand. This increases the level of no-load losses. It should be possible to achieve a reduction in annual energy losses by more closely matching the ratings of transformers to peak load at individual locations over a number of years as new transformers are purchased. Based on the number of customers/load connected per transformer it can be determined which distribution transformers are the best candidates to be rotated.

When buying new transformers, TAU should request sufficient data from bidders that can be used for evaluating copper and iron losses. A NZ$ value per kW should be applied as part of the evaluation by which the total transformer life cycle costs (capital and losses) can be calculated. This approach often shows that a transformer with lower losses, even if somewhat more expensive, can be more cost effective over its lifetime.

Overall, with technical losses of 4.46% there will not be much room for further improvement, except for the few issues as mentioned above. A final recommendation is to regularly check electrical connections of 11 kV cable terminations with substation switchgear and transformers and connections in the LV system. This could be done with an infrared camera. It is KEMA's experience that these types of connections to switchgear and transformer bushings can become hot spots after being in service for years. As such hot spots will bring higher losses.

C. Non-Technical Losses

KEMA recommends the following based on findings:

- Replacement of the old meter population by new meters in case the envisaged tests of a series of aged meters show that the meters have run out of their accuracy class. TAU could consider AMI as an alternative for a large replacement program. A cost/benefit analysis should be undertaken in order to determine whether introduction of AMI can be justified.

- Performing the monthly meter readings on or around the last day of the month in order to get a more accurate comparison between "energy entering into the feeders" and "energy sold", and achieve better and more accurate figures on total losses and non-technical losses.

- Keeping the meter readers alert and train them to identify tampering, by-passing, broken seals.

- Train a customer service staff member for auditing metering and billing processes (including quality checks of billing system data such as multiplying factors, tariff categories applied to customers, functioning of red flags in the case of irregularities) and non-technical loss causes found by meter readers, such as meter tampering or by-passing.

10. Tuvalu Electricity Corporation (TEC)

KEMA's analysis of Tuvalu Electricity Corporation (TEC) power system determined total losses of 19.29% consisting of the following:

- 8.63% in power station auxiliaries (station losses), which is a relatively high amount of losses. Typically, station losses are lower than 5%.
- 1.00% in street lighting, which should be accounted for and billed. If these revenues cannot be collected, street lighting should be considered a financial loss and not a system loss.
- 3.62% in technical losses
- 3.53% in non-technical loss
- Technical and non-technical losses total 7.15%.

Recommendations

(The individual report for TEC and its appendices contain detailed system loss analyses)

A. Generation

The fuel efficiency for Fogafale Power Station has been averaging 3.82 kWh/liter over the past few years. However, this figure has declined from 3.85 kWh/liter in 2008 to 3.79 kWh/liter in 2010. While this is a fairly good figure, it might be improved by changing the way the units are dispatched. TEC should consider options for its generation dispatch that could improve the overall fuel efficiency.

Fogafale Power Station's own usage was provided as 8.7% of thermal production (8.63% if including production from the PV station). This figure excludes office loads served from the power station, which consume another 2.51% of the annual energy production. These station losses are fairly high and suggest that a more detailed energy efficiency audit of the station, and particularly the office use, would be beneficial.

B. Distribution

The technical losses on the TEC distribution system are 3.62%, which is in the normal range. A typical figure is 5%, and TEC's technical losses are well below that.

KEMA recommends that TEC take advantage of the distribution transformer load data available to develop transformer loading, loss, and asset condition assessments. This can be accomplished either through software which takes into account the customer meters on each of the transformers, or through physically measuring the load by installing demand type meters on the secondary side of each of the transformers. This will provide more information on individual distribution transformer loading and asset condition.

These meters can be installed while using current transformers (CT's) mounted on the pole or on the pad mounted transformers. If customers are equipped with new digital meters and can be linked in a database or in the CIS to the distribution transformers, it may not be necessary to install these meters at the distribution transformers.

C. Non-Technical Losses

The non-technical losses on the TEC distribution system are 3.53%, which is also in the low to normal range and does not appear to pose any concerns at this time.

11. Tonga Power Limited (TPL)

KEMA's analysis of Tonga Power Limited (TPL) power system determined total losses of 17.50% consisting of the following:

- 2.96% in power station auxiliaries (station losses), which is a relatively low amount of losses. Typically, station losses are lower than 5%.
- 1.00% in street lighting, which should be accounted for and billed. If these revenues cannot be collected, street lighting should be considered a financial loss and not a system loss.
- 3.82% in technical losses
- 9.72% in non-technical loss
- Technical and non-technical losses total 13.54%.

Recommendations

(The individual report for TPL and its appendices contain detailed system loss analyses)

A. Generation

The fuel efficiency for Popua Power Station has been averaging 4.08 kWh/liter over the past year. This figure has remained reasonably constant through 2010 remaining between 3.87 and 4.18 kWh/liter. While this is a good figure, it may be possible to further improve it by changing the way the units are dispatched and by keeping the units in optimal operating condition. KEMA recommends that TPL consider looking at opportunities for improving its economic dispatch of generation resources.

B. Distribution

The technical losses on the TPL distribution system are 3.82%, which is lower than the normal range. A good figure is typically less than 5%, and TPL's technical losses are well below that. Therefore, KEMA has no recommendations to improve distribution system technical losses based on the figures provided. However, infrared inspection of critical system connections is recommended to ensure there are no degraded, corroded, or otherwise bad connectors.

C. Non-Technical Losses

The non-technical losses on the TPL distribution system are 9.72%, which is in the very-high range. A good value for non-technical losses would be below 5%. TPL personnel indicated during KEMA's visit that the monitoring system of meters is currently being overhauled. This will greatly enhance the reliability and accuracy of the metering improvement efforts, and will help identify sources of non-technical losses by ruling out inaccurate metering.

- Maintain a thorough program for checking old meters.
- Train meter readers to identify tampering, by-passing, broken seals, and unauthorized hook ups.
- Train a customer service staff member to audit metering and billing processes (including quality checks of billing system data such as multiplying factors, tariff categories applied to customers, functioning of red flags in the case of irregularities) and non-technical loss causes found by meter readers, such as meter tampering or by-passing.
- Select targets for inspection, also focusing on commercial customers. When selecting targets for inspection, the potential of the estimated amount of revenue recovery should be a major selection factor. With limited resources, selecting accounts with highest revenue recovery potential of and hit rates will be the most efficient use of the limited resources.
- Make operations less predictable. TPL's own experience may show that there are sophisticated fraud activities that take advantage of known patterns of Revenue Assurance operations. This should be countered with less predictable operations (e.g. occasional night inspections, computer-generated random daily target lists, and so on). This will help to identify these fraudsters and increase the deterrent effect.
- Prevent repeat fraud activities. Proper measures should be taken to ensure that it will not occur again.
- Prevent and curb internal collusion activities. One important aspect of effective revenue protection operation is to prevent and curb potential internal collusion. Internal collusion seriously undermines the effectiveness of any revenue assurance process. One possible solution is to bring in NON-LOCAL inspection teams to conduct critical revenue-protection operations, such as large account audits, under the direct control of TPL's top management.

- Employ tactics tailored to each group of customers, knowing that different types of customers have different needs for electricity, different usage patterns, and different payment capabilities. A successful revenue assurance strategy should take this into account to develop corresponding tactics for each group of customers. Establishing typical usage patterns and payment capabilities for each group of is an important task of a Revenue Assurance process.

- Assign a senior staff member to be Revenue Assurance Officer, responsible for Loss Reduction Strategies, and who plans and initiates loss reduction programs, keeps records of progress, and reports to the General Manager.

A more sophisticated approach would be to implement a Revenue Assurance Process that employs an advanced Revenue Intelligence system. Such a system can detect potential fraud based on information from multiple sources using advanced detection rules and would provide TPL with the most efficient fraud prevention/detection and revenue operations audit capability. However, for a small utility, implementation of a Revenue Assurance Department and Revenue Intelligence Software requires a large investment and may have a large organizational impact.