Quantification of the Power System Energy Losses in South Pacific Utilities

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1. Executive Summary

KEMA was contracted by the Pacific Power Association (PPA) to conduct an energy efficiency study titled: "Quantification of Energy Efficiency in the Utilities in South Pacific Utilities" for 10 Southern Pacific island utilities. This report summarizes study results for Fiji Electricity Authority (FEA) in the Republic of Fiji. There are five power systems owned and operated by the FEA; Viti Levu Interconnected System (VLIS), Labasa, Savusavu, Levuka, and Korovou. The VLIS covers the central, Western, and Northern regions of the main island of Viti Levu, and is by far the largest one with a peak demand of 128MW. Vitu Levu was the sole focus of this study.

Project objectives and deliverables:

1. Quantification of energy losses in the VLIS.
2. Preparation of a prioritized replacement list of power system equipment to reduce technical losses.
3. Identification of sources of non-technical losses.

1.1 VLIS System Energy Losses

KEMA's analysis of the VLIS determined that total system losses are estimated at 8.11% of annual generation, which is fairly low. These losses consist of:

- 8.01% in technical losses, which is a somewhat high value.
- 0.11% in non-technical losses, which is a very low value.

In addition to these losses, the power station auxiliary losses (station's own use) were estimated to be 1.06% of total production, which is quite low.

The total system losses are equal to the total energy entering into the distribution system out of the power station(s) minus the total energy sold and unaccounted for energy. The FEA power system provides power for street lighting and water utility on the island for which it is compensated by the government. The energy used for the street lighting and water utilities is therefore not part of the losses calculated for VLIS.

An overall summary of estimated losses is provided Table 10.

1.1.1 Generation

In addition to analyzing the power station's own usage and distribution systems losses, KEMA asked for generator fuel usage data to evaluate the VLIS diesel generators fuel efficiency. FEA provided monthly and annual generation statistics, as well as system load statistics in an Excel spreadsheet format. FEA also provided fuel efficiency values for all months, as well as the annual total, from 2002 through 2010.

VLIS annual generation production in 2010 was approximately 55% from renewable energy units and 45% from thermal stations (e.g., diesel units). On average the thermal power stations' own usage (auxiliary load) was estimated to be 1.06% of plant production, which is a very reasonable value. Fuel efficiency in 2010 for the VLIS Industrial Diesel Oil (IDO) generators averaged 4.06 kWh/Liter, and the fuel efficiency for the Heavy Fuel Oil (HFO) was 4.46 kWh/Liter. These are reasonably good rates which indicate that FEA dispatches its units in an efficient manner, and that the units, including coolers and auxiliaries, are well-maintained.

However, three of the stations had relatively low fuel efficiency figures in 2010: Rakiraki with 3.4 kWh/L, Deuba with 3.5 kWh/L, and Nadi with 3.6 kWh/L. According to the data provided by FEA, the generators at Rakiraki were installed in 2000, while Deuba and Nadi were installed in 2002. KEMA recommends a thorough evaluation of the equipment maintenance and dispatch practices at these three power stations.

The other thermal power stations had reasonable fuel efficiency figures, and are considered adequately dispatched and well maintained. It is assumed that auxiliary loads on the hydro units are negligible.

1.1.2 Transmission

Two 132 kV steel tower transmission lines link the Wailoa hydro power station in the center of the island to the Cunningham Road and Vuda substations on the East and West coasts of Viti Levu, respectively. A third overhead feeder rated 33 kV connects Wailoa to Wainikasou power station. The Northern Region operates independently, and does not have a transmission system.

Two radial 33 kV sub-transmission systems emanate from Cunningham Road and Vuda for the Central and Western regions of the island, respectively. KEMA estimated transmission system losses based on the ERAC power flow study results for peak demand provided by the FEA.

Losses on the transmission system and transformers were estimated to be 51% of the overall technical losses, which amounts to 4.11% of the annual energy production.

1.1.3 Distribution

Each of the strategically placed substations in the Central, Western, Northern regions serve their respective local community through an 11 kV distribution network. FEA provided KEMA with distribution network data including segment distance, conductor type and size, peak current and energy consumption for both primary and secondary feeders and nominal data for distribution transformers. Based on this information, KEMA developed feeder summaries for all feeders listing the peak demand, annual MWh consumption, total connected kVA capacity of all energized distribution transformers. These values were used to estimate the load, loss, and utilization factors and feeder losses in kW and kWh for each feeder with sufficient data.

Losses on the distribution system primary feeders, distribution transformers, and low voltage (LV) wires were estimated to be 45% of the overall technical losses, which amounts to 3.90% of the annual energy production.

1.1.4 Non-technical losses

FEA's non-technical losses were estimated to be 0.11%, which is a low value. . A summary of the non-technical (e.g., financial) losses for 2010 was provided to KEMA by FEA. This data was valuable in evaluating the non-technical losses, particularly those associated with metering issues.

FEA monitors the generator output and the auxiliary usage of power stations. The net energy dispatched (energy generated minus energy used for auxiliary) is used on calculation of the system losses. Although the auxiliary usage of VLIS transmission/distribution substations is not monitored, it is assumed to be insignificant to the calculation of system losses.

1.1.4.1 Metering

All major FEA buildings and depots such as the Head Office, Kinoya Depot, Navutu Depot, Namoli, etc. are metered and the kWh value consumed is included in the sales figure. Some street lights are metered, while others are estimated. Since the final amount (whether metered or estimated) is billed to the local city councils, this usage not considered a non-technical loss.

The data provided by FEA showed evidence that faulty meters and illegal activities, such as meter tampering and pilferage, are currently a source of concern. However, the data indicates that through the procedures and collection efforts FEA has in place roughly 80% of the reported financial losses associated with metering issues are being recouped. More details are provided on these metering issue losses in section 5.1.1.

1.2 Recommendations

The distribution system on Viti Levu Island is comprised mostly of overhead cables with a mix of copper and aluminum conductors for all feeders. The main 11 kV distribution loops are comprised mostly of 4 x 7/3.75 AAAC Helium or 3 x 6/1/3.66 ACSR Mink aluminum overhead conductors. There are also 95 mm^2 aluminum direct-buried cables used elsewhere. These conductors are adequately sized for load-serving purposes and do not require replacement to serve the existing load. As long as future load growth does not create a risk of the distribution feeder conductors being loaded beyond their thermal limits, KEMA does not recommend changing feeder conductors only for the purpose of reducing losses. Should system load or patterns require an increase in conductor size, then consideration should be given to losses in the choice of conductor size.

Thermal losses can occur at specific locations on the distribution system due to corrosion, bad connectors, and other conditions. These should be eliminated where-ever possible through a program of equipment inspection at regular intervals and replacement of corroded or ineffective connectors as soon as discovered. Field inspections with infrared cameras can be an effective approach to identifying such problems. While KEMA does not believe this to be a big problem on the island of Viti Levu, preventative inspections such as this at regular periodic intervals can identify potential problems before they become large.

The system-wide distribution transformer Utilization Factor (UF) was estimated at 26.41% of full capacity. This shows that the transformers installed on the FEA system are generally oversized. Therefore, KEMA recommends that FEA consider installing transformers in the future that more closely match the load served.

Due to the level of non-technical losses, KEMA recommends that FEA continue implementing 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.

KEMA recommends that FEA regularly audit its 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.

Based on the fuel efficiency data provided by FEA, 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.

FEA should also re-evaluate the resource reliability/reserve 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 for overlapping generator outage events.

2. Project Approach

In January 2011, KEMA launched 10 studies on behalf of the Pacific Power Association (PPA) to quantify power system energy losses by utility across the South Pacific region. The purpose of these studies is to review the power system energy losses in each utility's existing generation facilities, transmission and distribution networks, and billing procedures and to identify where losses occur in the system and to quantify those losses. Finally, these studies will supply recommendations to minimize energy losses and prioritize which assets will reduce losses most through upgrades or replacement for each utility.

Within weeks of contract award, KEMA submitted data requests to the appropriate utilities and proposed project execution methodologies to PPA for approval to gain an understanding of each utility's systems prior to conducting site visits.

2.1 Data Collection

Prior to visiting the island of Viti Levu for data collection and technical assessments of the FEA power system, KEMA sent data request documents on February 8, 2011. In response to KEMA's data request, FEA provided study results from the ERAC power flow study. This data was essential to evaluate the FEA transmission system losses. Information on the distribution feeders and LV wires provided by FEA was used to evaluate the distribution system losses.

Subsequently KEMA visited Viti Levu on March 18-21 to collect data, interview key FEA personnel, and assess the power system. During the visit much relevant data was gathered and FEA personnel provided very helpful information on billing, generation, T&D and loss statistics for Viti Levu.

After the on-site visit there were some e-mail requests for circuit data which were later provided by FEA personnel. Assumed data was used based on KEMA experience and making use of typical industry values and parameters, including data such as:

- Typical secondary service wire configurations from the *Areva Power Transformer Handbook (2008)* were used in the calculation of LV wire losses.
- The typical values of no load loss for power transformers as derived from the loss curve in the *Areva Power Transformer Handbook (2008)* are used to calculate core losses of power transformers.

- Typical values of no-load loss and total loss from *EN 50464-1, 2007* are used to calculate distribution transformers no-load loss and load loss.

2.2 Utility Operations

The VLIS power system is one of the larger island systems covered by the PPA loss quantification study. The maximum peak demand for the FEA system on Viti Levu Island was 127.92MW, recorded in 2010.

The power system consists of:

- **Wailoa Power Station**. This hydroelectric power station accounts for over 85% of the total energy generated on Viti Levu, with a rated capacity of 72MW.
- **Kinoya Power Station**. This conventional power station has a rated capacity of 41.9MW and runs on both industrial diesel oil and heavy fuel oil.
- **Vuda Power Station**. This conventional power station has rated capacity of 15.5MW and runs on industrial diesel oil.
- **Wainikasou Power Station**. This run-of-river hydroelectric power station has a rated capacity of 6.6MW.
- **Rokobilli Power Station**. This conventional power station has a rated capacity of 3.6MW and runs on industrial diesel oil.
- **Sigatoka Power Station**. This conventional power plant has a rated capacity of 4MW and runs on industrial diesel oil. At the time of KEMA's visit, one of the units (G1) was out of service, effectively reducing the combined rated capacity to 3MW.
- **Deuba Power Station**. This conventional power station has a rated capacity of 2.8MW and runs on industrial diesel oil.
- **Nadi Power Station**. This conventional power plant has a rated capacity of 2MW and runs on industrial diesel oil.
- **Rakiraki Power Station**. This conventional power station has a rated capacity of 2MW and runs on industrial diesel oil.
- **Korovou Power Station**. This conventional power station has a total rated capacity of 0.75 MW and runs on industrial diesel oil.

FEA operates a 132 kV transmission system and a 33 kV sub-transmission system, which supply its distribution substations. A brief description of these higher voltage facilities is as follows:

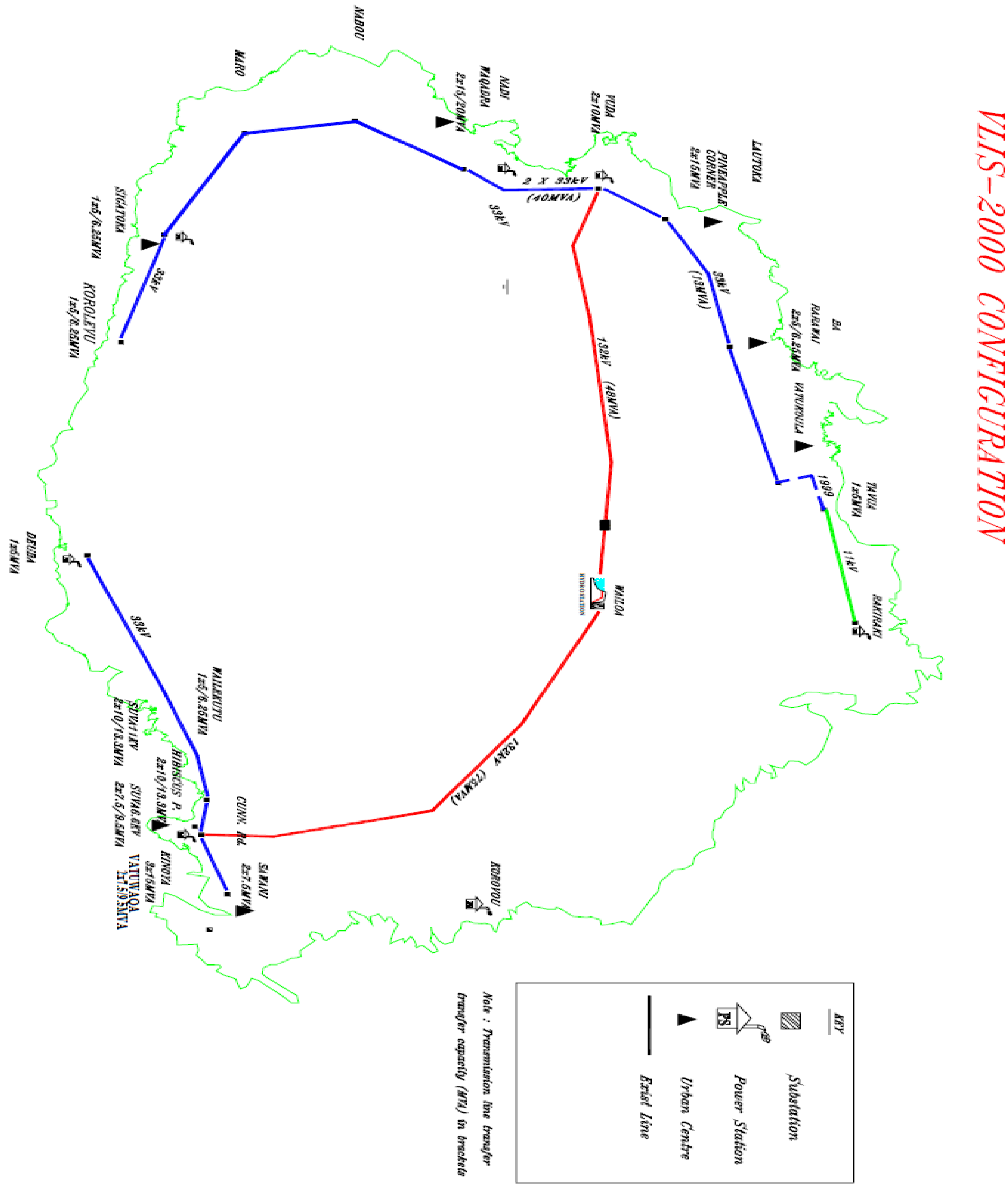
- Wailoa is connected to Cunningham Road and Vuda through two 132 kV steel tower feeders. It is also linked to Wainikasou through a 33 kV overhead line.
- The Central Region 33 kV radial sub-transmission system links a total of seven substations to Cunningham Road: Deuba, Hibiscus Park, Kinoya, Sawani, Suva, Vatuwaqa, and Wailekutu. The majority of this system is made up of underground cables.
- The Western Region 33 kV radial sub-transmission system links a total of six substations: Pineapple Corner, Rarawai, Tavua, Vatukoula, and Waqadra substations as well as the Sabeto switching station. The majority of this system is made up of overhead cables

The VLIS serves a total of 135,966 customers with the following breakdown:

Type	Percentage
Industrial	0.06%
Commercial	9.36%
Domestic	90.58%

The transmission system layout connecting Wailoa to the Western and Central Regions is show in Figure 1.

Figure 1 - VLIS Transmission System Layout



2.3 Identifying and Quantifying Losses

Electric power is generated in power plants and delivered through transmission and distribution systems to customers. Energy losses occur in each part of the power system from the generators to the customer's meter point. Power system energy losses are divided into the categories based on the where the losses happen and the cause of losses:

1. Power station losses – energy consumed by the equipment in support of power generation, also called power plant auxiliary load or power plant own usage.

2. System losses – losses occurred along power transferring through the transmission and distribution systems, such as transformers, over-head line conductors, areal cables or underground cables and service wires.

Losses in category 2 consist of both Technical Losses and Non-technical Losses. Technical losses are the losses that occurring as a result of electric current passing through the power system equipments. In contrast to technical losses, there are non-technical losses. Cause of non-technical losses can be: theft, inadequate or inaccurate meters, meter tampering or by-passing, meter-reading errors, irregularities with prepaid meters, administrative failures, and wrong multiplying factors.

There is another category of losses due to energy usage that is not accounted for and subsequently not billed for. The unbilled usage results in financial loss to the utility and should not be included as part of non-technical loss. Examples of unbilled usages can be: utility's own building usage, electric power used for supplying other utilities such as water and sewage, and other un-reimbursed social usage such as street lighting.

Furthermore, financial losses may be present due to a non-optimized efficiency of the generation system and individual generating units. Improvement of the generation efficiency will lead to fuel savings.

In this study, KEMA estimated technical losses through power equipment in the transmission system, distribution system and secondary service wires. Where sufficient information was not provided, assumptions were made to facilitate the loss estimation. FEA has a working power flow model for VLIS system 132 kV to 11 kV in ERACS. The model and power flow study result of a peak load case was provided to KEMA. KEMA estimated transmission system losses based on the power flow study result for peak demand. KEMA created Excel spreadsheet to estimate other losses such as transformer losses, distribution feeder losses, and service wires losses. These estimated losses in MW were then converted to MWh energy losses on an annual basis. FEA has identified usage of its own buildings, street light and power used for supplying water utility. Those usages are accounted for and billed. Therefore, no other unbilled usage was identified.

The total system loss was calculated as the difference between the total annual generation after station's own usage and annual energy sold. Non-technical loss was then derived by comparing the total system loss to the sum of the estimates for technical losses and any unbilled usage (in FEA's case, none).

3. Generation

The following sections pertain to the generation facilities on Viti Levu.

3.1 Equipment

- **Wailoa Power Station**. This central hydroelectric power station has a rated capacity of 72MW, and consists of four (4) TIBB Pelton wheels installed in 1983. At the time of KEMA's visit, these units were in all in good condition and available for service.
- **Kinoya Power Station**. This thermal power station has a total rated capacity of 41.9MW, and consists of six (6) units dispatched locally:
  - Four (4) Caterpillar 16CM32 units installed in 2005. These are Industrial Diesel Oil units (IDO) with a combined rated capacity of 29.2MW. At the time of KEMA's visit one of the units (G1) was out of service reducing the effective rated capacity to 21.9MW.
  - Two (2) Wartsila 18v38A units installed in 2005. These units were converted to Heavy Fuel Oil units (HFO) in August 2007. They have a combined rated capacity of 20MW.
- **Vuda Power Station**. This thermal power station has total rated capacity of 15.5MW, and consists of four (4) units dispatched locally:
  - Two (2) Mirrlees Blackstone KV16 units installed in 1976 with a combined rated capacity of 9.5MW. These units are manually synchronized.
  - Two (2) Wartsila 18V32LN units installed in 2001 with a combined rated capacity of 12MW. At the time of KEMA's visit, one of the two Wartsila units (G1) was out of service, effectively reducing the rated capacity to 6MW. These units are automatically synchronized.
- **Nadi Power Station**. This thermal power station consists of two (2) Caterpillar 3516DITA units installed in 2003 with a total rated capacity of 2MW. All units are manually dispatched locally.
- **Sigatoka Power Station**. This thermal power station consists of four (4) Caterpillar 3516DITA units installed in 2003 with a total rated capacity of 4MW. At the time of KEMA's visit, one of the units (G1) was out of service, effectively reducing the combined rated capacity to 3MW. All units are automatically dispatched.
- **Rakiraki Power Station**. This thermal power station has a total rated capacity of 2MW and consists of two (2) units dispatched remotely:
  - One (1) Caterpillar 3516DITA unit installed in 2003 with a rated capacity of 1MW.
  - One (1) Cummins 3516DITA unit installed in 2003 with a rated capacity of 1MW.

- **Deuba Power Station**. This thermal power station has a total rated capacity of 2.8MW, and consists of four (4) units:
    - One (1) Ruston 7VEB unit installed in 1954 with a rated capacity of 200 KW manually dispatched.
    - Three (3) Caterpillar PM3516 units installed in 2004 with a combined rated capacity of 3.6MW automatically dispatched. At the time of KEMA's visit, one of the Caterpillar Units (G6) needed repair because of an oil leak, effectively reducing the combined rated capacity to 2.6MW.
- **Korovou Power Station**. This thermal power station has a total rated capacity of .75MW, and consists of two (2) units:
    - One (1) Cummins KTTA19 unit installed in 1999 with a rated capacity of 250 KW automatically dispatched remotely.
    - One (1) Caterpillar unit with a generation capacity of 500 KW manually dispatched locally.
- **Rokobilli Power Station**. This thermal power station consists of three (3) Caterpillar units with a combined rated capacity of 3.6MW. At the time of KEMA's visit it was not yet commissioned, and therefore was not included in the study. It is to be automatically dispatched.

This power station information is summarized in Table 1.

Table 1 - VLIS Power Station Generators

	Station	Set	Make	Model	Speed (rpm)	Year	Installed Capacity	Rated Capacity	Total Installed Capacity	Total Rated Capacity
Renewable Power Stations	Wailoa	1	TIBB (Milano)-	Hydro	750	1983	20.8	18	**83.2**	**72**
		2	TIBB (Milano)-	Hydro	750	1983	20.8	18		
		3	TIBB (Milano)-	Hydro	750	1983	20.8	18		
		4	TIBB (Milano)-	Hydro	750	1983	20.8	18		
	Wainikasou	1	Frances Turbine	Hydro	1500	2003	3.3	3.3	**6.6**	**6.6**
		2	Frances Turbine	Hydro	1500	2003	3.3	3.3		
	Nagado	1	Pelton Wheel	Hydro	1500	2004	2.8	2	**2.8**	**1.4**
	Nadarivatu	1	-	Hydro	-	2010	-	-	**40**	-
		2	-	Hydro	-	2010	-	-		
	Butoni Wind	37	GEV MP Vergnet	Wind		2007	10	5	-	-
Thermal Power Stations	Kinoya-IDO	1	Mak Cat 1	CM32	750	2005	7.45	7	**29.8**	**28**
		2	Mak Cat 2	CM32	750	2005	7.45	7		
		3	Mak Cat 3	CM32	750	2005	7.45	7		
		4	Mak Cat 4	CM32	750	2005	7.45	7		
	Vuda	1	Mirrlees	KV16	500	1976	5.74	5	**24.08**	**22**
		2	Mirrlees	KV16	500	1976	5.74	5		
		3	Wartsila	18V32LN	750	2001	6.3	6		
		4	Wartsila	18V32LN	750	2001	6.3	6		
		5	Lister Blackstone -	EVS8	600	1976	0.37			
	Kinoya-HFO	8	Wartsila	W38	750	2001	10.3	10	**20.6**	**20**
		9	Wartsila	W38	750	2001	10.3	10		
	Sigatoka	1	Caterpillar	CAT3516	1500	2000	1.04	1	**4.16**	**4**
		2	Caterpillar	CAT3516	1500	2000	1.04	1		
		3	Caterpillar	CAT3516	1500	2000	1.04	1		
		4	Caterpillar	CAT3516	1500	2000	1.04	1		
	Deuba	1	Caterpillar	CAT3516	1500	2002	1.4	1.3	**4.2**	**3.9**
		2	Caterpillar	CAT3516	1500	2002	1.4	1.3		
		3	Caterpillar	CAT3516	1500	2002	1.4	1.3		
	Nadi	1	Caterpillar	CAT3516	1500	2002	1.04	1	**2.08**	**2**
		2	Caterpillar	CAT3516	1500	2002	1.04	1		
	Rakiraki	1	Caterpillar	CAT3516	1500	2000	1.04	1	**2.08**	**2**
		3	Caterpillar	CAT3516	1500	2000	1.04	1		
	Korovou	1	Cummins	VTA28G	1500	1999	0.4	0.3	**0.9**	**0.75**
	Qeleloa	1	Caterpillar	CAT3516	1500	2002	-	-	**1**	-
		2	Caterpillar	CAT3516	1500	2002	-	-		
		3	Caterpillar	CAT3516	1500	2002	-	-		

Note – This table excludes the Labasa, Savusavu, Levuka, Wainiqeu Power Stations because they are outside of the VLIS.

3.2 Analysis of Losses

Generation efficiency performance can be assessed by reviewing the generation fuel efficiency and station losses (own usage).

Fuel Efficiency

In 2010, the average fuel efficiency for the VLIS IDO generator units was 4.06 kWh/Liter, and the average fuel efficiency for the HFO generator units was 4.46 kWh/Liter. It should be noted that three of the stations had relatively low fuel efficiency figures in 2010:

1. Rakiraki with an average fuel efficiency of 3.38 kWh/Liter
2. Deuba with an average fuel efficiency of 3.50 kWh/Liter, and
3. Sigatoka with an average fuel efficiency of 3.64 kWh/Liter.

These three power stations were responsible for 5.8% of the total energy generated in 2010. According to the data provided by FEA, the generators at Rakiraki were installed in 2000, while Deuba and Nadi were installed in 2002. A summary of the fuel efficiency calculations are shown in Table 2.

Table 2 – Fuel Efficiency for 2010

Power Station	Energy Generated (MWh / year)	% of Production	Fuel Used (Liters / year)	Fuel Efficiency (kWh / Liter)
Kinoya HFO	126,237	34.8	28,273,765	4.46
Kinoya-IDO	130,737	36.1	30,959,517	4.22
Korovou	14	0.0	3,316	4.09
Vuda	79,723	22.0	20,108,753	3.96
Nadi	4,902	1.4	1,253,287	3.91
Sigatoka	14,167	3.9	3,891,250	3.64
Deuba	3,256	0.9	930,050	3.50
Rakiraki	3,559	1.0	1,051,800	3.38
Total (HFO)	236,356	65.2	58,197,973	4.06
Total (IDO)	126,237	34.8	28,273,765	4.46

Note: This table only includes the conventional power stations, and excludes IPP contribution.

Station Losses

Station losses are the difference between the total energy produced by the generating units and the total energy that entered the distribution system for a given time period. This represents the power station's own usage. For VLIS, this averaged 1.06% of production for 2010, which is a low value.

Reliability Criteria

FEA provided KEMA with a spreadsheet of all the available generating units' capacities. The rated capacities were extracted from the document to calculate the N-1 and N-2 reliability criteria. In 2010, the total rated capacity of all the generators in usage on Viti Levu was 168.25MW, and the peak demand was of 127.9MW.

These reliability criteria were evaluated considering the possible contingency of the 18MW Pelton wheels at the Wailoa Power Station, which are the largest generator units on the system. These scenarios are likely to happen during the dry season when the Monosavu Dam is at risk of becoming depleted. The results are shown in Table 3.

Table 3 – Reliability Criteria

Criterion	Available Capacity (MW)	% Reserve
n-1	150.25	17.5
n-2	132.25	3.4

Note: This table excludes IPP units.

3.3 Findings

Table 4 shows the annual system energy production of the VLIS conventional (thermal) stations and the station losses for 2008 through 2010. Thermal production has steadily been increasing since 2008 with the biggest increase in 2010.

Table 4 – VLIS Thermal Station Generation, Sales, and Station Usage

YEAR	Total Gross Generation		Net Energy Output		Station Usage		Station Usage as % of Gross Generation
	MWh	% CHANGE	MWh	% CHANGE	MWh	% CHANGE	
2008	223,373	-	216,216	-	7,157	-	3.20%
2009	266,254	19.20%	258,281	19.46%	7,973	11.40%	2.99%
2010	362,593	36.18%	354,674	37.32%	7,919	-0.68%	2.18%

Note: Excludes hydro and IPP generation.

Thermal power station auxiliary usage averaged 2.79% of total production from 2002 through 2010. However, as annual energy production has increased in recent years the station auxiliary losses have decreased as a percentage of production, dropping to 2.18% in 2010. This may be attributed to the installation of new units at Kinoya, New Labasa, Savusavu, and Levuka power stations within the 5 years prior.

In the event that two generator units at Wailoa trip off-line, the margin capacity reserve would be 3.4% above the peak demand in 2010, which is on the verge of being insufficient. This overlapping units outage condition can be caused by operating errors, equipment failure, natural disasters, or a sustained drought in this case, since Wailoa is a hydroelectric power station.

4. Transmission and Distribution

4.1 Equipment

The VLIS 132 kV transmission system and 33 kV sub-transmission systems are discussed in the following sections.

4.1.1 Transmission Lines

The VLIS transmission system consists of the following equipment:

- There is a 132 kV overhead circuit connecting Wailoa power station to the Cunningham Road substation using 356 mm^2 AL "Lime" conductor.
- There is one Grape (182 mm^2 Al overhead) cable that connects the Wailoa power station to the 132 / 33 kV Vuda substation.
- The 33 kV sub-transmission networks emanating from the Cunningham Road and Suva substations link strategically placed 33 / 11 kV substations along the Central and Western regions respectively.
- In the Western Region, the sub-transmission lines emanating from the Vuda substation link it to the Pineapple Corner, Rarawai, and Waqadra substations as well as the Sabeto switching station through overhead 3 x 6/1/3.66 ACSR MINK and direct-buried 95mm2 (3C) Aluminum conductors.
- A sub-transmission line runs from the Rarawai substation to the Tavua substation, and finally to the Vatukoula substation.
- A sub-transmission line runs from the Sabeto switching station to the Nagado hydroelectric power station. A separate feeder links the Sabeto switching station to the Waqadra substation creating a mesh network between them and the Vuda substation.
- A sub-transmission line runs from the Waqadra substation to the Qeleloa substation. The feeder then runs to Nabou, the Maro substation, Waibogi, and finally the Sigatoka power station.

- A sub-transmission line runs from the Sigatoka power station to the Nacocolevu substation, then to Vadratu, the Sovi Bay, Vatukarasa, the Tambua Sands, Tagaqe, and finally the Korolevu substation.

- A sub-transmission line links the Nacocolevu substation to the Butoni wind farm.

- In the Central Region, the sub-transmission lines emanating from the Cunningham Road substation link it to the Hibiscus Park, Sawani, and Vatuwaqa substations as well as the Kinoya power station through 4 x 7/3.75 AAAC HELIUM overhead and 95mm2 (3C) Aluminum direct-buried conductors.

- A sub-transmission line links the Hibiscus Park and Vatuwaqa substations creating a mesh network between them and the Cunningham Road substation. Another feeder connects the Suva power station to the Hibiscus Park substations.

- Two more sub-transmission lines link the Kinoya power station to the Vatuwaqa and Sawani substations creating a mesh network between them and the Cunningham Road substation. Another feeder connects Kinoya to Sawani creating a mesh network between them and Cunningham Road.

- A sub-transmission line links the Suva and Vatuwaqa substations creating a mesh network between them and the Cunningham Road substation.

- A sub-transmission line links the Wailekutu substation to the Deuba power station.

4.1.2 Distribution Lines

The distribution system on the VLIS emanates in a radial fashion from the 33 kV / 11 kV substations interconnected via the 33 kV sub-transmission systems. The substations are strategically situated on the East and West coasts of Viti Levu to accommodate the island needs.

Tables 5 and 6 show specific information on the Central and Western regions feeder loading.

Table 5 Central Region Feeder Loading

SUBSTATION	CURRENT CARRYING CAPACITY (AMPS)	EMANATING CONDUCTOR/CABLE
DEUBA		
PHD 1	80	Cable 240 mm sq Al pilswa
PHD 2	100	Cable 240 mm sq Al pilswa
NAVUA	100	Cable 150 mm sq Al
WAILEKUTU		
FIJI INDUSTRIES	300	Cable 185 mm sq Al
LAMI	300	Cable 185 mm sq Al
NABORO	198	Cable 185 mm sq Al
CIG	300	Cable 240 mm sq Al
HIBISCUS PARK		
MARINE	198	Cable 95 mm sq Al
FLOUR MILLS	300	Cable 240 mm sq Al
WAILADA	300	Cable 240 mm sq Al
KINOYA	300	Cable 240 mm sq Al
CARLTON BREWERY	198	Cable 95 mm sq Al
SUVA	300	Cable 240 mm sq Al
QUEENS	200	Cable 95 mm sq Al
SUVA 6.6KV		
SAMABULA	200	Cable 0.10 Cu
WALU STREET	200	Cable 95 mm sq Al
HIGH STREET	203	Cable 0.15 Cu
GORDON STREET	200	Cable 0.06 Cu
QUEEN ELIZABETH DRIVE	200	Cable 0.06 Cu
EDEN STREET	200	Cable 0.10 Cu
CARPENTERS MOTORS	225	Cable 0.06 Cu
WAIMANU RD	200	Cable 0.10 Cu
SUVA 11KV		
HIBISCUS PARK	300	Cable 240 mm sq Al
AIR PACIFIC H.S	198	Cable 95 mm sq Al
PD PATEL	250	Cable 185 mm sq Al
MH COMPUTER	250	Cable185 mm sq Al
RESERVE BANK	250	Cable 240 mm sq Al
KWONG TIY	198	Cable 150 mm sq Al
KINOYA	250	Cable 0.25 Cu
FNPF	250	Cable 240 mm sq xlpe Al
KINOYA		
VATUWAQA	300	Cable 185 mm sq Al
SEWERAGE	198	Cable 240 mm sq Al
SUVA	300	Cable 0.25 Cu
KINGS RD	248	Cable 240 mm sq Al
CWMH	225	Cable 0.15 Cu
HIBISCUS PARK	300	Cable 185 mm sq Al
SAMABULA RIVER	248	Cable 0.15 Cu
LAUCALA	198	Cable 95 mm sq Al
COCA COLA	300	Cable 240 mm sq Al
SAWANI		
PRINCESS RD	200	Cable 150 mm sq Al
NAUSORI	200	Cable 240 mm sq Al
WATER WORKS	200	Cable 185 mm sq Al
DILKUSHA	200	Cable 240 mm sq Al

Table 6 - Western Region Feeder Loading

SUBSTATION	CURRENT CARRYING CAPACITY (AMPS)	EMANATING CONDUCTOR/CABLE
PINEAPPLE CORNER		
NIRANJAN	150	Cable 95 mm sq Al
DRASA AVENUE	205	Cable 95 mm sq Al
PACIFIC LUMBER	205	Cable 95 mm sq Al
NATABUA	205	Conductor 6/1/2.36 ACSR
LAUTOKA INTERCON. 2	360	Cable 240 mm sq Al
FSC FDR 1	200	Cable 95 mm sq Al
FSC BULK	200	Cable 240 mm sq Al
LAUTOKA INTERCON. 1	300	Cable 300 mm sq Al
LAUTOKA SW STATION		
OLD HOSPITAL	200	Conductor 6/1/2.36 ACSR
SAULEI LANE	200	Cable 95 mm sq Al
BA FDR	200	Cable 185 mm sq Al
WAIYAVI	200	Cable 95 mm sq Al
STATION SERVICES	205	Cable 240 mm sq Al
VUDA		
SAWENI	150	Conductor 6/1/.093 ACSR
HIGH SECURITY	150	
SARU	100	
WAQADRA		
NADI BK/ROAD	200	Cable 185 mm sq Al
SKYLODGE	200	Cable 95 mm sq Al
NAMAKA	200	Conductor 6/1/2.36 AAC
VOTUA LEVU	200	Cable 240 mm sq Al
DENARAU 1	200	Cable 300 mm sq Al
SIGATOKA		
TOWN	160	Conductor 6/1/.093 ACSR
YANUCA	160	Conductor 6/1/.093 ACSR
RARAWAI		
BALEVUTO	200	Conductor 6/1/.144 ACSR
TOWN	195	Conductor 6/1/.093 ACSR
KORONUBU	200	Conductor 7/3.4 AAC
NADI POWER STATION		
NAVAKAI	205	Cable 300 mm sq Al
KOROWAI	150	Cable 95 mm sq Al
AIRPORT1	150	Cable 300 mm sq Al
OLD TOWN	75	Cable 95 mm sq Al
KOROLEVU		
NAVITI	150	Cable 95 mm sq Al
KOROLEVU	120	Conductor 6/1/.093 ACSR
HYATT	150	Cable 95 mm sq Al
TAVUA		
TAVUA	105	Conductor 7/4.39 Wasp
RAKIRAKI		
RURAL	68	Conductor 6/1/.144 ACSR
TOWN	88	Cable 240 mm sq Al

Distribution feeder data is aggregated in Appendix A.

4.1.3 Transformers

- There are four 11 / 132 kV transformers installed on the VLIS transmission system with a combined capacity of 100 MVA.
- There are five 132 / 33 kV transformers installed on the VLIS transmission system with a combined base capacity of 142 MVA and overload capacity of 182 MVA.
- There are twenty-seven 33 / 11 kV transformers installed on the VLIS transmission system with a combined base capacity of 239 MVA and overload capacity of 284 MVA.
- There are two 33 / 6.6 kV transformers installed on the VLIS transmission system with a combined base capacity of 15 MVA and overload capacity of 19 MVA.

A summary of distribution transformer data is provided in Appendix A.

4.1.4 Capacitors

Western Region

3.2 MVar at Sigatoka substation
Four (4) capacitor banks at the Rarawai substation: ratings not provided.

Central Region

2.4 MVar at Suva 11 kV substation busbar.
1.2 MVar each at Nausori and Dilkusha feeders at Sawani substation.
1.2 MVar on the Queens Road 11 kV feeder at Hibiscus Park.

4.1.5 Wires

Secondary service wire types and sizes were provided during KEMA's visit. Typical secondary service wire configurations were used in the calculation of LV wire losses.

4.2 Analysis of Losses

To quantify losses through the FEA transmission system and distribution system the following conditions and assumptions were taken:

1. Annual power station output from 2010 was used for the annual energy production and consumption.

2. The peak demand of VLIS system is assumed to equal total generation dispatched in the ERACS power flow case (127.92MW).

3. The typical value of no load loss for power transformers as derived from the loss curve[1] is used to calculate core losses of power transformers.

4. Typical values of no load loss and total loss from literature[2] are used to calculate distribution transformers' no load losses and load losses.

5. The effect of voltage drops through primary feeders is not considered in the loss estimations for distribution transformer losses and secondary wire losses.

6. Assumptions were made for typical structures of primary feeders to represent short feeder, medium length feeder and long feeder. Typical feeder conductor type and size were assumed based on the data for HV conductors and cables. Even though typical data as described above were utilized, primary feeder losses were estimated on per-feeder basis based on peak demand and annual MWh consumption for each feeder.

7. Assumptions were made for typical structure of secondary wire configurations. Typical secondary service wire types and sizes were assumed based on the data for LV conductors and cables. Secondary losses were estimated based on average customer consumption for each customer category. Secondary losses are estimated for LV feeder conductors. Since there is no information received describing service drop, no loss estimated for service drop.

[1] Areva Power Transformers Handbook (2008)

[2] EN 50464-1, 2007 Three-phase oil-immersed distribution transformers 50 Hz, from 50 kVA to 2500 kVA with highest voltage for equipment not exceeding 36 kV - Part 1: General requirements

8. KEMA assumed conductor length units were given in meters since the FEA uses metric system.

FEA provided a power system model for VLIS in ERACS database along with a one-line diagram and solution of the peak load case. This model includes power station generators, station transformers and power transformers, as well as the 132kV transmission system and 11kV distribution system. KEMA used this model for its analysis of system losses at peak load.

Distribution feeder information was provided in data files that contained feeder segment distance, conductor type and size for both primary and secondary systems. Distribution transformer data, feeder peak current and energy losses by section were also provided. One line diagrams for distribution feeders were also provided. Based on this information, KEMA developed summaries for all feeders listing the peak demand, annual MWh consumption, and total connected kVA capacity of all distribution transformers served. Furthermore, KEMA estimated load factor, loss factor, and utilization factor for each feeder (that had sufficient data) as well as feeder losses in kW and kWh.

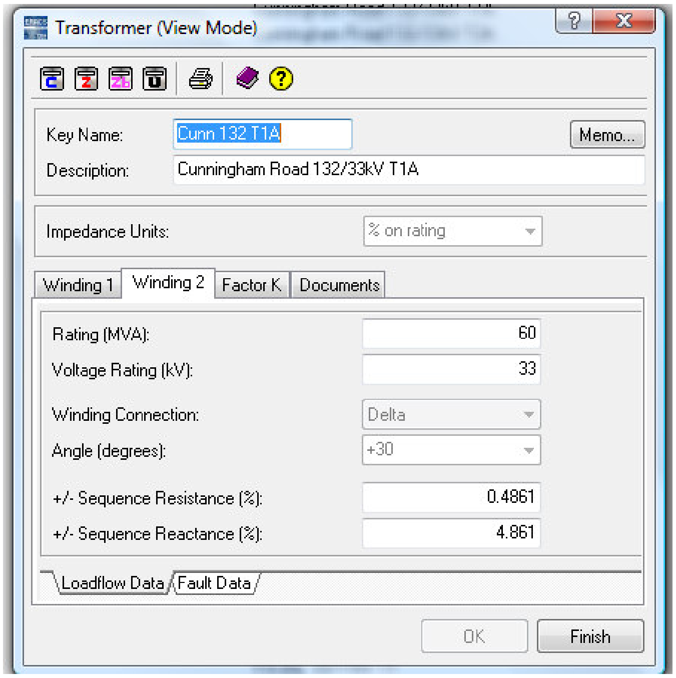
IPPs generation for 2010 was 19,803MWh, 90% of which was injected in the VLIS. The Independent Power Producers (IPP) total contribution amounted to an estimated 17,823MWh, or less than 2.5% of the total annual VLIS generation. KEMA took into account this IPP energy component when conducting the VLIS power system loss analysis.

Total energy sold in 2010 was 726,037MWh and peak demand was 127.92MW. The FEA system load factor for 2010 was estimated to be 68% and the loss factor was 51%.

4.2.1 Transmission System Losses

For the transmission system, technical losses consist of power transformer losses (both no-load and load losses), plus transmission line and cable losses. The peak load power flow case provided by FEA calculated the kW losses in the VLIS transmission system. FEA provided extraction of ERACS manual for transmission parameters as shown in Figure 12.

Figure 2 - ERACS Transformer Sample Illustration



As shown in the illustration, parameters defined for transformers are resistance and reactance for windings. It is KEMA's understanding[3] that losses calculated based on these parameters represent load losses or copper losses due to current flow through windings. Transformer no-load losses are not provided in this calculation. Therefore No-Load Losses are quantified separately and added to the transformer load losses from power flow study results.

Due to lack of transformer loss data, typical No-Load Loss data was derived from the transformer loss curve[4] and used to estimate No-Load Losses for the population of power transformers on the VLIS system. Since losses can be specified when purchasing power transformers, estimates based on typical loss data could result in a large margin of difference between the estimated losses and the actual losses. KEMA recommends that FEA collect No-

[3] FEA should verify this with the ERACS vendor.

[4] Areva Power Transformers Handbook (2008)

Load Loss data from manufacturer test reports, as well as Load Loss data, to improve the accuracy of transformer loss estimates.[5]

See Appendix B for formulas used in calculating annual energy losses on transmission, substation transformers and distribution. (Data for peak technical losses in kW was converted into kWh energy losses and the quantification methodology is discussed in the following sections).

4.2.2 Distribution System Losses

For the distribution system, technical losses consist of primary feeder losses, distribution transformer no-load losses plus load losses, and secondary wire losses.

Losses through primary feeders were estimated based on the peak MW load and MWh consumption per feeder on an annual basis. Typical feeder conductor types were determined based on LV conductor data. Feeder resistance based on unit length[6] for typical feeder conductor types were used for the feeder loss estimation. Feeder losses were estimated based on typical feeder structures provided on sample feeder drawings. All feeders in VLIS are separated into 3 groups and typical feeder structures were created each group:

Table 7 - Typical Primary Feeder Configuration Assumptions

Feeder Group	Load Character	Loss Estimation Assumption
Category 1: short feeder, with length less than 3000 meters	industrial load at the end of feeder	load at the end of feeder
Category 2: medium feeder, with length of 3,000 to 15,000 meters	mixed residential and commercial load in urban area, distribution transformers along the feeder	mixed residential and commercial loads evenly distributed along feeder
Category 3: long feeder, with length longer than 15,000 meters	rural area, long laterals along main trunk of feeder, less load density	assuming six laterals tapped along the main trunk in even distance, with 15% of total circuit length as main trunk and 85% of total circuit length as laterals cumulatively

[5] Note that transformer No-Load Losses are also referred to as “core losses” and Load Losses are known as “copper losses”.

[6] Feeder conductor data provided to KEMA does not specify length unit. It is assumed as meters and subsequent loss estimation for primary feeders and secondary feeders are based on this assumption.

* “Feeder length” refers to the cumulative length in meters of all sections on the feeder.

Typical feeder structures were defined based on the following drawings.

- File 04n20052.dwg for TAVUA substation in Western Region is referenced. It contains long feeder as NADARIVATU with cumulative circuit length of 98784 (meters as assumed unit).

- File FIL & Lami.dwg equivalent to 04N10008WAILEKUTU WAINADOI.dwg for station WAILEKUTU in Central Region, contains short feeder and medium feeders.

Losses through distribution transformers were estimated based on the typical losses for kVA capacity and average loading level. FEA has 3,607 distribution transformers with total connected capacity of 462,086kVA. On average they are loaded to 26.41% of full capacity during the peak load condition. Transformer load losses in MW were estimated for peak load and allocated among all distribution transformers proportionally to kVA size. See Appendix B for formula used in estimating energy losses.

Losses through secondary wires, referred as LV feeders in FEA data, were estimated by developing typical conductor type, typical conductor section length and typical secondary wire configuration. All typical values were developed based on the FEA LV conductor data and distribution transformer data provided. Assumptions are listed in the Exhibit below:

Table 8 - Typical Secondary Configuration Assumptions

Category of Customer	Phase	Secondary Voltage (V)
Industrial	3	415
Commercial	3	415
Domestic	1	240

The average consumption per customer for each customer category was estimated and secondary loss assumptions were made to estimate losses as shown in table 9.

Table 9 - Average per Customer Consumption

Customer Type	No.	Annual kWh Sold	Annual kWh per Customer	Annual kW Sold per Customer	Annual kVA Sold per Customer	Peak kW	Peak kVA
Industrial	83	183,275,298	2,218,408	253.24	281.38	372.736	414.152
Commercial	12,728	318,886,276	25,054	2.86	3.18	4.209	4.677
Domestic	123,155	212,609,997	1,726	0.2	0.22	0.29	0.322
Total	135,966	714,771,571	2,245,188	256.3	284.78	377.235	419.151

See Appendix B for the formula used in estimating annual energy losses through the secondary system.

In the distribution system, the utilization factor under the peak load condition was calculated for the overall system as well as for each feeder. This is based on the feeder maximum load and the sum of all distribution transformer kVA served by the feeder, as derived from distribution transformer data provided by FEA. Similarly, the system load factor and the loss factor under the peak load condition were calculated based on the system peak demand and annual energy consumption for the VLIS system. See Appendix B for definitions of factors mentioned above.

4.3 Findings

The total system losses are equal to the total energy that entered the system from the power stations, less the total energy sold and any unaccounted for energy. FEA usage for its own buildings, street lights and water utility are all accounted for and billed. A summary of estimated losses is provided in Table 10.

Table 10 – VLIS Annual Loss Estimation

Based on 2010 Data	MWh	% of Generation	% of System Consumption
Annual generation FEA	781,734,056		
Annual generation IPP	17,822,887		
Annual generation TOTAL	799,556,943		
Annual station auxiliary	8,445,747	1.06%	
Annual system consumption	773,288,309	96.71%	
Annual energy sold	726,037,133	90.80%	93.89%
Street Lignts	41,846	0.01%	0.01%
Institution	165,688	0.02%	0.02%
System loss	64,866,530	8.11%	8.39%
Technical loss	64,024,901	8.01%	8.01%
Non technical loss	841,629	0.11%	0.109%

The VLIS technical losses were 8.01% of total energy produced. This is a somewhat high percentage of technical losses. The portion of technical loss through transmission system (51.35%) was relatively high. Losses reflect the loading condition of power system equipment. With system peak load, most of the transmission lines are loaded close to 40% of rated capacity and most of the power transformers were loaded between 20% and 50% of capacity. Transformer core loss for both power transformers and distribution transformers are accounted for 20.56% of the technical loss. A total of 218 power transformers are modeled in the ERACS model, serving as generator step-up transformers, earthing transformers, generation plant auxiliary transformers as well as substation transformers transferring power between different voltage levels. No load losses for all power transformers are included as part of technical loss from transmission system, due to the fact that no load losses are exist as long as the transformers are energized, regardless of whether it is loaded or not.

The result from the estimation shows that VLIS non-technical loss in very low percentage.

A number of factors could contribute to the estimation error and these are listed below:

- Inaccuracy in historical statistics for total generation, consumption and energy sold.
- Errors introduced in loss estimation by taking assumptions where no sufficient or accurate data is available. Example here is that transformer no-load loss and full-load loss data is not available.
- Inaccuracy in system equipment data. An example is that over half of the LV feeder conductor type is unknown, over 10% of all LV sections not linked to a distribution transformer. For HV feeder conductors, some are assigned to feeder ID that is not identified in
- The loss quantification methodology for primary and secondary losses is developed from the system point of view. Estimation is carried out by utilizing typical conductor type, size and typical feeder configuration to represent load distribution over the whole system in general. Considering the diversity of the distribution system, estimation error introduced by these assumptions will not result in significant deviation in the total quantity of losses. FEA has a very large power demand compare to other Pacific Island utilities. However, when estimating feed losses, data and results are on per feeder basis. Errors in feeder data, such as switching of feeder sections, negative meter readings, both MW and MWh could result in big deviation in the estimated per feeder losses.

To improve the loss estimation result, 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.
- Keep records of all power equipment from manufacture including equipment specifications, name plate information and test data.
- Compare the power flow study results with test data of power transformers and adjust parameters to improve accuracy of MW loss calculated. FEA has already put efforts in this area.

5. Non-Technical Losses

In the category of non-technical losses one can identify different loss causes, such as meter inaccuracy, administrative and/or billing failures, electricity theft, meter tampering, meter by-passing, and others. Sometimes non-reimbursed power deliveries (for example for street lighting or water company activities) are also considered to be non-technical losses. Those power deliveries however – if they are not accounted for or not paid for – are a financial loss for the company and not a non-technical system loss.

As summarized under Section 4.3, the non-technical losses are low (0.11%). However, data provided by FEA indicates that there are ongoing issues with faulty meters, meter tampering and pilferage. FEA has ongoing programs to address such issues and has been able to recoup most of the losses associated with faulty meters and meter tampering in 2009-2010.

FEA advised that the non-technical losses were roughly 3 to 4%. KEMA evaluated non-technical losses as the residual of overall system losses minus the calculated technical losses. Since there was no existing distribution system model for evaluation through power flow analysis tools, these had to be estimated, and KEMA expects this to be the source of the discrepancy between the two estimates.

5.1 Sources of Non-technical Losses

5.1.1 Metering Issue Losses

Generator and feeders are monitored using revenue class meters. Electromechanical meters are used to monitor customer energy usage, and 10% of all customers have pre-paid energy meters. FEA losses vary per month between 7 and 13% because reading cycles are not strictly maintained.

The following table, provided by FEA, gives a summary of the financial impacts associated with the non-technical losses due to metering issues, and the success of the FEA collection processes.

Table 11 - Faulty Meters and Meter Tampering Cases

Lost Revenue Collection		2009	2010
Billed Amount		$410,756.99	$751,796.52
Faulty Meter	Cases	47	26
	$ Value	$302,635.51	$671,270.73
	Payment rec'd	$303,168.20	$547,654.99
Tamper & Pilferage	Cases	97	79
	$ Value	$108,121.48	$91,799.26
	Payment rec'd	$92,973.46	$45,057.92
Payment Received		$396,141.66	$592,712.91
Outstanding Balance		$14,615.33	$159,083.61
Total Fault & Pilferage Cases		144	105
Commercial Inspection Completed		207	857
Commercial Inspection Pending		23	0
Low Power Factor Letters Issued		53	4

This data shows that more than 96% of such losses were successfully recovered from 2009 and nearly 80% have been recovered to date from 2010, which are impressive results. Furthermore, KEMA assumes that efforts to recover the 2010 losses are still ongoing at this time.

5.1.1.1 Aged Meters

The reported potential financial losses due to faulty meters amounted to $671,270.73 before collection, which was more than twice the value reported in 2009. It is unknown whether the meters were faulty due to age, improper installation, or some other factor; however, the rigorous inspection program undertaken by the FEA has proven to be effective in catching errors due to aging meters. FEA's current policy does not provide for regular meter inspections; meters are inspected either when they are new or upon customer request.

5.1.1.2 Meter Tampering and Bypassing

FEA provided KEMA with a financial summary, which included meter tampering cases, and the estimated associated revenue loss on a monthly basis for 2010.

The reported potential revenue losses due to meter tampering and pilferage amounted to $91,799.26 before collection, which was slightly less than the value reported in 2009. The number of tampering and pilferage cases declined by roughly 20% in 2010 compared to 2009. Collection efforts successfully recovered $45,057.92 of the potential revenue losses.

5.1.1.3 Inaccurate Meter Reading

Inaccurate meter reading will result in irregular monthly figures for power usage, and therefore inaccurate system studies. Most inaccurate readings can be corrected by the next meter reading. A common source of metering inaccuracy is the unreliability of manual reads. In the FEA system, the system raises flags for heavy deviations in subsequent entries, which reduces the unreliability of this procedure. FEA also reported that communication problems occur between prepaid meters and service vendors.

5.1.2 Billing Losses

KEMA was not made aware of any billing losses.

5.1.3 Billing Collection Losses

Billing collection losses and bad debt are not to be counted to system losses. Any billing losses or bad debt amounts that are written off are actually financial losses and not system losses.

5.1.4 Loss through Theft

As already mentioned FEA non-technical losses are low. As shown in Table 11, the amount of reported tampering and pilferage cases decreased slightly in 2010, with 79 cases reported, compared to 97 cases in 2009.

5.1.5 Administrative Failures

The occurrence of administrative failures (in the process from meter reading to billing) was not identified as a problem for the FEA system.

5.1.6 Line Throw-ups

Line throw-ups were not identified as a problem during the KEMA visit to the site.

6. Overall Findings and Recommendations

This chapter provides a compilation of findings and recommendations.

6.1 Generation

Roughly 55% of the power generated on Viti Levu comes from renewable energy, the bulk of which is produced by the Wailoa hydroelectric power station. Most of the conventional generator units are fueled with IDO; with the exception of two diesel engines at Kinoya Power Station.

Most thermal Power Stations are adequately maintained and dispatched according to their respective fuel efficiency. Generators run more efficiently near their full rated output than when running at low percentage of rated output. Running the fewest number of units needed to maintain system reliability allows each unit to run nearer to its rated output, and helps to improve generator fuel efficiency.

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.

6.2 Transmission

The technical losses on the FEA transmission system (4.11%) are somewhat high, but this transmission loss level is not unusual for an island with a transmission system as extensive as VLIS.

6.3 Distribution

The technical losses on the FEA distribution system were estimated to be 3.90%, 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.

6.4 Non-Technical Losses

The FEA meter reading and inspection practices are appropriate and effective. It is recommended that meter readers are consistently trained 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.

KEMA recommends that FEA continue implementing 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.

KEMA recommends that FEA regularly audits its 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.

A. Data Handbook

See attached FEA data handbook.docx

B. Loss Worksheet

See attached FEA loss worksheet.xls