University of Southern Queensland

Faculty of Engineering & Surveying

Analysis of Providing Affordable Electricity Supply for the Outer Islands in the Maldives

A dissertation submitted by

Nofoaluma Worrall

in fulfilment of the requirements of

Courses ENG4111 and ENG4112 Research Project

Towards the Degree of

Bachelor of Engineering (Electrical and Electronics)

Submitted: January 2006

Abstract

The smaller of the Maldivian outer islands are vulnerable to food shortages during rough seas, drought, epidemics and natural disasters, of which the recent tsunami is a dramatic example[1]. The stunting of children and adults from food shortages is common, and infant mortality rates are around 10 per thousand. Life expectancy in the islands is low, caused mainly by common infectious diseases. A United Nations survey[2] indicates that the poor quality electricity supply in these islands contributes substantially to the population's vulnerability[3].

Existing electricity supply on the smaller islands is usually provided by a private supplier or by the Island Development Committee. These enterprises are not effectively regulated, and their supply systems are under designed. Distribution cables are extended to new customers until the voltage at the customer premises falls below marginal usefulness. Diesel generators are always purchased second-hand, and are unreliable and inefficient. Under the existing technology and regulations these communities are unable to propose a financially viable undertaking with affordable tariffs and therefore are unable to obtain bank loans to finance a reliable electricity supply. In some cases, where island communities are able to raise money to establish a central electricity system, they cannot afford to maintain the system properly.

This research project investigates several possible means of reducing the lifetime cost of providing electricity in these islands. The possibilities investigated are modifying conventional engineering design criteria to be more relevant to the needs of small poor islands, using digital instead of expensive analogue equipment for metering, protection, control and synchronization, and utilizing renewable energy, particularly solar and wind power in hybrid with diesel generators.

[1] Although a poor example as due to widespread publicity extensive international aid was available to the islands affected.
[2] *Vulnerability and Poverty Assessment, Maldivian Outer Islands, (VPA)* United Nations Development Program (UNDP), 1998
[3] An island may be vulnerable because of its small population and extreme isolation, yet may have a high cash income by Asian standards. This cash income is usually sourced from fishing, or by supplying labour to the tourist resorts.

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111 & ENG4112 *Research Project*

Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Nofoaluma Worrall

Student Number: 0011021720

____

Signature

____

Date

Acknowledgements

Thanks must go to the following people for their cooperation and support by providing information, advice and their experience for this Research Project.

- John Worrall — Electrical Engineer.
- Mohammad Rasheed — Generation Engineer.
- Sarah Griffith — Business Manager - Power Electronics (South Pacific) Cummins Power Generation.
- Herbert Wade — Renewable Energy Technical and Policy Consultant.
- Ron Sharma — Research Supervisor.

Abbreviations

AAGR	Average Annual Growth Rate
ALF	Annual Load Factor
ELCB	Earth Leakage Circuit Breaker
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
IDC	Island Development Committee
IEU	Island Electricity Utility
MoAD	Ministry of Atolls Development
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
MCE	Ministry of Construction and Environment
MEB	Maldives Electricity Bureau
NREL	US National Renewable Energy Laboratory
NGO	Non Government Organisation
O&M	Operation and Maintenance
PV	Photovoltaic
PVC	Poly Vinyl Chloride
PVCPVCSWA	Poly Vinyl Chloride Poly Vinyl Chloride Steel Wire Armed
Rf	Maldivian Rufiyaa
SFE	Specific Fuel Efficiency
STELCO	State Electric Company Limited
STO	State Trading Organisation
VPA	Vulnerability and Poverty Assessment, 1998; UNDP
VT	Voltage Transformer
WACC	Weighted Average Cost of Capital
WDC	Women's Development Committee

Measures

A	Ampere	Unit of electrical current
Ah	Ampere-hour	Unit of battery capacity
kV	kilovolt	1,000 volts
kVA	kilovolt-Ampere	Unit of apparent power = 1,000 VA
kW	kilowatt	Unit of real (active) power = 1,000 watts
kVAR	Reactive kilovolt-Ampere	Unit of reactive power = 1,000VAr
kWh	kilowatt-hour	Unit of energy = 1,000Wh
kWp	Kilowatts-peak	1000Wp
l	litre	Unit of volume
Hz	Hertz	Unit of frequency
MW	megawatt	Unit of real (active) power = 1,000kW
m	meter	Measure of length
MWh	megawatt-hour	Unit of energy = 1,000,000Wh
V	Volt	Unit of electrical pressure (voltage)
VDC	Volt Direct Current	Unit of electrical pressure (voltage)
Wp	Watt-Peak	PV panel power at standard condition

NOTES

The fiscal year of the Government corresponds to the calendar year. The official currency of the Republic of Maldives is the Rufiyaa (Rf). There are 100 Larees to the Rufiyaa. The exchange rate used in this report is Rf 9.65 to the Australian Dollar.

Summary for Maaeboodhoo

Island Data

Population (Census 2000)	597
Number of Households (Census 2000)	99
Household Size (Census 2000)	6.0
Estimated Average Household Income, $/Month, 2003	446
Island Area, Hectares	17.5
Distance from Male', km	175
Main Economic Activities	Fishing

Electricity Data

	2005	2007 (Proposed)
Ownership of Electricity Utilities	IDC	IDC
Number of Electricity Customers	125	129
Tariff $/kWh	0.75	0.87
Electricity Sales (Estimated) MWhpa	75	78
Peak Load	27	22
Production Efficiency, l/kWh	0.45	0.32
Safety of Electricity Supply	Not compliant	Fully Compliant
Quality of Electricity Supply	Poor	Fully Compliant
Distribution Losses	24%	5%
Installed Generation Capacity, with Synchronising, kW	117	80
Affordable Tariff (2005 Prices)	0.52	0.87

Electricity Supply Capital Costs and Required Tariffs (2005 Prices)

ADB Project Design with Analogue Control Protection and Synchronizing[1]		
Total Capital Cost	AUS$	499,739
Required Tariff[2] (Exceeds Affordable Tariff)	$/kWh	1.12
Redesigning Underground Cables		
Total Capital Cost	AUS$	487,368
Required Tariff (Exceeds Affordable Tariff)	$/kWh	1.12
Single Busbar without Synchronizing		
Total Capital Cost	AUS$	487,799
Required Tariff (Exceeds Affordable Tariff)	$/kWh	1.15
Two Busbars Without Synchronizing: Split Load		
Total Capital Cost	AUS$	478,412
Required Tariff (Exceeds Affordable Tariff)	$/kWh	1.11
Single Busbar with Synchronizing (Digital)		
Total Capital Cost	AUS$	376,325
Required Tariff (Exceeds Affordable Tariff)	$/kWh	0.89
Single Busbar with Synchronizing (Digital) plus Improved Distribution Design Criteria Option		
Total Capital Cost	AUS$	363,954
Required Tariff (Within Affordable Tariff)	$/kWh	0.87

1. Project on this island rejected by ADB Project Engineers as domestic tariff was not affordable.
2. Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island.

Summary for Mukurimagu

Island Data

Population (Census 2002)	841
Number of Households (Census 2002)	138
Household Size (Census 2002)	6.1
Estimated Average Household Income, $/Month, 2003	253
Island Area, Hectares	na
Distance from Male', km	247
Main Economic Activities	Fishing

Electricity Data

	2005	2007 (Proposed)
Ownership of Electricity Utilities	IDC	IDC
Number of Electricity Customers	140	145
Tariff $/kWh	0.51	0.42
Electricity Sales (Estimated) MWhpa	138	162
Peak Load	45	44
Production Efficiency, l/kWh	0.38	0.32
Safety of Electricity Supply	Not compliant	Fully Compliant
Quality of Electricity Supply	Poor	Fully Compliant
Distribution Losses	21%	5%
Installed Generator Capacity, with Synchronising, kW	180	164
Affordable Tariff (2005 Prices)	0.42	0.51

Electricity Supply Capital Costs and Required Tariffs (2005 Prices)

ADB Project Design with Analogue Control Protection and Synchronizing[1]		
Total Capital Cost	AUS$	466,512
Required Tariff[2] (Exceeds Affordable Tariff)	$/kWh	0.63
Redesigning Distribution Design		
Total Capital Cost	AUS$	397,549
Required Tariff (Exceeds Affordable Tariff)	$/kWh	0.57
Single Busbar without Synchronizing		
Total Capital Cost	AUS$	435,183
Required Tariff (Exceeds Affordable Tariff)	$/kWh	0.65
Two Busbars Without Synchronizing: Split Load		
Total Capital Cost	AUS$	439,163
Required Tariff (Exceeds Affordable Tariff)	$/kWh	062
Single Busbar with Synchronizing (Digital)		
Total Capital Cost	AUS$	394,197
Required Tariff (Exceeds Affordable Tariff)	$/kWh	0.57
Single Busbar with Synchronizing (Digital) plus Improved Distribution Design Criteria Option		
Total Capital Cost	AUS$	342,687
Required Tariff (Within Affordable Tariff)	$/kWh	0.51
Photovoltaic Hybrid System		
Financial Internal Rate of Return		22%
Total Capital Cost	AUS$	643,014
Required Tariff	$/kWh	Not applicable
Wind Hybrid System		
Financial Internal Rate of Return		13%
Total Capital Cost	AUS$	176,780
Required Tariff	$/kWh	Not applicable

1. Design by previous engineers rejected as domestic tariff was not affordable.
2. Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island.

TABLE OF CONTENT

APPENDICES

TABLES

CHARTS

Chapter 1:

Introduction

1 INTRODUCTION

Existing electricity supplies on the smaller of the Maldivian outer islands are of poor quality. Under existing technology and regulations, small islands are unable to propose a financially viable undertaking with affordable and acceptable tariffs, and are thus unable to raise loans to finance their proposals. This research project examines alternative means to improve electricity quality while keeping tariffs affordable on the small islands of Mukurimagu and Maaeboodhoo.

The quality[4] of electricity is lower than that required by the regulator and desired by customers. Tariffs on each on each of these two islands are not adequate to cover fuel and operational costs and the utilities are drawing down their cash reserves. Electricity supplies on these islands are community run and customers are understandably reluctant to pay more for a poor quality electricity supply.

A good quality electricity supply would require a higher tariff. Island residents are unanimous in agreeing they are willing, within reason, to pay a higher price for better quality. However the tariff needs to be affordable[5] and acceptable to domestic customers. Studies by Government engineers and Asian Development Bank project engineers have failed to identify a design which would improve quality at an affordable tariff[6]. With specific reference to the islands of Mukurimagu and Maaeboodhoo, this research project considers:

- The suitability of existing design criteria for the smaller islands;
- The use of digital meter, control, protection and synchronizing equipment instead of expensive analogue equipment; and
- The use of renewable energy.

---

[4] See Section 2.6.
[5] From studies on other islands residents are unwilling to pay more than 10% of their cash income on a good quality electricity supply. See *Preparing the Outer Islands Electrification Study,* Asian Development Bank TA 3232 MLD, December 2000
[6] *Appraisal Report, Batch 1, Appendix 15, Mukurimagu*, Asian Development Bank (ADB), August 2003, and Draft *Appraisal Report, Batch 2, Appendix 32, Maaeboodhoo*, ADB, October 2005.

1.1 Description of the Project Area

Maldives is an archipelago of about 1,200 islands set in the Indian Ocean to the southwest of India. It has a tropical climate, which is warm and humid, with two pronounced monsoon seasons.

The Muslim population of 339,330 in July 2004 is widely scattered among 200 inhabited islands. In addition, there are 87 islands devoted solely to tourist resorts. The population is geographically separated from tourist activities, and tourists require difficult to obtain permits to visit the inhabited atoll islands.

The two main economic activities are fishing and tourism. While the economic benefits of fishing are spread throughout the community, the economic benefits of tourism are concentrated with the political and business elite.

This has lead to considerable inequalities with the land and resource poor outer island population suffering deprivation which includes food and water shortages and lack of access to basic services. United Nations studies have shown that these populations are very vulnerable to catastrophic misfortune[7]. The United Nations identifies poor quality electricity supply as a substantial contribution to the population's vulnerability[8].

1.2 Government Policy

The Government is not willing to allow these electricity authorities to continue to supply poor quality electricity in defiance of statutory regulations. However the Government requires that individual islands finance their electricity undertakings in a sustainable manner without tariff cross subsidies, or Government support.

A problem with this policy is that small outer islands are unable to raise money to finance adequate electricity investment, whilst maintaining an affordable tariff sufficient to meet loan servicing and operational costs.

[7] UNDP, *Vulnerability and Poverty Assessment (VPA), Republic of Maldives*

1.3 Technical Problems and Costs with Electricity Supply

The existing technical problems and costs of the two islands selected for this project will be discussed in Chapter 3, however before doing so, these problems and costs are discussed for all the outer islands generally, in Chapter 2, so that the particular applications can be viewed in the general context.

Chapter 2:

Existing Power Systems

in the Outer Islands

2 EXISTING POWER SYSTEMS IN THE OUTER ISLAND

2.1 Introduction

Before proceeding to consider the two islands targeted for study in this research project this Chapter gives a general outline of the operation, particular technical problems, and costs involved in electricity supply in the Maldivian Outer Islands, so that the analysis of the two target islands can be viewed within the context of the Maldivian outer islands generally.

2.2 References and Sources of Information

References to electricity supplies in the outer islands are limited to studies carried out by the Asian Development Bank between 1999 to 2005, although there are passing references to the inadequacy of outer island electricity supplies in a number of publications, most importantly the Vulnerability and Poverty Assessment (VPA), UNDP, published in 1998. Detailed statistical data on the utilities has been collected by Maldives Electricity Bureau but has been found by the author to be highly inaccurate.

The author has inspected electricity supply systems on a number of the smaller outer islands as part of the Asian Development Bank team from 2002 to 2005.

2.3 Operation and Ownership of Outer Island Electricity Utilities

Almost all islands have some central electricity utility. About 50% of these are operated by a community based Island Development Committee (IDC), however around 30% are operated either by private individuals or NGOs, while the remaining 20% are operated by the Government owned State Electricity Company (STELCO). The State Electricity Company provides a full quality supply by cross-subsidizing tariffs from the capital, Male', and is restricted to the larger islands, or to those islands which have political importance. It is the Government's expressed desire not to expand the franchise of STELCO. The Government is legislating to establish electricity cooperatives on each non STELCO island. These cooperatives will be similar to the existing IDCs, but will be granted specific monopolistic legal powers to operate the island's electricity supply.

2.4 Availability of Electricity

Most residences throughout the outer islands have electricity available to them. On each island, all residences, and government and commercial premises, are clustered together, usually in the centre of the island, so the distribution network is compact.

Supply usually is on for 24 hours a day, although there are brief interruptions when generating sets are changed, as there is no synchronizing equipment in the power stations.

2.5 Equipment Currently Installed

2.5.1 Introduction

Single line diagrams illustrating the generation, control, and distribution systems in use in the outer islands are given in Charts 2.1, 2.2, and 2.3.

2.5.2 Generation

Generation is universally by small 1500 rpm diesel engines, generating at 3-phase 400/230 Volts with earthed neutral. These engines are rated between 18kW to 144kW, the size installed being more or less dependent on the island's electrical load. Most of the diesel generators are old, usually purchased second-hand from the market in Male'. These are usually unreliable, inefficient and well past their economic life. These older diesel generators are fault prone. They also have slow acting mechanical governors and automatic voltage controllers. Newer engines tend to have faster acting and more reliable electronic governors and automatic voltage generators.

The Government gives some new diesel generators to islands on an ad hoc basis, especially in the twelve months prior to elections. Local members of parliament often provide generators, or in some cases complete electricity systems. Unfortunately the generators and cables provided are often not well matched to the load on the island.

2.5.3 Main Control Panel

Main control panels usually have switches and fuses for both generator and feeder control and protection, often mounted on a sheet of plywood. There is no synchronizing equipment on the smaller islands. On most islands the busbar is not split, so the total load must be met with one engine at a time, See Chart 2.1. Some islands have a split busbar that allows them to independently feed different portions of the load (called splitting the load), thus running two engines independently, each meeting part of the system load, See Chart 2.2. Synchronising equipment is rare even though its use would results in lower overall generation costs although it is used in all resort and STELCO islands. A single line diagram illustrating the system is shown in Chart 2.3. Monitoring instruments are very limited. Only rarely is there a kWh meter measuring the generation output. Commonly, instrumentation is limited to generator voltage, frequency meter and engine hours run.

2.5.4 Distribution

Distribution is by low voltage three phase and neutral PVC insulated and PVC sheathed cable buried underground along the side of the sandy roads. Cables are purchased at the general market in Male', the country's capital. As the islands cannot do cable calculations, and as the smaller the cross section of the cable the less the cost, inevitably distribution cables are undersized. Distribution cables originate from the power station main control panel and terminate on distribution boxes mounted on household boundary walls. These distribution boxes are generally home made and usually are wooden boxes with a galvanised iron lid.

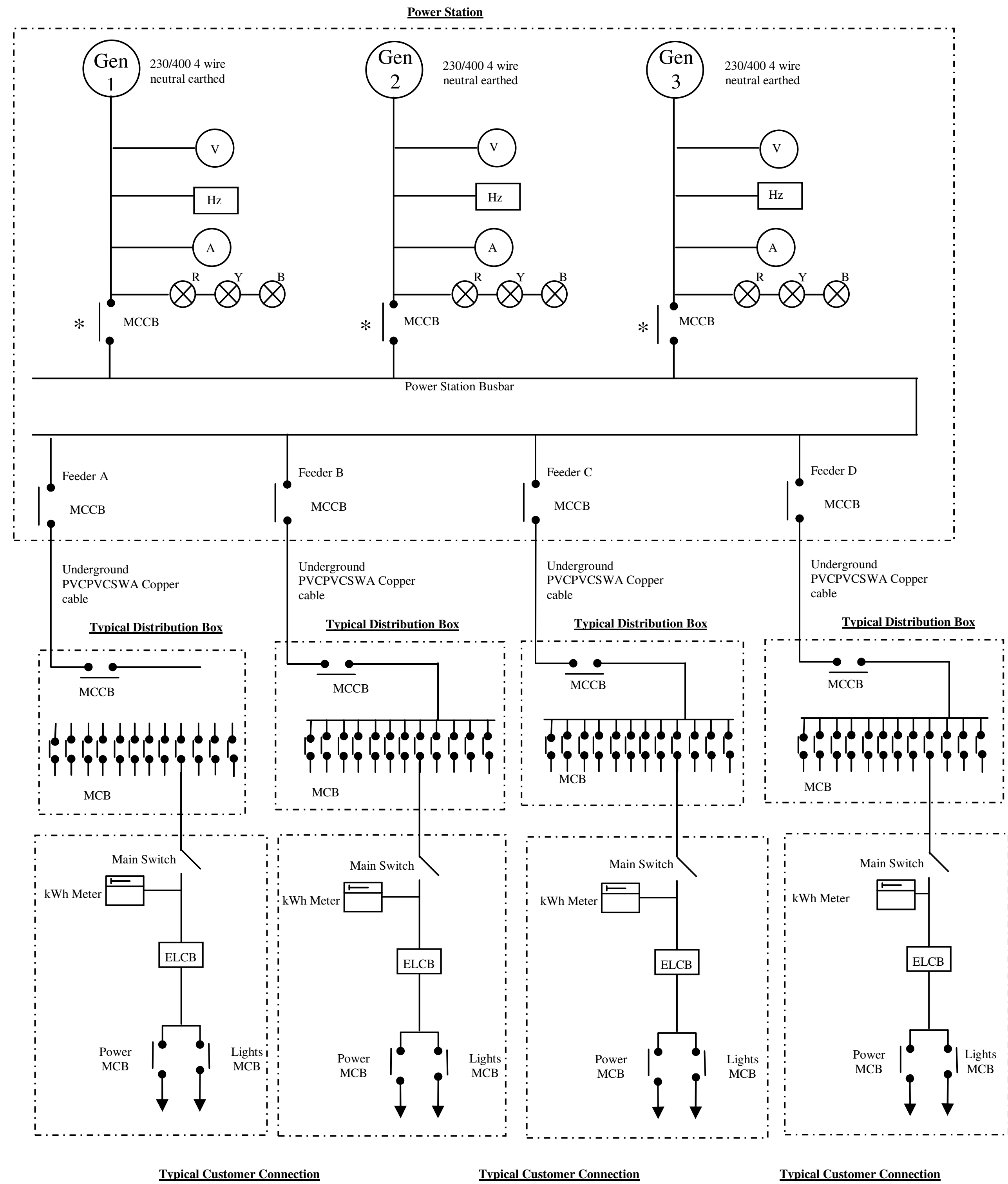
2.5.5 Customers' Services and Meter boxes

Most consumers have a single phase supply, directly earthed at the customers meter board. There are no multiple earthed neutral (MEN) installations[8]. All customers have an earth leakage circuit breaker. New customers are expected to purchase their own meter board, meters, and service cables, which they obtain from the main market in the capital, Male'. This equipment is installed by the power station staff. There is usually no house wiring; lights and appliances are connected directly to switched power outlets mounted on the meter board.

[8] Australia almost universally uses the MEN system.

Chart 2.1: Single Line Arrangement of a Typical Island Power Supply without Split Busbar

(No synchronising: single generator supply)



* Note: As there is normally no synchronising equipment only one generator can be connected at any one time.

Legend

Hz Frequency meter

A Ammeter

Indicating lights

kWh Meter

V Volt meter

Circuit Breaker

Switch

ELCB Earth Leakage Circuit Breaker

Chart 2.2: Single Line Arrangement of a Typical Island Power Supply with Split Busbar

(No synchronising: single generator supply)

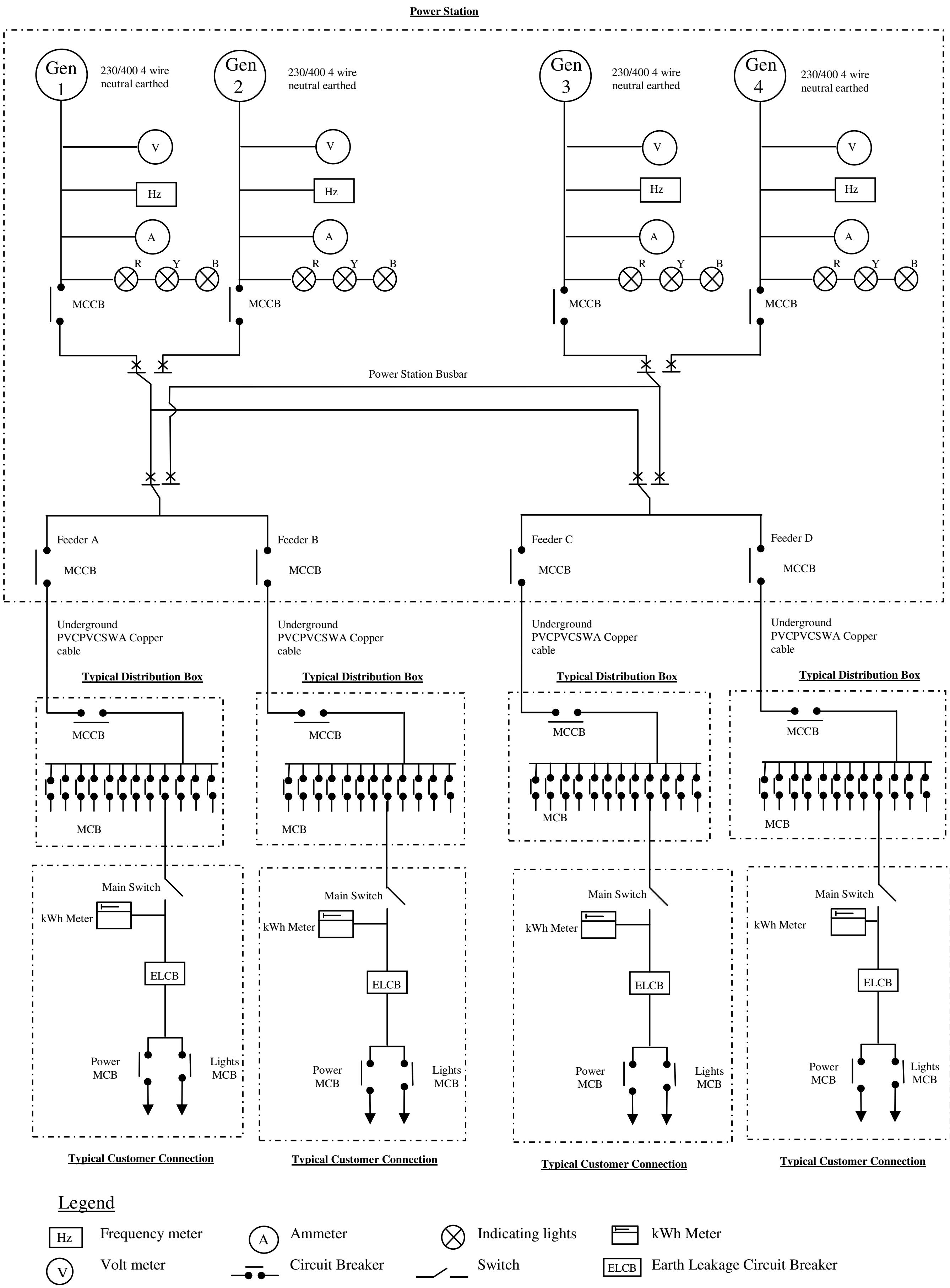
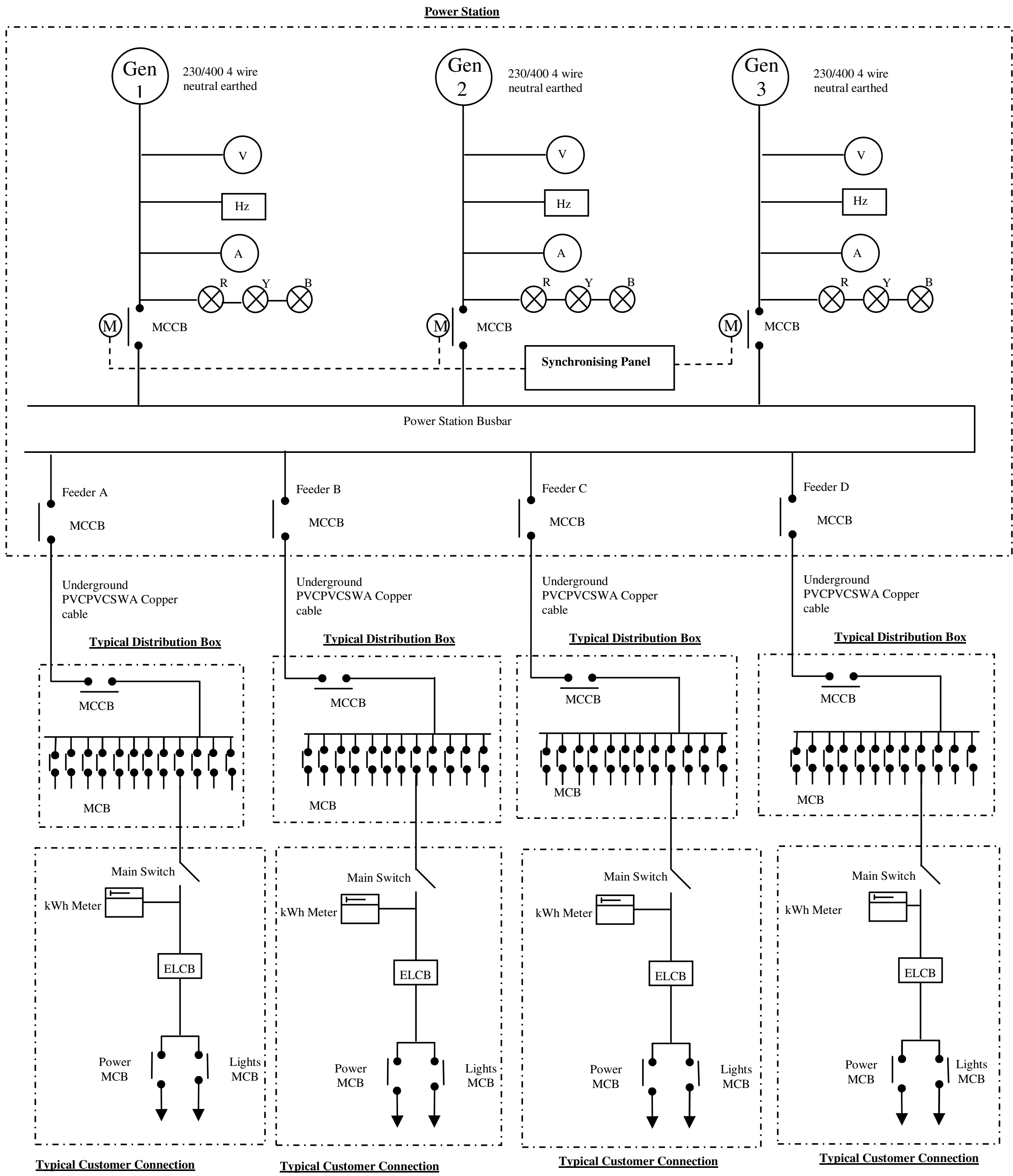


Chart 2.3: Single Line Arrangement of a Typical Island Power Supply with Synchronizing



Note: Synchronizing panel measures and compares voltage, frequency and phase angle between the selected generator and busbar, and closes selected motorised MCCB when conditions are satisfactory.

Legend

- Hz — Frequency meter
- V — Volt meter
- A — Ammeter
- Circuit Breaker
- Indicating lights
- Switch
- kWh Meter
- ELCB — Earth Leakage Circuit Breaker
- M — Motorised Circuit Breaker

2.6 Existing Electricity Quality

The quality of electricity supply at the customer's point of supply is taken to cover long period voltage variation, short period voltage spikes and dips, excessive frequency variation, and frequent interruptions of electricity supply.

2.6.1 Long Period Voltage Variation

Nominal voltage in the Maldives is 230 Volts. For the outer islands, the regulator, MEB, requires a maximum voltage variation at the customers' point of supply within ± 5% around nominal, which is in the range of 218 to 241 Volts. An operational constraint on low voltage is that the commonly used fluorescent tubes will not start below about 180 Volts[9], although once started these tubes will usually continue to operate at a lower voltage[10]. At evening peak, voltage on the outer islands commonly sags to below 180 Volts at the customers' point of supply because of undersized distribution cables. This low voltage is sometimes aggravated by poorly performing generator automatic voltage regulators[11].

Customers are aware that it is difficult to start fluorescent lights during the peak, so those at the end of a distribution run usually turn on their lights while it is still daylight. The next most common appliance, the refrigerator is expensive and is likely to be damaged by excessively low voltage. Owners of refrigerators generally restrict their use to the Ramadan fasting period, when the refrigerators are most useful, and even then turn off the refrigerator during the evening peak load period when the voltage is low. Discussions with women on these islands indicate that the life of a refrigerator is about two years. Television is also common in the outer islands, and the sets are prone to damage by low voltage. Owners usually turn on the television only when they want to watch a particular program, and then rarely over the evening peak period.

---

[9] Minimum striking voltage depends on the type of starter, the type of ballast, the length of the tube, the diameter of the tube, the humidity and the ambient temperature

[10] Though at a lower light output.

[11] Sometimes the voltage regulator is faulty, but more often are set incorrectly.

2.6.2 Voltage Spikes and Surges

Excessive surges and spike in the voltage are usually caused by faulty mechanical governors; by faulty automatic voltage controllers; by constant system interruptions required to changed diesel generator in the absence of synchronizing equipment, and frequently by faulty alternators. Other contributors are unbalanced loads across the three phases causing excessive neutral load[12], faulty earthing, and in some cases excessive third harmonic current.

Customers fear voltage spikes and surges, generally blaming them for the short lives of fluorescent lights and electrical appliances.

2.6.3 Excessive Frequency Variation

Frequency recordings sometimes indicate substantial frequency difference between machines, indicating that governors or governor settings are at fault. This affects synchronous motor speed, especially in fans and refrigerators, and leads to reduced appliance life, though frequency variation does not seem to annoy customers.

2.6.4 Interruptions to Electricity Supply

On almost all islands electricity is interrupted twice daily for about 30 minutes each time, at about sunrise to change the night generator for a lower rating daytime diesel generator and prior to darkness, to bring on line a larger generator (or to split the load) to meet the evening peak load.

Customers find this constant interruption to supply, and associated system voltage disturbance, very irritating, and cite it as another reason why their appliances have such a short life.

[12] Excessive neutral current often leads to generator burnout even when the generator is not operating on full load.

2.7 Annual Energy Generated and Annual Peak Load

2.7.1 Typical Demand Levels

In the smaller outer islands annual units generated vary between 100 and 400 MWhpa, while peak load varies between 30 and 90kW. Annual load factor is generally between 38% and 42%[13].

2.7.2 Methodology of Calculation

There usually is no instrument measuring power station energy output or power demand, so it not possible to directly calculate either distribution losses or generation fuel efficiency. However usually the past 12 months electricity sales are available from billing records and generation efficiency is estimated from a combination of fuel consumed and electricity sales, balancing likely fuel efficiency against estimated distribution losses and probable annual load factor. The assumed diesel engine efficiency and distribution losses need to be consistent with the condition of the equipment. Annual peak load is then calculated from the annual energy and the annual load factor. This needs to be consistent with the operators' estimate of the size of engine required to meet monthly peak.

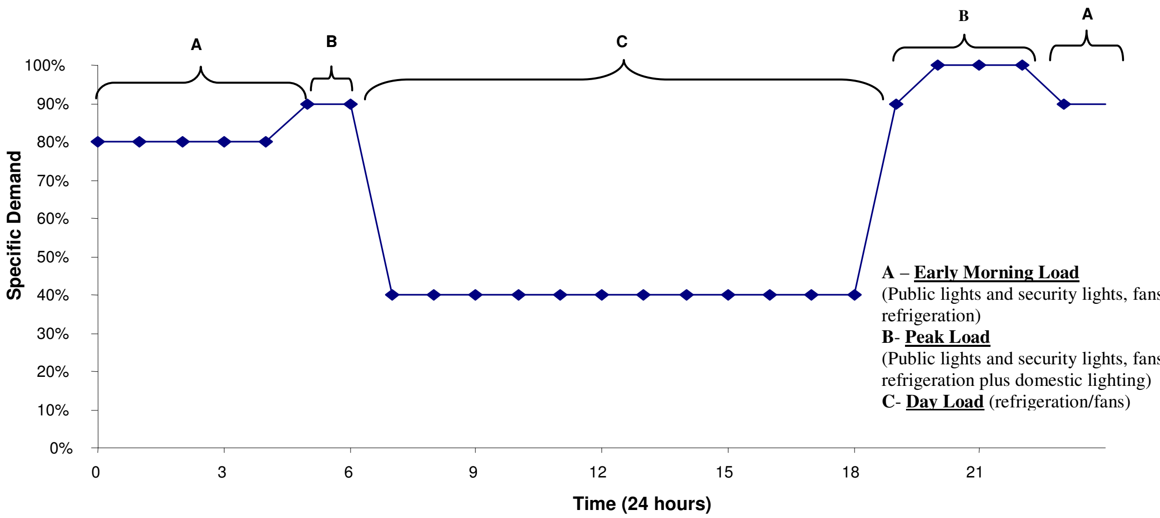
2.7.3 Daily Load Pattern

On small islands daily load charts always indicate a large night load and a smaller day load. During the hours of darkness public lights and security lights dominates the load. Public lights include high wattage area lights installed and owned by the Government. These lanterns are usually installed at the wharf area and other areas considered a security risk. The government pays a monthly fee to the island to cover maintenance and electricity used. Street light load is usually fairly minimal, however most households leave a compact fluorescent security light on in the main living room throughout the hours of darkness. Air conditioners are unusual, but may be installed in the mobile telephone equipment hut, if one exists.

Peak load occurs when the load from domestic lights, pubic lights, street lights, refrigeration, and fans coincide, See Chart 2.4.

[13] *Preparing the Outer Islands Electrification Study*, ADB TA 3232 MLD, December 2000

Chart 2.4: Typical Small Island Daily Load Demand



2.8 Electricity Supply Efficiencies

2.8.1 Introduction

The data quoted in this section is from a recent Asian Development Bank Report[14]. This study reveals that there is considerable room for improvement in fuel efficiencies, distribution losses, and labour efficiencies.

2.8.2 Fuel Efficiencies

Average non STELCO outer island generation fuel efficiencies are poor at 0.38 l/kWh, whereas STELCO islands average 0.32 l/kWh[13]. Poor fuel efficiency is a result of old engines whose cylinders are glazed from light load running, and the poor match of generator capacity to load where synchronizing equipment is not installed.

2.8.3 Distribution Losses

Distribution losses average 15%, varying from a low in one island of 7% to a high in another island of 26%[17]. Estimated distribution losses are almost entirely losses in low voltage distribution cables as there is almost no electricity theft, and as the customers' meters are generally accurate[15].

[14] *Appraisal Report, Batch 2, Outer Island Electrification, Republic of Maldives*, ADB, December 2005
[15] In part this is because the brand and type of customer kWh meter is strictly regulated by the Government, who also insist that all meters must be tested in a Government laboratory before being shipped to the islands.

2.8.4 Labour Productivity

Labour productivity varies from a high of 105 MWhpa sold per employee to a low of 23 MWhpa. This variation is mainly due to the difference between islands in the sales of electricity. Most islands have four or five employees, on shift work at the power station. A number of islands make do with two employees, leaving diesel generators unattended other that at peak load time.

2.9 System Operation

Normally only one diesel is operated at a time. Ideally the operator has one engine sized for the peak load and one sized for the off peak, though more often the engine is not well matched to the load. If the busbar can be split, when the peak load exceeds the generator size the operator splits the load, with each generator supplying a separate load. No small island has synchronising equipment.

Most power station operators log starting and stopping times of the generators. While the generator is running, the operators read and record amps, volts, frequency, oil pressure and water temperature every hour from the set mounted instrument panel. In some islands power station logs are not kept.

The engine operating hours meter is observed for maintenance, oil and filter changes, and overhauls. Oil changes are carried out every 250 operating hours. Records of fuel and lubricating oil consumption are kept as are generating set operating hours, and the hours at which oil, and filters, are changed. There is usually only one skilled, though usually unqualified, mechanic. There are usually no electricians on the island, either qualified or unqualified.

2.10 Cash Flow, Household Income, Tariffs and Affordability

2.10.1 Cash Flow

All the IDC islands keep detailed cash in and cash out records, but do not discriminate between capital and maintenance expenditure. There are no accountants or bookkeepers on the islands. The private operators and the NGO's either do not keep financial records, or if they do they are unwilling to disclose that they have records.

Table 2.1 indicates that most income comes from electricity sales, and that most expenditure is on fuel. Expenditure on loan repayments are low, because most small island electricity utilities have difficulty proving to the Banks that they will have a sufficient return on investment to meet loan servicing.

Table 2.1: Typical Proportion of Cash Flow, Small Outer Islands for IDC Operated Electricity Utilities, 2003

Cash in	Percent
Electricity	90%
Public Lights payment from Government	5%
Other (fines and fees)	5%
Cash out	
Wages for powerhouse operators	10%
Fuel	70%
Lube Oil	5%
Spare parts	2%
Distribution	0%
Travel	0%
Office and administration	8%
Loan repayments	5%

Source: Ministry of Atolls Development, Male', Republic of Maldives

Since 2003 fuel oil prices have nearly doubled, from about \$0.44 to \$0.83. This will have increased the percentage of fuel expenditure from around 70% to 80%.

2.10.2 Income of Domestic Electricity Customers

Consideration of the income of potential customers, and the amount they will be willing to pay for electricity is a basic engineering design parameter for electricity supply systems in developing counties.

In the smaller islands sales are around 93% domestic, 4% commercial (small shops) and 3% government (schools and an island office). In effect, electricity improvements must be funded by domestic customers. The government will not permit any subsidy or cross-subsidy of electricity cost between islands.

Per capita income varies greatly between the Maldivian outer islands, depending on the occupation adopted by the island[16], the remoteness of the island from the nation's capital Male', the proximity of resort islands and the island's political influence[17].

Studies done by the Asian Development Bank indicates that on a number of islands have shown that populations are willing to spend average percentage of 10% of their per capita cash income on a good quality electricity supply. For an island with a population of 1000, monthly revenue of the electricity utility is practically limited to about AUS$20,000. This provides a limit on what can be spent to provide electricity.

GDP in the Maldives is projected to grow at a very rapid 5% per year in the medium term. Much of this will trickle down to the island economies, and therefore an annual growth rate in there per capita income of 3% pa is assumed.

2.10.3 Tariffs

2.10.3.1 Tariffs Design

Almost all islands charge a flat tariff regardless of usage and class of customer, although a few islands charge large commercial customers and government installations a slightly higher tariff. No islands charge a lifeline tariff for small domestic customers, and all are opposed to this concept, on the basis that the poorest people should be assisted by family, or by NGOs or by the Women's Development Committee rather than by the Electricity Utility.

2.10.3.2 Required Level of Tariffs

Tariffs must be sufficient to meet operating and maintenance costs as well as investment in replacement equipment. Where the island has been able to obtain bank loans to finance capital expenditure the revenue must also be sufficient to cover loan service charges. Studies

[16] Islands specialising in fishing are wealthier, islands specialising in agriculture tend to be poorer.
[17] It should be noted that the islands are considered disadvantaged because of their vulnerability to disasters such as epidemics, food shortages, drinking water shortages and natural disaster. By Asian standards their cash income is high, but cash has a limited value in an isolated subsistence island.

have suggested that for an efficient outer island utility the minimum viable tariff is $0.63/kWh in 2005 prices[18].

2.10.4 Affordability

Affordability (of proposed electricity tariffs) is defined as the percentage of household income spent on electricity. In low income communities affordability places a limit on the revenue which can be collected from electricity sales, and thus directly a limit on how much money may be borrowed by an electricity authority. In Maldives the lending banks calculate affordability of proposed tariffs to ensure that the utility can raise sufficient funds to service a loan. The level of affordability varies by community, so the Asian Development Bank has devoted some effort to determine affordability levels in the outer islands of the Maldives[19].

Studies indicate households with a good electricity system are welling to spend 10% of their cash income on electricity[19]. Given typical household income levels on a small island with a 100 households, the annual revenue of the electricity utility has an upper limit of about $42,000, of which $35,000 is required for fuel. The reminder of $7,000 per year for all non fuel purposes provides a limit on the cost of investment in electricity.

2.11 Regulation

Regulation of the electrical industry is the responsibility of the Maldives Electricity Bureau (MEB). MEB does not have the funds to travel to the islands and inspect the electrical operations. It therefore operates by correspondence, advising each island of MEB requirements. The islands are generally keen to comply with MEB requirements, but sometimes these are impossible[19], and on occasions the islands do not understand MEB technical language, for example confusing kVA with kW.

One of the conditions of bank finance is usually that the equipment financed must comply with MEB standards, and be certified by MEB. Maldives Electricity Bureau standards are not

[18] ADB, *Preparing the Outer Islands Electrification Study.*
[19] Such as the requirement to locate the power station 200 meters from the nearest residence, when the island may not be much bigger than that.

especially suited to the smaller islands, and the difficulty of complying with MEB standards makes loan finance too expensive for the smaller islands. Environmental regulation is the responsibility of the Ministry of Construction and the Environment (MCE). Due to lack of finance MCE must take a light handed approach to regulation, and as a result many of the electricity utilities have poor environmental records.

Chapter 3:

The Two Outer Islands

Selected for the Project

3 THE TWO OUTER ISLANDS SELECTED FOR THE PROJECT

3.1 Introduction

Two typical small target islands were selected for this study. This chapter describes the selection of those islands, and outlines the situation of the electricity utilities in each island, including ownership and control, equipment currently installed, the availability of electricity, quality issues, annual energy generated and peak load, and efficiency issues. Also discussed are current income and costs, and the adequacy and affordability of existing tariffs. It will be seen that the utilities are small, cash starved and inefficient.

3.2 Island Selection

For this research project two outer islands, Mukurimagu and Maaeboodhoo, were selected for close study.

The existing electrical system on each of these islands is of poor quality being unreliable and having a high level of appliance damaging voltage spike and surges. Many customers receive voltage well below statutory limits during the evening hours.

The communities are anxious to provide a reliable and good quality central electricity supply, but under the existing technology and design criteria they are unable to propose a financially viable undertaking with acceptable and affordable tariffs, and are thus unable to raise loans to finance improvements. Asian Development Bank Consultants have proposed what they regard as minimal improvements for each island, but their proposals for each island failed the tariff affordability test[20] [21].

These two islands are typical examples of small islands that are unable under existing institutional arrangements to provide a reasonable electricity supply to their communities.

[20] ADB, *Preparing the Outer Islands Electrification Study,* and *Draft Appraisal Report, Batch 2, Appendix 32, Maaeboodhoo, Republic of Maldives*, ADB, October 2005.
[21] For the definition of affordability, see Section 2.10.4

They are thus good candidates for an investigation to determine if alternative engineering approaches will be financially viable for this type of island.

3.3 Operation and Ownership

The electricity utility on each of the islands is owned and operated by the Island Development Committee. The Island Chief on each island heads the Island Development Committee, and is thus the Chief Executive Officer of the utility. Mukurimagu has three full time employees at the power station, responsible for maintaining and operating the generation plant and distribution network and attending to requests from consumers. Maaeboodhoo has only two full time employees.

3.4 Equipment Currently Installed

3.4.1 Generation

Mukurimagu has three 1500 rpm, 230/400 Volt diesel generating sets, 84 kW Deutz, an old 56 kW Yanmar, and a 40 kW Yanmar. Two of the generating sets are in reasonable condition, but nearing the end of their economic life.

Maaeboodhoo has three old 1500 rpm, 230/400 Volt diesel generating sets an old 48 kW Munradtech, 34 kW Himoinsa, and 35 kW.

3.4.2 Main Control Panel

At both power stations the main control panel is of a simple design with the instruments and equipment mounted on a 25mm thick sheet of plywood.

The control panels have change-over switches to connect any one of the three generating sets to the four outgoing feeders. Each feeder is controlled by a MCB. On each island metering is limited to three ammeters and a voltmeter. There is no kW meter, power factor meter, or kWh meter. Generally the connections follow that illustrated in Chart 2.1. The bus bar is not split and it is not possible to supply power from two generating sets simultaneously. The generator sets are changed at 06:00 hours and 18:00 hours.

3.4.3 Distribution

In Mukurimagu, distribution is by single phase 2 core, 16 mm^2, copper conductor, PVC insulated, PVC sheathed twin flat cable buried at the side of the sandy roads. Wooden distribution boxes installed on household boundary walls. In Maaeboodhoo distribution is by three phase utilising 16 mm^2, copper conductor, PVC insulated, PVC sheathed twin flat cable buried side by side at the side of the sandy roads. The distribution boxes are fibre-glass and mounted on the boundary wall of premises.

Distribution on both islands is evidently unsatisfactory. In neither island do the cables or the distribution boxes meet the requirements of the Maldives Electricity Bureau.

3.5 Availability of Electricity

All residences on both islands have electricity available. Supply is for 24 hours a day, although there are brief interruptions when generating sets are changed, as there is no synchronising equipment in the power station.

3.6 Existing Electricity Quality

3.6.1 Mukurimagu

An accurate portable data logger was connected to the power station switchboard for one day in March 2003. There have been no voltage measurements at customers' premises.

Please note that all charts are on a per phase basis.

Recorded power station phase voltages, see Chart 3.1, indicate reasonable voltage range at the power station, but a surprising difference in voltage between phases which indicates either an unbalanced load, with high neutral current, or the presence of a large third harmonic current in one phase. The voltage curves show a large number of short term voltage variations, which indicates that the automatic voltage regulator is not operating properly.

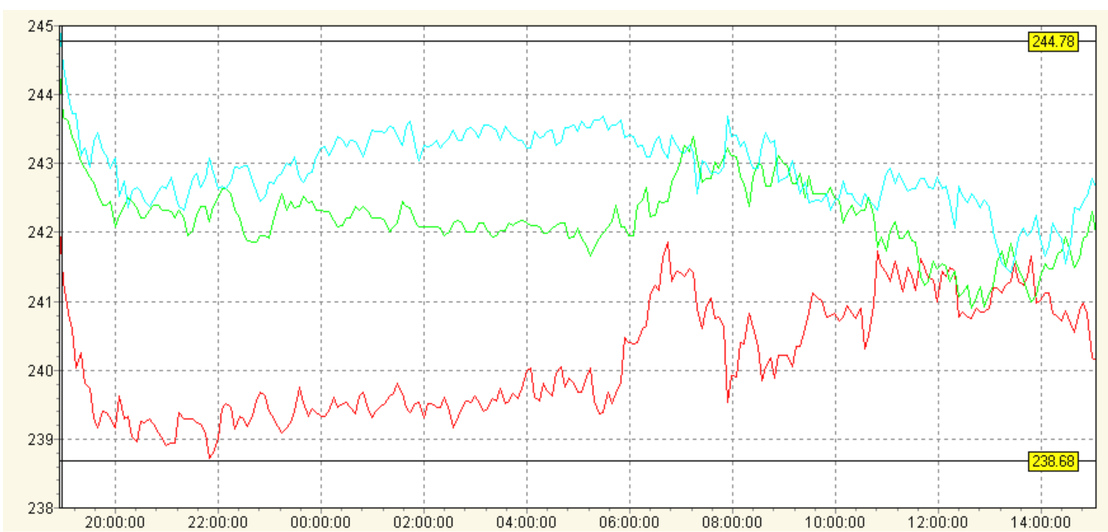
Chart 3.2 indicates a satisfactory power factor level, but shows considerable variation of power factor during the daytime. This is probably because the day load is substantially comprised of refrigerators and fans. It could also indicate that the automatic voltage regulator is "hunting" at low load.

Chart 3.3 indicates that the phases are substantially unbalanced, and that there is a high neutral current.

As is discussed above, the existing distribution is single phase. Having three phase generators supplying four single phase distribution feeders is almost certainly a major cause of the unbalance of load and unbalance of voltage at the generator terminals. Nevertheless given that the distribution cables are only 16mm^2 copper, and given the poor voltage conditions at the generator terminals it can be assumed that the quality of electricity at the customer's terminals will be very poor indeed.

Chart 3.1: Power station Voltage, per Phase, Mukurimagu

Tuesday 4th to Wednesday 5th March 2003



Voltage per Phase

Time (24 hours)

Chart 3.2: Power station Power Factor, per Phase, Mukurimagu
Tuesday 4th to Wednesday 5th March 2003

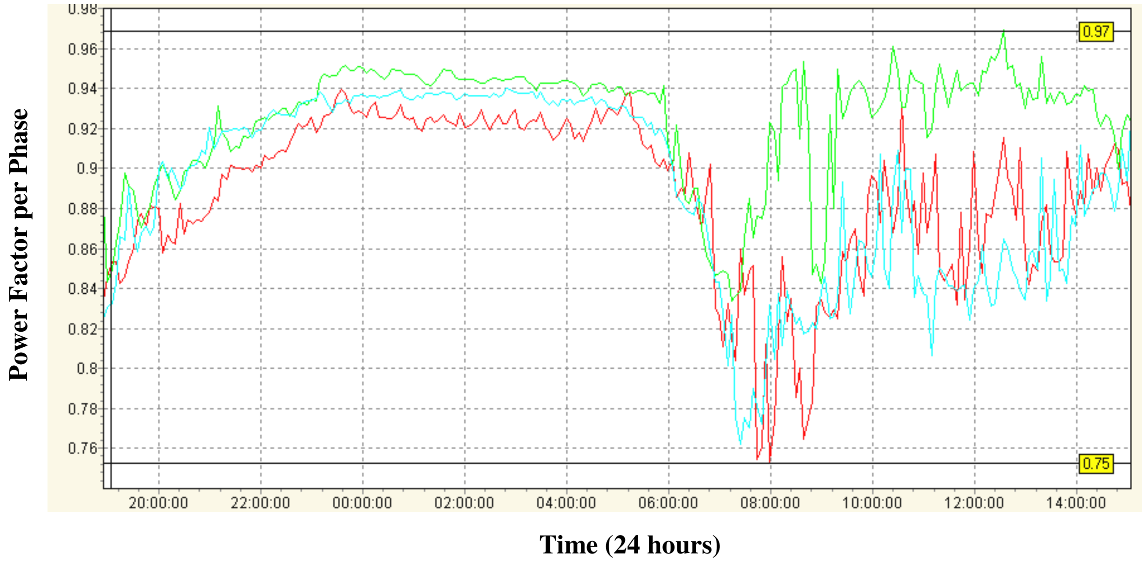
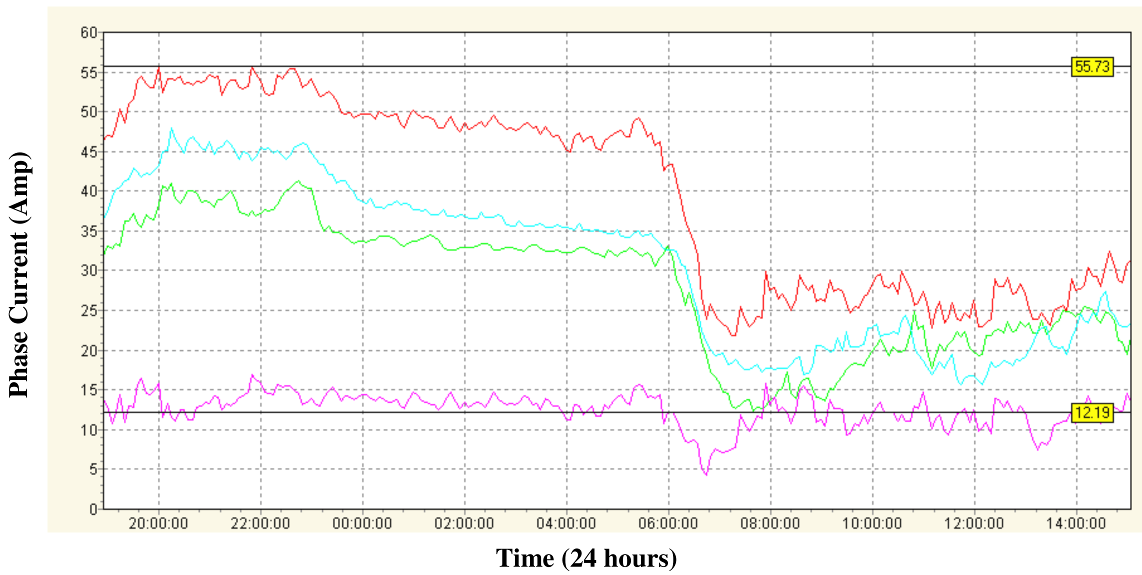


Chart 3.3: Power station Phase Currents, Amps, Mukurimagu
Tuesday 4th to Wednesday 5th March 2003



3.6.2 Maaeboodhoo

An accurate portable data logger was connected to the power station switchboard for one day in February 2004. There have been no voltage measurements at customers' premises.

Recorded power station phase voltages, see Chart 3.5, indicate a substantial voltage difference between diesel generators used. The voltage regulator on the day time diesel generator appears to work properly, but to be set incorrectly, while the voltage regulator for the night time generator appears to be malfunctioning. Power station phase voltage does not reach the permitted maximum of 241 Volts, and droops at times to 202 volts, nearly 17% below permitted maximum volts.

Chart 3.6 indicates a satisfactory power factor level, but shows considerable variation of power factor during the daytime and in particular on one phase. This could be caused by an air conditioning plant at the Government offices.

Chart 3.7 indicates that the phases are reasonably balanced, and that there is a high neutral current.

Chart 3.5: Power station Voltage, per Phase, Maaeboodhoo

24th to 25th February 2004

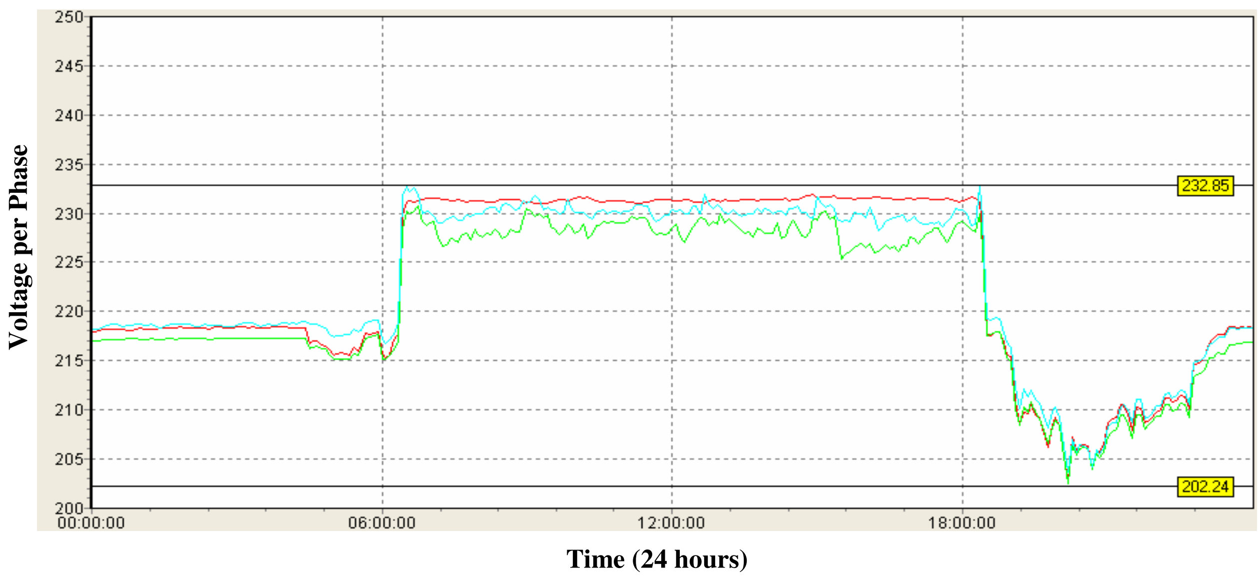


Chart 3.6: Power station Power Factor, per Phase, Maaeboodhoo

24th to 25th February 2004

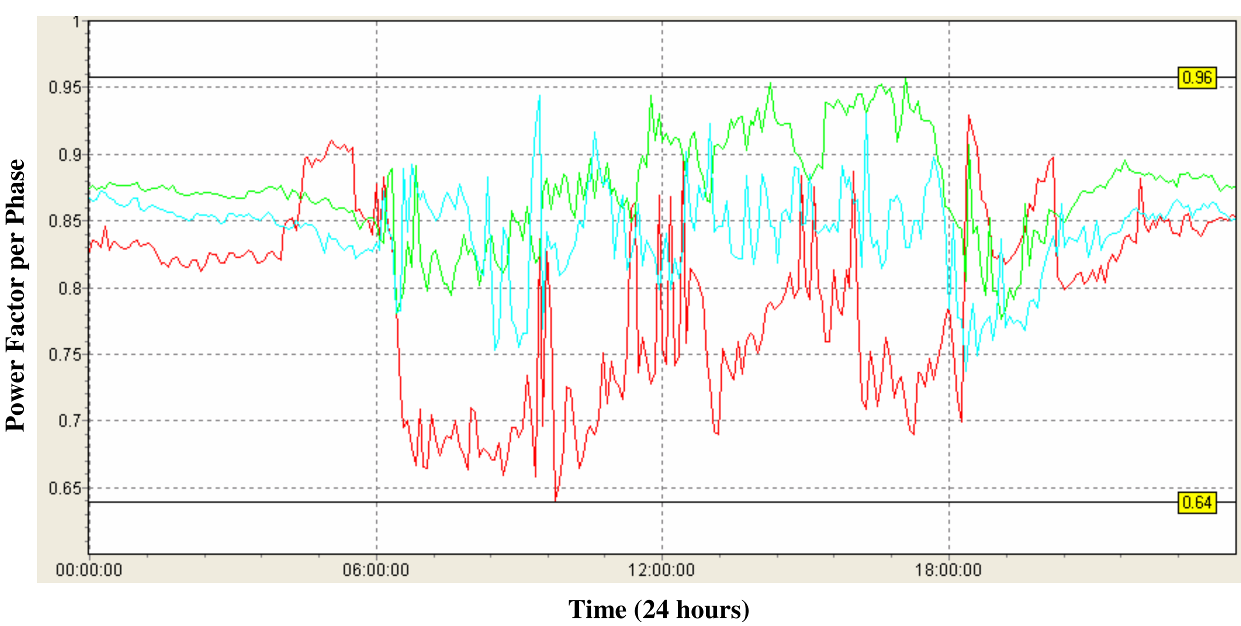
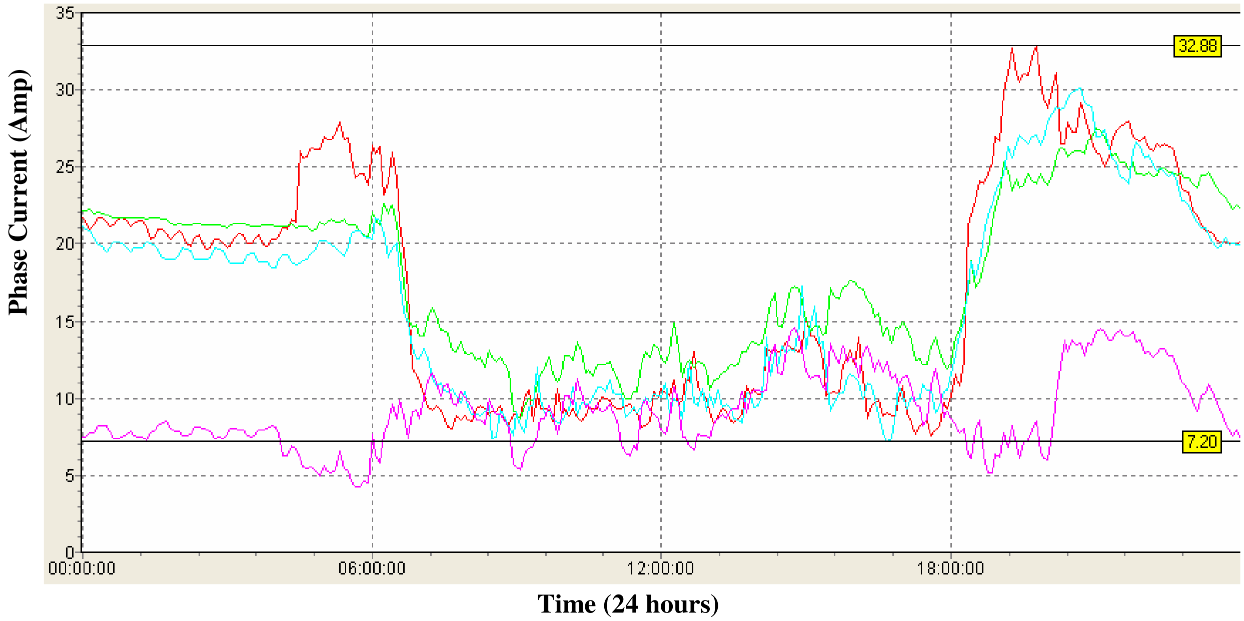


Chart 3.7: Power station Phase Currents, Amps, Maaeboodhoo

24th to 25th February 2004



3.7 Annual Energy Generated and Annual Peak Load

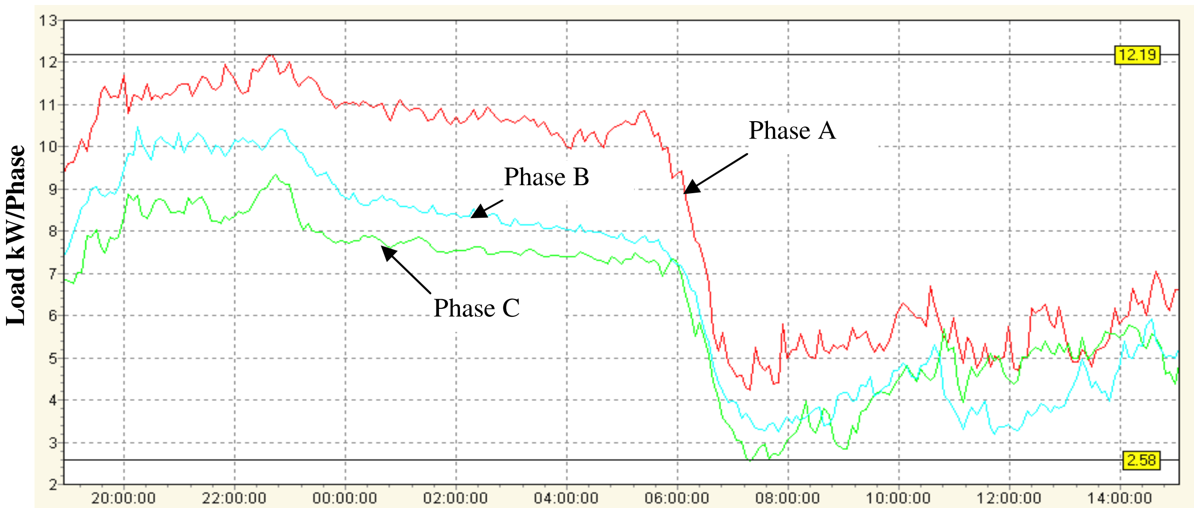
Power station logs are not kept in either island. Generated kWh and peak loads are not recorded as there are no instruments. The hours run counter in the set mounted control panel is observed for maintenance such as oil and filter changes and overhauls.

Fuel and lubricating oil consumption was determined from the quantity of oil purchased. Based on oil purchased, and kWhs billed, and for Mukurimagu assuming an engine fuel efficiency of 0.38 l/kWh, total calculated annual energy generated was 175,000 kWhpa, resulting in distribution losses of 21%. For Maaeboodhoo the engine fuel efficiency was 0.45l/kWh, total annual energy generated was 99,000 kWhpa, resulting in distribution losses of 24%

From the data logger recording of power station load, the evening peak at Mukurimagu was 31kW, (See Chart 3.8). From the nature of the load in Mukurimagu an annual load factor of about 42% is anticipated, which gives an annual peak of an annual peak of 34 kW, consistent with the peak of 32 kW recorded by the data logger.

The base load of about 12 kW comprises refrigerator and fan loads, and operates for 24 hours a day. The peak load occurs between 8 pm and 11pm, and is made up of domestic lighting (for general activities and security night lights), by public lighting and by the base load. The load from 11 pm until 6 am comprises the base load, plus domestic security lighting and public lighting.

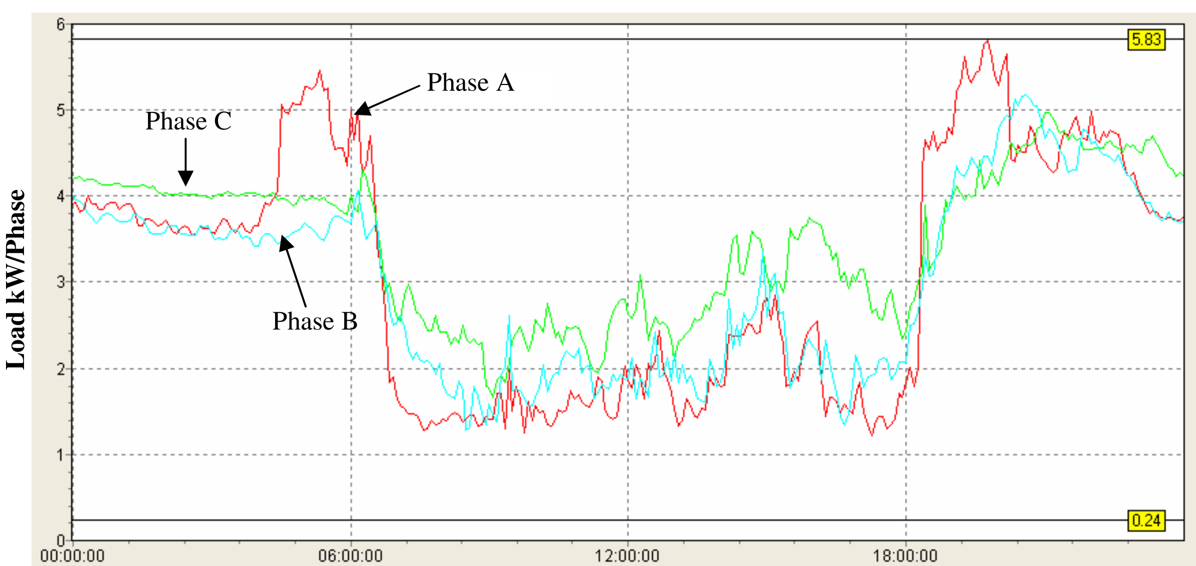
Chart 3.8: Power station Load, kW per Phase, Mukurimagu
4th to 5th March 2003



Time (24hours)

The daily load curve for Maaeboodhoo has essentially the same shape as that at Mukurimagu, and for the same reasons. The evening peak is 15 kW. An annual load factor is expected to be close to 41% for the Maaeboodhoo system, and based on estimated units generated; this gives an annual peak of 22kW.

Chart 3.9: Power station Load, kW per Phase, Maaeboodhoo
24th to 25th February 2004



3.8 Electricity Supply Efficiencies for Study Islands[22].

3.8.1 Fuel Efficiencies

Fuel efficiency at Mukurimagu is 0.38 l/kWh while at Maaeboodhoo it is 0.45 l/kWh. Given engines which are reasonably new, and which with synchronizing can match the load, an efficiency of 0.32 l/kWh should be easily achievable, a reduction of about 30% in fuel consumption in Maaeboodhoo. As Maaeboodhoo spends 93% of its expenditure on fuel oil, a savings of 30% in fuel used would represent a very substantial saving.

3.8.2 Distribution Losses

In 2005 the distribution losses in Mukurimagu was 21%, while at Maaeboodhoo it was 24%. There is almost certainly no theft on these small strictly Muslim islands, and as the domestic household meters are accurate[23], the losses are almost certainly almost entirely in the distribution cables. The system are geographically compact so with the load reasonably balanced between the phases the losses should be less than 5%, with a cable network designed for acceptable voltage drop. Reduction of distribution losses would directly reduce fuel consumption in the diesel generators. Thus with improved engine efficiency and reduced losses, fuel consumption could be cut by around 40%. Unfortunately this has not been sufficient to justify the cost of replacement of the diesel generators and cable networks given the existing regulatory requirements and using existing technology. See Chapters 4 and 5.

3.8.3 Labour Productivity

Both Mukurimagu and Maaeboodhoo have three employees. There are no further practical savings to be made in this area.

3.9 System Operation for Study Island

Only one diesel is operated at a time as the busbar is not split. Engines are changed at 6 am and 6 pm. The power station operators log starting and stopping times of the generators and record hours run.

[22] Data from Appraisal Report, Batch 2, Outer Island Electrification, Republic of Maldives, ADB, December 2005
[23] In part this is because the brand and type of customer kWh meter is strictly regulated by the Government, who also insist that all meters must be tested in a Government installation before being shipped to the islands.

There are no electricians on the island, either qualified or unqualified. Mechanical repairs are carried out by the operators, who are not trained.

Power station operators install customers' service mains, meter boards and attend to customer complaints. They also read meters on a monthly basis and prepare billing invoices.

3.10 Cash Flow, Income, Tariffs and Affordability for Study Islands

3.10.1 Cash Flow

The financial records kept by each island are limited to cash in and cash out. All financial transactions are by cash. There are no banks so there are no bank accounts or cheques. Cash must always be in surplus in this system, and this surplus cash is kept in a safe, held ready to meet the cost of spare parts. Table 3.1 gives the annual summary of the cash position for each island. This Table is reproduced here for it gives a clear view of the small size of the utilities, and the very limited cash available for improving their equipment. Neither island utility has a bank loan, almost certainly because they have been unable to provide a satisfactory investment return scenario.

Table 3.1: Cash Flow, Mukurimagu and Maaeboodhoo Electricity Utilities, 2003

	Mukurimagu		Maaeboodhoo	
	AUS$	Percent	AUS$	Percent
Cash in				
Electricity	34,485	86%	26,753	93%
Public Lights payment from Government	5,354	13%	1,886	7%
Other (fines and fees)	31	0%	0	0%
Total	39,870	100%	28,639	100%
Cash out				
Wages for powerhouse operators	3,979	12%	3,527	15%
Fuel[1]	23,005	67%	18,212	77%
Lube Oil	955	3%	411	2%
Spare parts	3,267	10%	319	1%
Distribution	0	0%	526	2%
Travel	176	1%	57	0%
Office and administration	2,909	8%	452	2%
Loan repayments	0	0%	0	0%
Total	34,292	100%	23,504	100%

Source: Ministry of Atolls Development, Male', Republic of Maldives

Note 1. Fuel price have almost doubled since this cash flow statement was presented 2003.

3.10.2 Tariffs

3.10.2.1 Present Tariffs

The 2005 tariff in Mukurimagu was $0.42 per kWh, flat, with the Island Chief claiming a monthly loss of $519 and in Maaeboodhoo was $0.52 per kWh for all consumers, the Island

Chief claiming a monthly loss of $1245. These tariff levels are low for the outer islands, see Section 2.10.3, and as the tariff are not sufficient to cover fuel cost the utilities are drawing down their cash reserves. Even without the increased fuel costs, the tariff were insufficient to cover plant replacement. The tariffs are set by the communities who believe the quality of electricity supply is too low to justify a higher tariff. Investment in new equipment would increase fuel efficiency and reduce distribution losses thus reducing costs.

3.10.3 Income of Domestic Electricity Customers and Affordability

Average monthly household income in Mukurimagu is $471 while average monthly income in Maaeboodhoo is $491[24]. In 2005 domestic customers in Mukurimagu spend 6.7% of their income on electricity while in Maaeboodhoo they spent 3.6%[25].

3.11 Stakeholder Issues with Electricity

In both islands the stakeholders stated that electricity provision is unsatisfactory. Reasons given were that electricity is unreliable with voltage drops, sags and surges and has not been improved in recent years.

The existing electricity supply on the island is too unreliable to operate freezers, or refrigerators at the community health centres, at pharmacies or laboratories or at the schools or in shops. Domestic customers usually only turn on their refrigerators for special occasions, for fear of them being damaged. Similarly customers rarely use their TVs or video players. The school cannot install computers and internet cafes cannot start up.

Both communities expressed a willingness to pay a reasonably higher tariff if quality was improved. It was emphasised by both communities that the major issue was quality of electricity.

[24] Source: Ministry of Atolls Development, Male', Republic of Maldives

[25] Calculated from average domestic consumption, from Tables 4.1 and 4.2, multiplied by tariff.

Chapter 4:

ADB Project Engineering Design

For

Mukurimagu and Maaeboodhoo

4 ADB PROJECT ENGINEERING DESIGN FOR MUKURIMAGU AND MAAEBOODHOO

4.1 Introduction

Asian Development Bank is currently financing a major rural electrification project in the outer islands. ADB commenced preparing design studies in 1998. Construction has commenced and is expected to be complete by 2007. ADB will finance a continuation of this project after 2007. While there are other funds available to the outer islands[26], ADB is by far the largest participant in outer island electrification, and provides a benchmark for design. However, many of the islands in the greatest need for electrification fail the ADB economic and financial tests and so receive no funding. This study is attempting to find engineering means whereby these islands can qualify for ADB or commercial bank funding. This chapter describes and considers ADB engineering criteria and design assumptions as they apply to the outer islands electrification.

4.2 ADB Engineering Design Criteria

The present ADB Outer Island Electrification Project has the following design criteria approved by the electricity regulator, the Maldives Electricity Bureau (MEB).

1. Generating plant:

- The project would provide sufficient diesel generating capacity to last for at least 3 years, based on load projections;
- New powerhouses and control panels to be large enough to accommodate the diesel generator sizes anticipated over the 15 year planning period;
- Each year 80% of installed capacity, minus the capacity of the largest machine, is to exceed the annual peak load;

[26] Including commercial banks, Red Cross, Japan International Cooperation Agency and other bilateral donors.

- Where the load at the power station is anticipated to exceed 100 kW any two machines should operate over peak in synchronism to improve reliability and quality of supply;
- Where the load at a power station is less than 100 kW, there need not be provision for synchronous running, unless it is the least cost solution. Where load splitting is to be installed the off-load switches will split load within a 40 to 60 ratio, and arranged so that each split load may be connected to any generator;
- Under normal operation no machine is to operate less than 60% load;
- After 35,000 hours of service (approximated to seven years) the fuel efficiency of a 1,500 rpm diesel generating set has normally fallen to a level that justifies its overhaul or replacement

2. Distribution

A. For proposed cable installations

- Voltage drop between the power station and the consumers' point of supply should not exceed 10%, over the 15 years following the loan;
- Losses should not exceed 8%, over 15 years following the loan; and
- The number and capacity of distribution boxes should be sufficient to meet anticipated connections over the 15 years following the loan, and at commissioning should have 40% spare capacity.

B. For existing cable installations

- Voltage drop between the power station and the consumers' point of supply should not exceed 10%, over 5 years following the loan;
- Losses should not exceed 8%, over the 5 years following the loan; and
- The number and capacity of distribution boxes should be sufficient to meet anticipated connections over the 5 years following the loan.

4.3 Environmental Criteria

Any project must have a positive impact on the environment. Generally the efficiency of the diesel engines should be improved and system losses reduced. This will have the effect of reducing carbon and nitrous oxide emissions.

The regulator requires that all power stations be located 200 meters from the nearest residence if that is physically possible on the island. The regulator also requires that the sound level does not exceed 65 dB(A) at 100 meters in any direction from the power station. In addition any project is to consider means to reduce oil spills, means to dispose of waste lubricating oil, and a satisfactory dispersal of exhaust gasses.

4.4 ADB Project Load Projections

4.4.1 Introduction

The load projections used in the ADB Outer Islands Electrification, which are outlined below for the target islands of Maaeboodhoo and Mukurimagu are accepted without alteration for this study. As there are no generation and billing records older than 12 months on either island, normal electrical utility load forecasting methods cannot be used.

Billing records were analysed on each island to determine the percentage of sales to each classification of customer, see Table 4.1. Forecasts were undertaken separately for each type of customer.

Table 4.1: Percentage of Electricity Sales by Classification, 2003

Type of Customer	Mukurimagu		Maaeboodhoo	
	Number	Percent of Total Sales	Number	Percent of Total Sales
Domestic	120	93%	100	68%
Commercial	6	4%	9	17%
Government	3	3%	8	14%

Note: Excludes Public Lighting sales
Source: Islands billing records.

4.4.2 Increase of Per-capita Consumption over Time

There are no data on island income over time, however the country's long term gross domestic product has increased by 6% to 7% per year in inflation adjusted terms[27] The Government anticipate that this growth rate will continue in the medium term. Both Maaeboodhoo and Mukurimagu have been selected by the Government as focus islands for development, which implies an investment growth rate by the Government in the island at least equal to GDP growth rate. Much of this investment will increase island household income. A growth rate of per-capita domestic electricity consumption of 3.5% per year has been assumed for Maaeboodhoo. For Mukurimagu, which is more commercially active than Maaeboodhoo, a per capita domestic electricity growth rate of 4% was assumed by the ADB study[28].

4.4.3 Rate of Household Formation

Households were projected to increase at the same rate as over the past ten years providing that average household occupancy did not drop below four.

4.4.4 Commercial Consumers

Over the planning period, it is assumed that the number of commercial consumers will increase at the same rate as household formation. The per capita commercial annual growth rate has been taken as 3%.

4.4.5 Government

The number of Government installations is projected to increase at the same rate as the population increase. The annual rate of increase in the per capita consumption of Government installations is assumed to be around 4% p.a.

---

[27] *The Statistical Yearbook of Maldives* Ministry of Planning and National Development, Male', Republic of Maldives

[28] ADB, *Appraisal Report, Batch 1, Appendix 15, Mukurimagu*, and *Draft Appraisal Report, Batch 2, Appendix 32, Maaeboodhoo*

4.4.6 Streetlights

For Mukurimagu the consumption of the existing streetlights for 2005 was estimated as 11.5MWh. For Maaeboodhoo the consumption was estimated for 2005 as 5.0MWh based on a count based on a count of public lights. An allowance of 3% continuing average annual growth rate for lights was assumed.

4.4.7 Annual Load Factor

For Mukurimagu the annual load factor is estimated to increase from around 43% to 47% over the forecast period where as Maaeboodhoo will increase from around 41% to 42%. The load factor is low because the load is predominantly domestic. However, the load factor will slowly increase as domestic consumers use more day load appliances.

4.4.8 Load Projection Calculations

Load projection calculations are carried out using Excel tables, which are reproduced in Tables 4.2 and 4.3.

Table 4.2: Generation and Sales Projections, Mukurimagu

Year		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total Number of Customers		**137**	140	142	145	148	150	153	156	159	162	165	168	172	175	178	182	185	189	192
Total Electricity Billings (Including Streetlights)	MWhpa	**124**																		
Domestic	MWhpa	**102**																		
Commercial	MWhpa	**5**																		
Government	MWhpa	**6**																		
Street Lights	MWhpa	**11**	11	12	12	13	13	13	14	14	15	15	15	16	16	17	17	18	18	19
Domestic Customer Projections																				
Domestic Customers	No.	**125**	127	129	132	134	137	140	142	145	148	150	153	156	159	162	165	168	172	175
Load increase with release of Suppressed Demand	kWhpa		57	57																
Base Domestic Sales per customer	kWhpa	**817**	907	1000	1040	1081	1125	1170	1216	1265	1316	1368	1423	1480	1539	1601	1665	1731	1801	1873
Total domestic sales per annum	MWhpa	**102**	115	129	137	145	154	163	173	183	194	206	218	231	245	260	275	292	309	327
Commercial Customer Projections																				
Commercial Customers	No.	**7**	7	8	8	8	8	8	8	8	9	9	9	9	9	9	10	10	10	10
Commercial Sales per Customer pa	kWh	**673**	693	714	736	758	780	804	828	853	878	905	932	960	988	1018	1049	1080	1113	1146
Total commercial sales per annum	MWhpa	**4.9**	5.1	5.4	5.6	5.9	6.2	6.5	6.8	7.2	7.5	7.9	8.3	8.7	9.2	9.6	10.1	10.6	11.1	11.7
Government Projections																				
Government Installations	No.	**5**	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7
Known Additional Sales	MWhpa																			
Government Sales per Installation pa	MWhpa	**1.2**	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4	2.5
Total Government sales per annum	MWhpa	**6**	7	7	7	8	8	9	9	10	11	11	12	13	13	14	15	16	17	18
Total Sales																				
Domestic	MWhpa	**102**	115	129	137	145	154	163	173	183	194	206	218	231	245	260	275	292	309	327
Commercial	MWhpa	**5**	5	5	6	6	6	7	7	7	8	8	8	9	9	10	10	11	11	12
Government	MWhpa	**6**	7	7	7	8	8	9	9	10	11	11	12	13	13	14	15	16	17	18
Streetlights	MWhpa	**11**	11	12	12	13	13	13	14	14	15	15	15	16	16	17	17	18	18	19
Total		**124**	138	154	162	172	181	192	203	215	227	240	254	268	284	300	318	336	355	376
Generated units	MWhpa	**155**	175	194	171	181	191	202	214	226	239	253	267	282	299	316	334	354	374	396
Losses	MWhpa	**31**	37	41	9	9	10	10	11	11	12	13	13	14	15	16	17	18	19	20
Losses % of Generation	%	**20%**	21%	21%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Annual Peak Load	kW	**40**	45	50	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94
Annual Load Factor	%	**44%**	44%	44%	45%	45%	45%	45%	45%	46%	46%	46%	46%	47%	47%	47%	47%	48%	48%	48%
Population		**873**	890	907	924	942	959	978	996	1015	1034	1054	1074	1095	1115	1137	1158	1180	1203	1225
Total Consumption per capita per annum		**142**	155	169	176	182	189	196	204	211	219	228	236	245	254	264	274	285	295	307
Average number per household		**6.9**	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9

AAGR	
Domestic	4%
Commercial	3%
Government	4%
Streetlights	3%
Population	1.90%
Household Formation	1.90%

Table 4.3: Generation and Sales Projections, Maaeboodhoo

Year		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total Number of Connected Customers		**119**	125	127	129	131	134	136	138	141	143	144	146	147	148	150	151	152	154	155
Total Electricity Billings (Including Streetlights)	MWhpa	**63**																		
Domestic	MWhpa	**40**																		
Commercial	MWhpa	**10**																		
Government	MWhpa	**8**																		
Street Lights	MWhpa	**5**	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8
Domestic Customer Projections																				
Domestic Customers	No.	**102**	103	105	107	109	111	113	114	116	118	119	120	121	122	123	125	126	127	128
Lower base load with higher tariff	kWhpa																			
Base Domestic Sales per customer	kWhpa	**395**	408	423	438	453	469	485	502	520	538	557	576	596	617	639	661	684	708	733
Total domestic sales per annum	MWhpa	**40**	42	44	47	49	52	55	57	60	64	66	69	72	76	79	82	86	90	94
Commercial Customer Projections																				
Commercial Customers	No.	**9**	11	12	12	12	12	12	13	13	13	13	13	13	13	13	14	14	14	14
Known Additional Sales	MWhpa		4																	
Commercial Sales per Customer pa	kWh	**1106**	1140	1174	1209	1245	1283	1321	1361	1401	1444	1487	1531	1577	1625	1673	1724	1775	1829	1883
Total commercial sales per annum	MWhpa	**10**	17	13	14	15	16	16	17	18	19	19	20	21	22	23	23	24	25	26
Government Projections																				
Government Installations	No.	**8**	10	10	10	11	11	11	11	11	12	12	12	12	12	13	13	13	13	13
Known Additional Sales	MWhpa		2																	
Government Sales per Installation pa	MWhpa	**1.0**	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9	2.0
Total Government sales per annum	MWhpa	**8**	10	11	11	12	13	13	14	15	16	17	18	19	20	21	22	24	25	26
Total Sales																				
Domestic	MWhpa	**40**	42	44	47	49	52	55	57	60	64	66	69	72	76	79	82	86	90	94
Commercial	MWhpa	**10**	17	13	14	15	16	16	17	18	19	19	20	21	22	23	23	24	25	26
Government	MWhpa	**8**	10	11	11	12	13	13	14	15	16	17	18	19	20	21	22	24	25	26
Streetlights	MWhpa	**5**	5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8
Total		**63**	75	74	78	82	86	90	95	100	105	109	114	119	124	130	136	142	148	155
Generated units	MWhpa	**84**	99	98	83	88	92	97	102	107	112	117	123	128	134	140	146	152	159	166
Losses	MWhpa	**20**	24	24	6	6	6	7	7	7	8	8	9	9	9	10	10	11	11	12
Losses % of Generation	%	**24%**	24%	24%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Annual Peak Load	kW	**23**	27	27	23	24	25	26	28	29	30	32	33	34	36	37	39	40	42	44
Annual Load Factor	%	**42%**	42%	42%	42%	42%	42%	42%	42%	42%	42%	43%	43%	43%	43%	43%	43%	43%	43%	43%
Population		**556**	547	537	528	518	509	501	492	483	475	466	458	450	442	435	427	420	412	405
Total Consumption per capita per annum		**114**	136	138	147	157	168	180	193	206	220	234	249	265	281	299	318	338	359	382
Average number per household		**5.4**	5.2	5.0	5.0	4.7	4.5	4.4	4.2	4.1	3.9	3.8	3.7	3.6	3.6	3.5	3.4	3.3	3.2	3.1

AAGR		
Domestic	3.5%	2003 to 2006 and 2012 to 2022
	3.5%	2007 to 2011
Commercial	3.0%	
Government	4.0%	
Streetlights	3.0%	
Population	-1.75%	
Household Formation	1.70%	2003 to 2013
	0.85%	2014 to 2022

4.5 ADB Existing Generation Design

4.5.1 Generator Control

The main control panel is designed for control, monitoring and protection with automatic synchronization. The panel is designed for three generator sets with three incoming MCCBs. It is a large, free standing, four panel, analogue equipment, three meters long, two meters high and one meter deep, requiring an air-conditioned control room in the power station.

This control panel is major item of expenditure for these islands. The alternative of a cheaper split load busbar, where each engine could independently meet about one half of the peak load was considered by the designers, but was rejected because the synchronising panel reduced the capacity of the engines required to meet the peak load, and therefore had a lower overall lifetime cost.

4.5.2 Selection of Generator Size and Number

The ADB project design proposes that diesel generators be upgraded in size to meet load growth every seven years, The diesel generators are due to be replaced after a seven years life, approximately 35,000 hours, because by that time the engine efficiency has fallen sufficiently to warrant replacement or major overhaul. Further, studies have indicated that if synchronising equipment is installed, the least cost arrangement is a power station capacity of three engines.

Diesel generating sets are sized to ensure that for each year 80% of the installed capacity minus the largest engine is greater than the annual peak, and that normally no machine should operate at less than 60% load. For Mukurimagu this requires the initial installation of two 40kW diesel generators and the continued use of an existing 84kW engine, while for Maaeboodhoo two 31kW and a 18kW diesel generators are required for the initial installation.

For a tabulation of the planting schedule with synchronizing see Chapter 7, Table 7.1 Option 4 and 3, and 7.3. Option 4 and 3.

4.6 ADB Project Distribution Design

4.6.1 Distribution Design

The existing underground cables at Mukurimagu and Maaeboodhoo are undersized and are in poor condition. They require complete replacement.

Under the existing design criteria where new replacement underground cable and distribution boxes are installed they are required to be capable of meeting the estimated load for fifteen years and that at commissioning should have 40% spare capacity. For cable calculation using this criteria, see Appendix B and C.

4.6.2 Distribution Design for Mukurimagu

ADB Project engineering design calls for four outgoing feeders, three on each busbar. Each outgoing feeder is protected by a 100 Amp MCCB are rated at 100 Amps. In addition there is an MCCB for power supply for the power station, and one spare MCCB with feeder protection.

Proposed distribution is by underground three phases PVC insulated, PVC sheathed and steel wired armoured cable sized between 95mm^2 and 35mm^2. Each distribution box has a capacity of 15 single pole MCBs pole. Distribution boxes are installed on household boundary walls. A total of 29 distribution boxes (5 to 8 per feeder) are to be installed see Table 4.4. Streetlights cables are to be two core PVC insulated flat cables of 2.5 mm^2 conductor size. Consumer mains are to be 2 core, 6 mm^2 copper conductor, PVC insulated, PVC sheathed twin flat cable. For cable calculation using this criteria, see Appendix B.

Table 4.4: Quantities Required for ADB Proposed Distribution System Mukurimagu

Cable Size	unit	Power Cables Required	No. of Connections
Main Cables			
4CX95SQ.MM	meter	827	6
4CX70SQ.MM	meter	1738	30
4CX50SQ.MM	meter	761	22
Service Cables			
4CX 6SQ.MM	meter	150	9
2Cx6SQ.MM	meter	7250	290
2Cx2.5SQ.MM	meter	1000	6
GRP Distribution Boxes	#	29	

Note

1. 3 three phase customers are Health Centre and Friday Mosque
2. 145 customer connection
3. Connection of 10 Harbour Lights

4.6.3 Distribution Design for Maaeboodhoo

The distribution boxes proposed in the ADB project contain single pole MCBs for connecting customer mains, a neutral link and terminals for connecting the distribution cables. There are 20 distribution boxes require. See Table 4.5.

The main distribution cables proposed are four core, PVC insulated cables of 25 mm^2 and 16 mm^2. Customer service mains are two core, PVC insulated flat cables of 6 mm^2 and 2.5 mm^2. Customer service cables and streetlight cables require replacement in order to meet with MEB requirements.

For Maaeboodhoo the ADB underground cables design calls for three outgoing MCCB's, one for the powerhouse and spare. For cable calculation using this criteria, see Appendix C.

Table 4.5: Quantities Required for Proposed Distribution System Maaeboodhoo

Cable Size	Unit	Power Cables Required	No. of Connections
Main Cables			
4CX25SQ.MM	meter	675	16
4CX16SQ.MM	Meter	1439	80
Service Cables			
4CX6SQ.MM	Meter	50	3
2Cx6SQ.MM	Meter	6450	258
2Cx2.5SQ.MM	Meter	0	
GRP Distribution Boxes	#	20	

Note

1. 1 three phase customer
2. 129 customer connection

Chapter 5:

Methodology of Measurement of Lifetime Costs and Benefits

5 METHODOLOGY OF MEASUREMENT OF LIFETIME COSTS AND BENEFITS

5.1 Introduction

Each option considered in this study will be graded in accordance with the tariff required to meet the total costs of the operation, maintenance, fuel and lubricating oil cost and capital cost of the option, tabulated in a 15 year cash flow calculation.

The tariff required must result in an average household expenditure of less than 10% of average household income, and the tariff must be sufficient so that the financial internal rate of return (FIRR) exceeds the weighted average cost of capital (WACC), that is the island can service the loan required for the option.

This Chapter also discussed the derivation of base costs for investment, operation and maintenance and loan servicing.

5.2 Capital Costs

The unit prices of investment were obtained for conventional equipment from international tenders called in the Maldives for the years 2004 and 2005.

Prices for digital generator control, monitoring and synchronising equipment were obtained from discussions with Sarah Griffiths at Cummins Power Generation in their Victoria office[29].

Renewable energy equipment prices were obtained from the US National Renewable Energy Laboratory (NREL) and internet sites, and modified to suit Maldives following discussions with a renewable energy consultant, Herbert Wade.

[29] Cummins Power Generation, design and manufacture of power generation systems.

5.3 Operational and Maintenance Costs

For the simplicity of the analysis, operational and maintenance costs are keep constant in the various options of design considered. There is not a great difference in maintenance and operational costs between the options See Table 5.1 and 5.2.

These costs are based on existing costs in the islands of Mukurimagu and Maaeboodhoo, see Table 4.1. However with the installation of new engines and improved load matching with synchronizing, fuel efficiency is expected to improve to 0.32 l/kWh in both islands, as this is the average fuel efficiency in islands that already have synchronizing equipment and reasonably new diesel generators. Similarly lubricating oil consumption is expected to improve to 0.0023 l/kWh.

5.4 Loan Servicing

Interest was assumed to be the current commercial interest rates while repayment periods from the initial investment was taken as 12 years, with a grace period on interest payments of 4 years, with subsequent loans being repaid over 5 years with no grace period. These conditions are the conditions currently available on approved loans to the Outer Islands.[30]

5.5 Projections of Income and Expenditure

Financial projections of income, expenditure and cost of borrowing were carried out over 15 year period, using 2004 prices[31] but, because of the recent volatility of fuel prices, the price for 2005 was used.

5.6 Cash Flow and Tariffs

An annual cash flow was carried out and tariffs selected to ensure that cumulative cash flow was always positive.

[30] Ministry of Atolls Development, Male' Republic of Maldives
[31] The year the basic data was collected from the Islands

Affordable tariffs need to be sufficient to provide adequate cash, after maintenance, operation and minor annual capital costs, to meet principal and interest payments for the project loan, plus the cost of replacement of the diesel generator sets.

Negative cash flow in any year was permitted providing previous cumulative cash flows were adequate to finance the shortfall. Commercial bank loans[32] were assumed to finance the purchase of replacement of diesel generators if the purchase could not be funded from cumulative cash flow.

Practical tariffs cannot exceed 10% of the average household income spent by domestic households on electricity, given the projected level of physical sales assumed[33].

Financial Internal Rates of Return (FIRR) were then calculated for the calculated tariff[34]. The FIRR was considered adequate if it exceeded the Weighted Average Cost of Capital (WACC).

5.7 Financial Internal Rate of Return and Weighted Average Cost of Capital

The FIRR was required to exceed the Weighted Average Cost of Capital over 15 years. The FIRR is the rate of discount for which the present value of the revenue stream is equal to the present value of the cost stream.

The benefits of a project are taken as the increased sales permitted by the installation of the projects. A further benefit counted was the costs saved, based on year 2006, by the reduction of distribution losses and the improvement of diesel fuel efficiency which are anticipated to be a result of the project. The costs associated with these benefits were the cost of the project, plus the additional costs due to increased sales, of fuel, lubrication oil, maintenance, labour, and other administrative costs.

[32] At 8% pa interest and a five year repayment period.
[33] See Section 2.10.4
[34] That is the tariff which is sufficient to ensure a positive cumulative cash floe in all year for 15 years.

The Weighted Average Cost of Capital (WACC) is the real cost of funding to the island assuming an interest rate of 8%, local inflation of 3%, and loan proportion of total funding of 92%, with 8% equity funding from the island community.

If the FIRR does not exceed the WACC then the community cannot afford to finance the project at the tariff selected.

For this research project the FIRR was held at 4.7% for all options examined. This was done by adjusting the tariff.

5.8 Methodology of Financial Analysis of Renewable Energy

The benefits of renewable energy hybrids were taken as the savings of fuel, maintenance and replacement costs of diesel generators if any caused by the installation of the renewable energy component whilst the costs were taken as the capital cost of the renewable components (including their design and installation, and the cost of maintenance, labour and replacement parts. As with other projects, for the renewable energy component to be viable the FIRR was required to exceed the WACC.

It was assumed that the Government of Maldives would permit the duty free admission of renewable energy components. Credits were given for the reduction in diesel fuel and the extension of operating life for the diesel provided by the solar hybrid system allowing the diesel to be shut down during the day. Credit was also given for the reduction of greenhouse gas due to lower fuel consumption in both solar and wind hybrid system. Although the accepted carbon credit was added to the benefits, such a credit would not accrue to the island.

Table 5.1 Maaeboodhoo Operational and Maintenance Costs

Year		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Generated Units	MWhpa	84	99	98	82	86	90	95	100	105	110	115	120	125	131	137	143	149	156	163
Annual Fuel Oil Consumption	Kl	38	44	44	26	27	29	30	32	34	35	37	38	40	42	44	46	48	50	52
Fuel Oil Specific Efficiency	l/kWh	0.45	0.45	0.45	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Fuel Cost	$	16433	36781	36436	21656	22758	23916	25134	26415	27763	29180	30469	31816	33225	34697	36235	37844	39525	41283	43121
Annual Lube Oil Consumption	Kl	0.21	0.25	0.25	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.28	0.29	0.30	0.31	0.33	0.34	0.36	0.37
Lube Oil Specific Efficiency	l/kWh	0.0025	0.0025	0.0025	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
Lube Oil Costs	$	432	1152	1141	876	920	967	1016	1068	1122	1180	1232	1286	1343	1403	1465	1530	1598	1669	1743
Maintenance Costs	$	1116	1313	1301	1087	1142	1200	1262	1326	1394	1465	1529	1597	1668	1742	1819	1900	1984	2072	2164
Other Costs	$	558	656	650	544	571	600	631	663	697	732	765	799	834	871	909	950	992	1036	1082
No of Employees	No.	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Employee Productivity	MWh/Emp.	28	33	33	20	21	23	24	25	26	28	29	30	31	33	34	36	37	39	41
Employee Costs	$/pa	389	388	388	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
Total Operating Costs	$	18927	40291	39916	24680	25909	27201	28560	29990	31493	33075	34513	36016	37587	39229	40946	42741	44617	46578	48629

Table 5.2 Mukurimagu Operational and Maintenance Costs

Year		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Generated Units	MWhpa	155	175	194	171	181	191	202	214	226	239	253	267	282	299	316	334	354	374	396
Annual Fuel Oil Consumption	kl	59	67	74	55	58	61	65	68	72	76	81	85	90	96	101	107	113	120	127
Fuel Oil Specific Efficiency	l/kWh	0.38	0.38	0.38	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Fuel Cost	$	27519	55240	591	438	463	489	517	547	578	611	646	684	723	765	809	856	905	957	1013
Annual Lube Oil Consumption	kl	0.43	0.49	0.54	0.39	0.42	0.44	0.46	0.49	0.52	0.55	0.58	0.61	0.65	0.69	0.73	0.77	0.81	0.86	0.91
Lube Oil Specific Efficiency	l/kWh	0.0028	0.0028	0.0028	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
Lube Oil Costs	$	1119	2274	2518	1831	1936	2046	2164	2288	2419	2558	2705	2861	3026	3200	3385	3580	3787	4006	4238
Maintenance Costs	$	2068	2335	2586	2273	2403	2541	2686	2840	3003	3176	3359	3552	3756	3973	4202	4445	4702	4974	5262
Other Costs	$	2912	2912	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905
No of Employees	No.	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Employee Productivity	MWh/Emp.	56	42	47	50	53	56	60	63	67	71	75	79	84	89	94	100	106	112	119
Employee Costs	$/pa	3735	3839	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933	3933
Total Operating Costs	$	37354	66600	73117	56229	59052	62041	65203	68550	72093	75842	79810	84011	88457	93164	98146	103420	109003	114914	121171

Fuel Cost	$
2003 Price	0.51
2004 Price	0.47
2005 Price	0.83
Lube Cost	
2003 Price	2.32
2004 Price	2.59
2005 Price	4.66
Oil Inflation Rate assumed 2003/2004pa	3.00%
Non Oil Inflation Rate assumed 2003/2004pa	3.00%

Chapter 6:

Proposals for the Modification of Design and Financial Criteria

6 PROPOSALS FOR THE MODIFICATION OF DESIGN AND FINANCIAL CRITERIA

6.1 Introduction

Based on the Asian Development Bank Project design, Mukurimagu and Maaeboodhoo, despite their need, failed the ADB Project financial criteria. The island communities could not afford to service the loans.

If the islands are to have an acceptable electricity supply the ADB project designs need to be re-examined to see if a more cost effective design can be found, without sacrificing safety or quality issues. The first place to start is to examine the engineering design and financial criteria agreed between the regulator, Maldives Electricity Bureau, and the ADB Project design staff[35].

These criteria cover all island utilities, large and small. It may well be that the criteria penalise small islands by requiring a substantially higher level of investment than can be justified in those islands.

This Chapter considers the applicability to the smaller outer islands of each of the ADB Project criteria.

6.2 Discussion of Criteria

6.2.1 Generating Plant Criteria

1. Sufficient diesel generating capacity should be provided to last for at least 3 years, based on load projections;

This criterion should be considered in light that diesel generators have a 7 year economic life. Island communities would not be willing to replace diesel generators with 3 years life left in them. Nor would such communities be willing to buy generators now for a need which may

[35] For engineering design criteria see Section 4.2

occur in 3 years. In 3 or 4 years time the community could, if necessary could raise a commercial bank loan to augment their generating capacity without a great deal of difficulty.

The criterion appears appropriate to Mukurimagu and Maaeboodhoo.

2. New powerhouses and control panels should be large enough to accommodate the diesel generator sizes anticipated over the 15 year planning period;

The costs associated with power station and main control panel is high and the life-time of a power station is at least 20 years, while that of a control panel is at least 15 years. There are no efficiency considerations, and the marginal costs of installing a larger capacity power station or control panel is relatively small.

The criterion appears appropriate to Mukurimagu and Maaeboodhoo.

3. Each year 80% of installed capacity, minus the capacity of the largest machine, is to exceed the annual peak load;

This criterion allows the largest machine to fail or be taken out of service without requiring electricity to be rationed. Running the engines at 80% of full load allows for fluctuations in load, and provides sufficient capacity to clear line faults should there be a fault during peak.

The criterion appears appropriate.

4. Where the load at the power station is anticipated to exceed 100 kW any two machines should operate over peak in synchronism to improve reliability and quality of supply;

This study is concerned with small islands which have a peak load well under 100kW.

The criterion is not relevant to this study.

5. Where the load at a power station is less than 100 kW, there need not be provision for synchronous running, unless synchronizing is the least cost solution. Where load splitting is to be installed the off-load switches will split load within a 40 to 60 ratio, and arranged so that each split load may be connected to any generator;

This criterion allows the designer to opt for a split load system in small islands when synchronizing may not be affordable. However financial analysis undertaken on Mukurimagu and Maaeboodhoo have indicated that the lifetime costs of synchronizing equipment is much lower than the lifetime costs of split load switching.

The criterion is further considered in Chapter 7.

6. Under normal operation no machine is to operate at less than 60% full load capacity;

If the generators are operated at low load, for long periods, this leads to high rates of cylinder grazing and consequent poor fuel efficiency. Thus planning should allow for a minimum engine operating load of 60%.

The criterion appears appropriate to Mukurimagu and Maaeboodhoo.

7. After 35,000 hours of service (approximated to 7 years) the fuel efficiency of a 1,500 rpm diesel generating set has normally fallen to a level that justifies its overhaul or replacement.

This criterion restates common experience in the outer island and is not questioned. It does not suggest that the diesel generators must be replaced every 7 year, but that forward planning should allow for such replacements.

The criterion appears appropriate.

6.2.1.1 Comment

Most of the generating plant criteria appear appropriate to the smaller outer islands. One of the criteria is irrelevant and one criteria is examined in chapter 7.

6.2.2 Distribution Criteria

As in both Mukurimagu and Maaeboodhoo the existing cables need to be replaced, the design criteria for distribution are most important in determining costs.

1. Voltage drop between the power station and the consumers' point of supply should not exceed 10%, over the 15 years following the loan;

The criterion requiring the voltage drop between the power station and the consumers' point of supply should not exceed 10%, over a 15year period, requires an excessive investment for the smaller islands. Load growth will be uneven across the feeders but the designer has little knowledge on which to base his estimate of future feeder load. In order to comply with this criterion he generally allows load growth to be split evenly across all feeders, wastefully increasing the cable size on those feeders which may not experience load growth. The criterion appears to imply that cable investment now should be sufficient to last 15years without augmentation. This misunderstands the manner in which a utility augments a cable distribution network to meet load growth. For increased load growth either additional feeders are added, or the copper size is increased in critical sections of the feeder run.

By requiring an investment horizon of 15 years this criterion requires an excessive initial investment in distribution.

2. Losses should not exceed 8%, over 15 years following the loan; and

The same argument applies to this criterion as applies to the voltage drop criteria above.

By requiring an investment horizon of 15 years this criterion requires an excessive initial investment in distribution.

3. The number and capacity of distribution boxes should be sufficient to meet anticipated connections over the 15 years following the loan, and at commissioning should have 40% spare capacity.

As load grows in particular areas, additional customer numbers are met by adding additional distribution boxes. An investment period of 15 years would require a large investment, as the designer has little idea where the growth will occur over that time, and therefore builds excessive capacity into his design.

As with the previous distribution criteria, this criterion requires an excessive initial investment in distribution.

6.2.2.1 Comment

Underground cable represents a major investment for the small electricity utilities. All the criteria require a large initial investment which cannot be fully utilized for many years.

The criteria also appear to misunderstand the nature of underground cable growth in small utilities. By reducing the time frame of the distribution criteria's from 15 years down to 10years, and allowing for additional cable augmentation beyond 10 years, significant cost savings can be made.

6.2.3 Financial Criteria

Financial criteria are as follows, for each island:

1. That the annual cumulative cash flow for each island should always be positive

This criterion allows for income to be less than operating and capital expenditure and cost of borrowing on an annual basis, providing that previous cash flows have build up a reserve to meet the deficit.

2. That the average proportion of income spent by households on electricity must not exceed 10%.

Experience indicates a household expenditure limit of 10% of income for a good electricity supply[36]. This caps what expenditure can be made in order to improve electricity supply.

3. That the Financial Internal Rate of Return (FIRR) must exceed the Weighted Average Cost of Capital (WACC).

This criterion states that the investment must earn enough to meet the cost of capital. It is in effect a check on Criterion 1.

6.2.3.1 Comment

Given that each island is expected to be self sufficient, and that the Government does not permit subsidies for electricity, or cross subsidies between islands these financial criteria appear to be unavoidable.

6.2.4 Conclusion

Generating and financial criteria appear to be applicable to Mukurimagu and Maaeboodhoo, but the distribution design criteria in requiring a 15 year investment horizon leads to over design, and high initial investment costs. A more practical solution would be to design the distribution for an investment horizon of 10 years, and allow the utility to augment cables and distribution boxes as required thereafter. If cash flow does not permit cable augmentation, the utility could seek a commercial bank loan to allow it to meet increased sales.

36 ADB, *Preparing the Outer Islands Electrification Study*

6.3 Redesigning Underground Cables for a 10 Year Investment Horizon

Recent engineering proposals for new replacement underground cable and distribution boxes are required to be capable of meeting the estimated load for 15 years and that at commissioning to have 40% spare capacity.

For Mukurimagu, underground reticulation has been redesigned for this study for a 10 year projected load rather that 15 years, thus the cable sizes required are reduced from 95sqmm to 50sqmm and from 50sqmm and 35sqmm. See Appendix D.

Without the constraint of 40% spare capacity at commissioning the number of distribution boxes were reduced from 29 to 15. See Table 6.1

Table 6.1: Comparison of Quantities Required for Redesigned Underground Cables Mukurimagu

Cable Size	Unit	Original Design		For 10 year Period and Reduced DB Capacity	
		Power Cables Required	No. of Connection	Power Cables Required	No. of Connection
Main Cables					
4CX95SQ.MM	meter	827	6	0	0
4CX70SQ.MM	meter	1738	30	0	0
4CX50SQ.MM	meter	761	22	278	2
4CX35SQ.MM	meter	0	0	1990	28
Service Cables					
2CX16SQ.MM	meter	100	6	100	6
2Cx6SQ.MM	meter	7250	290	7250	290
2Cx2.5SQ.MM	meter	1000	6	1000	6
GRP Distribution Boxes	#	29		15	

Note
1. 3 three phase customers are Health Centre and Friday Mosque
2. 145 customer connection
3. Connection of 10 Harbour Lights

For Maaeboodhoo 25sqmm cables were reduced to 16sqmm, See Appendix E. The constraint of 40% spare capacity at commission on the distribution boxes was lifted, thus the number of distribution boxes required was reduced from 20 to 13. See Table 6.2.

Table 6.2: Comparison of Quantities Required for Redesigned Underground Cables Maaeboodhoo

Cable Size	unit	Original Design		For 10 year Period and Reduced DB Capacity	
		Power Cables Required	No. of Connection	Power Cables Required	No. of Connection
Main Cables					
4CX25SQ.MM	meter	675	16	0	0
4CX16SQ.MM	meter	1439	80	1891	52
Service Cables					
4CX6SQ.MM	meter	50	3	50	3
2Cx6SQ.MM	meter	6450	258	6450	258
2Cx2.5SQ.MM	meter	0		0	
GRP Distribution Boxes	#	20		13	

Note
1. 1 three phase customer
2. 129 customer to be connected

6.3.1 Financial Analysis

For Maaeboodhoo, the alteration of the distribution criteria enables only a slight reduction in the capital cost and a moderate increase the financial internal rate of return (FIRR) see Table 6.3.

For Mukurimagu however the alteration of the distribution criteria enables a substantial reduction of cable sizes, capital costs and tariffs, and increases the FIRR, even though allowance is made for additional cable augmentation after 10 years see Table 6.4.

Table 6.3: Financial Summary, Maaeboodhoo

Existing Tariff	$/kWh	0.57
FIRR[1, 3.]	%	4.7%
ADB Project Design with Analogue Control Protection and Synchronizing		
Required Tariff (Exceeds Affordable Tariff)	$/kWh	1.12
Capital costs1.	$	$499,739
Redesigning Underground Cable		
Required Tariff (Exceeds Affordable Tariff)	$/kWh	1.12
Capital costs[2.]	$	$487,368

Note: 1.See Appendix K Table 5 2. See Appendix K Table 8, the capital costs of the diesel alternatives is total project cost including power station, generation, distribution, tools and spare parts.

Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island. See Appendix G Table 3 and 5

Table 6.4: Financial Summary, Mukurimagu

Existing Tariff	$/kWh	0.36
ADB Project Design with Analogue Control Protection and Synchronizing		
Required Tariff (Exceeds Affordable Tariff)	$/kWh	0.63
Capital costs[1.]	$	$466,512
Redesigning Underground Cables		
Required Tariff (Exceeds Affordable Tariff)	$/kWh	0.57
Capital costs[2.]	$	$387,549

Notes: 1. See Appendix L Table 5 2. See Appendix L Table 8

Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island. See Appendix H Table 3 and 5

Chapter 7:

Proposal for Generation Control and Protection Using Digital Equipment

7 PROPOSAL FOR GENERATION CONTROL AND PROTECTION USING DIGITAL EQUIPMENT

7.1 Introduction

Four options of generation control gear are investigated in this chapter to discover which results in the lowest tariff over a period of 15 years using 2005 prices.

Tariffs are calculated on the basis of annual expenditure on all anticipated capital investment over a 15 year (including the generation control option under consideration), fuel and lubricating oil consumption, operating and maintenance costs, wages and administration costs.

Firstly this chapter looks at the power utility is 15 year total capital cost[37] required by each of three types of analogue control equipment currently used in the outer islands. This includes

(i) Single busbar without any synchronising equipment;

(ii) Two busbars which allows different portions of the load to be supplied by generators running independently; and

(iii) Synchronising equipment with check relays.

For there capital cost and operating and maintenance cost, tariff are derived.

Using the same unit costs, the total utility capital costs and operating and maintenance, the tariff required for digital control, monitoring and synchronising equipment are to be derived.

A comparison of these above options indicates that the use of digital control, monitoring and synchronising equipment results in the lowest tariff.

This chapter then looks at the combination of digital control, monitoring and synchronising equipment in combination with improved distribution design criteria (See Section 6.3), to

[37] Total utility capital costs are required as there will be different generator planning schedules with each type of generator control.

determine the it resultant tariff in Mukurimagu and Maaeboodhoo is affordable, and is sufficient to ensure that the FIRR exceeds the WACC.

The conclusion is that the only solution that results in an affordable tariff is the combination of digital control, monitoring and synchronising equipment in combination with the reduction in distribution design. That Mukurimagu and Maaeboodhoo, previously rejected for finance by the ADB Project would qualify under the revised designs. That as Mukurimagu and Maaeboodhoo are typical of small outer islands, then the probability is that an electricity supply of with an internationally accepted quality of supply can indeed be afforded on those islands, and that therefore small islands should be included as candidates for bank financing.

7.2 Generation

7.2.1 Generator Control

On both Mukurimagu and Maaeboodhoo the existing control gear is such that only one engine can be run at a time, as there is a single busbar and no synchronising equipment. For reserve purposes, each island must therefore have two generators each sized to meet the peak[38]. For fuel efficiency purposes, each island should also have at least one engine sized to meet the off peak load[39].

There options considered in this chapter to improve load matching are:

- Using two busbars so that the load can be split into two approximately equal independent sections[40] each being met by a separate generator. This is usually called "load splitting".

[38] Allowing for one machine to be under maintenance or repair.
[39] When the smallest "off peak" diesel generator is out of service, continuity of supply can be maintained using a larger engine, accepting the reduced efficiency of it running at less than 60% load.
[40] As the load on any particular feeder is not known accurately in advance, for planning purposes it is generally assumed that the load is split into a 60/40 ratio, but that which generator meets the largest load is indeterminate.

- Using a single busbar with synchronising equipment to run two or three diesel generators synchronously. Such equipment could be either the conventional analogue equipment, or as is proposed in this study, microprocessor based digital equipment.

Typically analogue control, protection, metering and synchronising equipment require an air-conditioned control room with freestanding electrical panels measuring about two meters by about four meters wide. Microprocessor based digital equipment is much smaller and is typically mounted on or near the alternator, and does not require a control room.

Typical purchase price of this control monitoring and protection equipment for three diesel generators is:

Option 1: Single busbar without synchronising with two changeover switches (Analogue)	$4,000
Option 2: Two busbars with five changeover switches (Analogue)	$8,000
Option 3: Single busbar with generator synchronising (Analogue)	$43,000
Option 4: Control Equipment with synchronising (Digital)	$36,000[41]

The higher price of synchronising equipment is usually justified by the smaller size of diesel-generators which can be used to achieve the same system reliability, and the better fuel efficiency achieved by closer load matching possible with synchronising equipment[42].

7.3 Generation Planning Schedules

For Mukurimagu generator sizes required to meet the load over a 15 year period given the reliability criteria, for each of the generator control options, are given in Table 7.1.

For the Maaeboodhoo diesel generator 15 year planting schedule are given in Table 7.3.

[41] Where a new power station is required this option can also save the capital cost of an air-conditioned control room.
[42] Synchronising is also preferred by the customers who are always irritated by the twice daily system outages needed to switch engines of split load without synchronising.

7.4 Generation Reliability Criteria

7.4.1 Option 1: Single Busbar

Two machines are required each sufficient to meet the peak at 80% capacity[40 43]. (A third machine is required to meet the off peak load.)

7.4.2 Option 2: Split Busbar

That the largest machine be under maintenance. That 80% of the capacity of each of the next two smaller machines to be sufficient to meet 60% of peak load[44]. See Section 7.2.1 above.

7.4.3 Option 3 and 4: Synchronising

Where the largest machine is allowed to be under maintenance. That 80% of the combination of the next two largest machines must be sufficient to meet the peak.

7.4.4 Projected Capital Costs for 15-Years

For each island and for each option of generator control equipment, and associated planting schedule, capital cost estimates have been prepared. The justifications of the costs are discussed in section 5.2.

Over a 15 year period, given projected load growths, projected future capital cost are developed from generation planning schedules.

Future service main cable costs and metering capital costs are derived from the projected annual increase in the number of customers multiplied by the current unit cost per customer. Main distribution cables to be installed under the project have been sized to be adequate for 10-year load growth, however capital projection assume that annual distribution augmentation work will meet the load growth and additional customers through the 15 year

[43] Allowing for one machine to be under repairs or maintenance, and allowing sufficient capacity for fault clearance at full load.
[44] Allowing for:
The largest machine to be under repairs or maintenance, and
Sufficient capacity for fault clearance at full load.
Load split approximately 60/40 range, and that it cannot be predicted which feeders will have the greatest load.

period. For Mukurimagu capital cost projections see Table 7.1. For the Maaeboodhoo capital cost projections see Table 7.2.

Table 7.1: Generation Planning Schedule to meet Reliability Criteria, Mukurimagu

Option 1: **Single Busbar with No Synchronizing**

Year		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Peak Load	kW	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94
Installed Capacity	Year																
Generator No 1	**2003**	**84**	**84**	**84**	**84**												
Generator No 2	**2007**	**80**	**80**	**80**	**80**	**80**	**80**	**80**									
Generator No 3	**2007**	**30**	**30**	**30**	**30**	**30**	**30**	**30**									
Generator No 4	*2011*					*120*	*120*	*120*	*120*	*120*	*120*	*120*					
Generator No 5	*2014*								*120*	*120*	*120*	*120*	*120*	*120*	*120*		
Generator No 6	*2014*								*40*	*40*	*40*	*40*	*40*	*40*	*40*		
Generator No 7	*2018*												*144*	*144*	*144*	*144*	*144*
Generator No 8	*2021*															*144*	*144*
Generator No 9	*2021*															*50*	*50*
Total	kW	194	194	194	194	230	230	230	280	280	280	280	304	304	304	338	338
Firm Capacity	kW	64	64	64	64	64	64	64	96	96	96	96	96	96	96	115	115
Spare Capacity		20	18	16	13	10	8	5	34	30	27	23	19	15	11	26	21

Option 2: **Two Busbars, No Synchronizing, Split Load**

Year		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Peak Load	kW	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94
Installed Capacity	Year																
Generator No 1	**2003**	**84**	**84**	**84**	**84**												
Generator No 2	**2007**	**50**	**50**	**50**	**50**	**50**	**50**	**50**									
Generator No 3	**2007**	**30**	**30**	**30**	**30**	**30**	**30**	**30**									
Generator No 4	*2011*					*70*	*70*	*70*	*70*	*70*	*70*	*70*					
Generator No 5	*2014*								*70*	*70*	*70*	*70*	*70*	*70*	*70*		
Generator No 6	*2014*								*40*	*40*	*40*	*40*	*40*	*40*	*40*		
Generator No 7	*2018*												*100*	*100*	*100*	*100*	*100*
Generator No 8	*2021*															*100*	*100*
Generator No 9	*2021*															*60*	*60*
Total	kW	164	164	164	164	150	150	150	180	180	180	180	210	210	210	260	260
Firm Capacity	kW	40	40	40	40	40	40	40	56	56	56	56	56	56	56	80	80
Spare Capacity		14	12	11	9	8	6	5	19	16	15	12	10	7	5	27	24

Option 3 and 4: Single Busbar with Synchronizing

Year		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Peak Load	kW	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94
Installed Capacity	Year																
Generator No 1	**2003**	**84**	**84**	**84**	**84**												
Generator No 2	**2007**	**40**	**40**	**40**	**40**	**40**	**40**	**40**									
Generator No 3	**2007**	**40**	**40**	**40**	**40**	**40**	**40**	**40**									
Generator No 4	*2011*					*48*	*48*	*48*	*48*	*48*	*48*	*48*					
Generator No 5	*2014*								*48*	*48*	*48*	*48*	*48*	*48*	*48*		
Generator No 6	*2014*								*68*	*68*	*68*	*68*	*68*	*68*	*68*		
Generator No 7	*2018*												*68*	*68*	*68*	*68*	*68*
Generator No 8	*2021*															*68*	*80*
Generator No 9	*2021*															*80*	*80*
Total	kW	164	164	164	164	128	128	128	164	164	164	164	184	184	184	216	228
Firm Capacity	kW	64	64	64	64	64	64	64	76.8	76.8	76.8	76.8	92.8	92.8	92.8	108.8	118.4
Spare Capacity		20	18	16	13	10	8	5	14.8	10.8	7.8	3.8	15.8	11.8	7.8	19.8	24.4

Table 7.2 Projected Capital Costs Mukurimagu AUS$

Option 1: Single Busbar with No Synchronizing

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2022
Peak Load				50	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94	99
Annual Electricity Sales	MWhpa			154	162	172	181	192	203	215	227	240	254	268	284	300	318	336	355	376	398
Number of Customers				142	145	148	150	153	156	159	162	165	168	172	175	178	182	185	189	192	196
	Unit	Size	Cost/Unit																		
Civil Works				187681																	
Diesel Generator, Installed	kW	31	23681	23681																	
	kW	40	29680									29680									
	kW	48	30077																30077		
	kW	68	30872																		
	kW	80	36715	38750																	
	kW	100	40331																		
	kW	120	45903						45903			45903									
	kW	144	50741													50741			50741		
Daily fuel tank and fuel lines				10325																	
Generator panels			17560	4002																	
Feeder Panel			187	5853																	
Governors/AVRs			23	7961																	
Distribution System per kW			700	125944		1591	1675	1764	1858	1957	2061	2171	2287	2409	2537	2673	2815	2966	3124	3291	3467
Service Lines per customer	Each		407		0	924	973	1025	1079	1137	1197	1261	1328	1399	1474	1553	1636	1723	1815	1912	2014
Meters	Each		44		0	100	105	111	117	123	130	136	144	151	159	168	177	186	196	207	218
Spares				2471																	
Tools				7546																	
Inflation 1 years at 2.5%				20970																	
Total				**435183**	**0**	**2615**	**2754**	**2900**	**48957**	**3217**	**3388**	**79151**	**3759**	**3959**	**4171**	**55134**	**4628**	**4875**	**85953**	**5410**	**5700**

Option 2: Two Busbars, No Synchronizing, Split Load

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Peak Load				50	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94
Annual Electricity Sales	MWhpa			154	162	172	181	192	203	215	227	240	254	268	284	300	318	336	355	376
Number of Customers				142	145	148	150	153	156	159	162	165	168	172	175	178	182	185	189	192
	Unit	Size	Cost/Unit																	
Civil Works				187681																
Diesel Generator, Installed	kW	31	23681																	
	kW	40	29680																	
	kW	50	30077	60154																
	kW	68	30872						30872			61743								
	kW	80	36715	2035												36715			73430	
Daily fuel tank/fuel lines				10325																
Generator panels			17560	8033																
Feeder Panel			187	5853																
Governors/AVRs			23	7961																
Distribution System per kW			700	125944		1591	1675	1764	1858	1957	2061	2171	2287	2409	2537	2673	2815	2966	3124	3291
Service Lines per customer	Each		407		0	924	973	1025	1079	1137	1197	1261	1328	1399	1474	1553	1636	1723	1815	1912
Meters	Each		44		0	100	105	111	117	123	130	136	144	151	159	168	177	186	196	207
Spares				2471																
Tools				7546																
Inflation 1 years at 2.5%				21161																
Total				**439163**	**0**	**2615**	**2754**	**2900**	**33926**	**3217**	**3388**	**65312**	**3759**	**3959**	**4171**	**41108**	**4628**	**4875**	**78566**	**5410**

Option 3: Single Busbar with Synchronizing (Analogue)

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2022
Peak Load				50	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94	99
Annual Electricity Sales	MWhpa			154	162	172	181	192	203	215	227	240	254	268	284	300	318	336	355	376	398
Number of Customers				142	145	148	150	153	156	159	162	165	168	172	175	178	182	185	189	192	196
	Unit	Size	Cost/Unit																		
Civil Works				187681																	
Diesel Generator, Installed	kW	31	23681																		
	kW	40	29680	59359																	
	kW	48	30077						30077			30077									
	kW	68	30872									30872				30872			30872		
	kW	80	36715	2035															36715		
Daily fuel tank/ fuel lines				1551																	
Generator panels			17560	43502																	
Feeder Panel			187	5853																	
Governors/AVRs			23	7873																	
Distribution System per kW			700	125944		1591	1675	1764	1858	1957	2061	2171	2287	2409	2537	2673	2815	2966	3124	3291	3467
Service Lines per customer	Each		407	0	0	924	973	1025	1079	1137	1197	1261	1328	1399	1474	1553	1636	1723	1815	1912	2014
Meters	Each		44	0	0	100	105	111	117	123	130	136	144	151	159	168	177	186	196	207	218
Spares				2690																	
Tools				7546																	
Inflation 1 years at 2.5%				22479																	
Total				**466512**	**0**	**2615**	**2754**	**2900**	**33131**	**3217**	**3388**	**64517**	**3759**	**3959**	**4171**	**35265**	**4628**	**4875**	**72722**	**5410**	**5700**

Option 4: Single Busbar with Synchronizing (Digital)

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2022
Peak Load				50	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94	99
Annual Electricity Sales	MWhpa			154	162	172	181	192	203	215	227	240	254	268	284	300	318	336	355	376	398
Number of Customers				142	145	148	150	153	156	159	162	165	168	172	175	178	182	185	189	192	196
	Unit	Size	Cost/Unit																		
Civil Works				156,018																	
Diesel Generator, Installed	kW	31	23,681																		
	kW	40	29,680	47,482																	
	kW	48	30,077						30,077												
	kW	68	30,872									61,743				30,872					
	kW	80	36,715	2,035															73,430		
Daily fuel tank/ fuel lines				1,551																	
Generator panels			17,560	11,750																	
Feeder Panel			187	12,224																	
Governors/AVRs			23	7,873																	
Distribution System per kW			700	125,944		1591	1675	1764	1858	1957	2061	2171	2287	2409	2537	2673	2815	2966	3124	3291	3467
Service Lines per customer	Each		407		0	924	973	1025	1079	1137	1197	1261	1328	1399	1474	1553	1636	1723	1815	1912	2014
Meters	Each		44		0	100	105	111	117	123	130	136	144	151	159	168	177	186	196	207	218
Spares				2,780																	
Tools				7,546																	
Inflation 1 years at 2.5%				18,995																	
Total				**394197**	**0**	**2615**	**2754**	**2900**	**33131**	**3217**	**3388**	**65312**	**3759**	**3959**	**4171**	**35265**	**4628**	**4875**	**78566**	**5410**	**5700**

Table 7.3: Generation Planning Schedule to meet Reliability Criteria, Maaeboodhoo

Option 1: Single Busbar with No Synchronizing

Year		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Peak Load	kW	22	23	25	26	27	28	30	31	32	33	35	36	38	39	41	43
Off Peak Load	40%	9	9	10	10	11	11	12	12	13	13	14	15	15	16	16	17
Installed Capacity	Year																
Generator No 1	**2007**	**48**	**48**	**48**	**48**	**48**	**48**	**48**									
Generator No 2	**2007**	**48**	**48**	**48**	**48**	**48**	**48**	**48**									
Generator No 3	**2007**	**48**	**48**	**48**	**48**	**48**	**48**	**48**									
Generator No 4	*2014*								*68*	*68*	*68*	*68*	*68*	*68*	*68*		
Generator No 5	*2014*								*68*	*68*	*68*	*68*	*68*	*68*	*68*		
Generator No 6	*2014*								*68*	*68*	*68*	*68*	*68*	*68*	*68*		
Generator No 7	*2021*															*80*	*80*
Generator No 8	*2021*															*80*	*80*
Generator No 9	*2021*															*80*	*80*
Total	kW	144	144	144	144	144	144	144	204	204	204	204	204	204	204	240	240
Firm Capacity	kW	38	38	38	38	38	38	38	54	54	54	54	54	54	54	64	64
Spare Capacity		16	15	13	12	11	10	8	23	22	21	19	18	16	15	23	21

Option 2: Two Busbars, No Synchronizing, Split Load

Year		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Peak Load	kW	22	23	25	26	27	28	30	31	32	33	35	36	38	39	41	43
Off Peak Load	40%	9	9	10	10	11	11	12	12	13	13	14	15	15	16	16	17
Installed Capacity	Year																
Generator No 1	**2007**	**31**	**31**	**31**	**31**	**31**	**31**	**31**									
Generator No 2	**2007**	**31**	**31**	**31**	**31**	**31**	**31**	**31**									
Generator No 3	**2007**	**40**	**40**	**40**	**40**	**40**	**40**	**40**									
Generator No 4	*2014*								*50*	*50*	*50*	*50*	*50*	*50*	*50*		
Generator No 5	*2014*								*40*	*40*	*40*	*40*	*40*	*40*	*40*		
Generator No 6	*2014*								*40*	*40*	*40*	*40*	*40*	*40*	*40*		
Generator No 7	*2021*															*68*	*68*
Generator No 8	*2021*															*48*	*48*
Generator No 9	*2021*															*48*	*48*
Total	kW	102	102	102	102	102	102	102	130	130	130	130	130	130	130	164	164
Firm Capacity	kW	25	25	25	25	25	25	25	32	32	32	32	32	32	32	38	38
Spare Capacity		12	11	10	9	9	8	7	13	13	12	11	10	9	9	14	13

Option 3 and 4: Single Busbar with Synchronizing

Year		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual Peak Load	kW	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94
Off Peak Load	40%	18	18	19	20	21	23	24	25	26	28	29	31	32	34	36	38
Installed Capacity	Year																
Generator No 1	**2007**	**31**	**31**	**31**	**31**	**31**	**31**	**31**									
Generator No 2	**2007**	**31**	**31**	**31**	**31**	**31**	**31**	**31**									
Generator No 3	**2007**	**18**	**18**	**18**	**18**	**18**	**18**	**18**									
Generator No 4	*2014*								*31*	*31*	*31*	*31*	*31*	*31*	*31*		
Generator No 5	*2014*								*31*	*31*	*31*	*31*	*31*	*31*	*31*		
Generator No 6	*2014*								*31*	*31*	*31*	*31*	*31*	*31*	*31*		
Generator No 7	*2021*															*40*	*40*
Generator No 8	*2021*															*40*	*40*
Generator No 9	*2021*															*31*	*31*
Total	kW	80	80	80	80	80	80	80	93	93	93	93	93	93	93	111	111
Firm Capacity	kW	39.2	39.2	39.2	39.2	39.2	39.2	39.2	49.6	49.6	49.6	49.6	49.6	49.6	49.6	56.8	56.8
Spare Capacity		17.2	16.2	14.2	13.2	12.2	11.2	9.2	18.6	17.6	16.6	14.6	13.6	11.6	10.6	15.8	13.8

Table 7.4 Projected Capital Costs Maaeboodhoo AUS$

Option 1: Single Busbar with No Synchronizing

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Peak Load				27	23	24	25	26	27	28	30	31	32	33	35	36	38	39	41	43
Annual Electricity Sales	MWhpa			74	78	82	86	90	95	100	105	109	114	119	124	130	136	142	148	155
Number of Customers				127	130	132	134	136	139	141	143	145	146	147	149	150	151	153	154	156
	Unit	Size	Cost/Unit																	
Civil Works				283,348																
Diesel Generator, Installed	kW	31	23681																	
	kW	40	29680																	
	kW	48	30077	90,231																
	kW	68	30872									92,615								
	kW	80	36715																110,145	
Exhaust Systems				7829																
Daily fuel tank/ fuel lines				10325																
Governors/AVRs				7961																
Generator Control Panel				4,002																
Generator Feeder Panel				5853																
Distribution System per kW			700	57295		175	175	175	175	218	239	215	225	234	244	255	266	277	289	301
Service Lines per customer	Each		407			407	407	407	407	506	556	501	522	544	567	592	617	644	671	700
Meters	Each		44			88	88	88	132	88	88	88	44	44	88	44	44	88	44	88
Spares				1670																
Tools				7388																
Inflation 1 Year @ 2.5%pa				11898																
Total				**487799**	**0**	**670**	**670**	**670**	**714**	**812**	**884**	**93419**	**791**	**822**	**900**	**890**	**927**	**1009**	**111149**	**1089**

Option 2: Two Busbars, No Synchronizing, Split Load

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Peak Load				27	23	24	25	26	27	28	30	31	32	33	35	36	38	39	41	43
Annual Electricity Sales	MWhpa			74	78	82	86	90	95	100	105	109	114	119	124	130	136	142	148	155
Number of Customers				127	130	132	134	136	139	141	143	145	146	147	149	150	151	153	154	156
	Unit	Size	Cost/Unit																	
Civil Works				283348																
Diesel Generator, Installed	kW	31	23,681	47362																
	kW	40	29,680	29680								59359								
	kW	48	30,077									30077							60154	
	kW	68	30,872																30872	
	kW	80	36,715																	
Exhaust Systems				7829																
Daily fuel tank//fuel lines				10325																
Governors/AVRs				7961																
Generator Control Panel				8033																
Generator Feeder Panel				5853																
Distribution System per kW			700	57295		175	175	175	175	218	239	215	225	234	244	255	266	277	289	301
Service Lines per customer	Each		407	0		407	407	407	407	506	556	501	522	544	567	592	617	644	671	700
Meters	Each		44	0		88	88	88	132	88	88	88	44	44	88	44	44	88	44	88
Spares				1670																
Tools				7388																
Inflation 1 Year @ 2.5%pa				11669																
Total				**478413**	**0**	**670**	**670**	**670**	**714**	**812**	**884**	**90240**	**791**	**822**	**900**	**890**	**927**	**1009**	**92030**	**1089**

Option 3: Single Busbar with Synchronizing (Analogue)

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Peak Load				27	23	24	25	26	27	28	30	31	32	33	35	36	38	39	41	43
Annual Electricity Sales	MWhpa			74	78	82	86	90	95	100	105	109	114	119	124	130	136	142	148	155
Number of Customers				127	130	132	134	136	139	141	143	145	146	147	149	150	151	153	154	156
	Unit	Size	Cost/Unit																	
Civil Works				283348																
Diesel Generator, Installed	kW	31	23681	47362								71044							23681	
	kW	40	29680																59359	
	kW	48	30077																	
Exhaust Systems				7829																
Daily fuel tank/ fuel lines				10325																
Governors/AVRs				7961																
Generator Control Panel				43502																
Generator Feeder Panel				5853																
Distribution System per kW			700	57295		175	175	175	175	218	239	215	225	234	244	255	266	277	289	301
Service Lines per customer	Each		407	0		407	407	407	407	506	556	501	522	544	567	592	617	644	671	700
Meters	Each		44	0		88	88	88	132	88	88	88	44	44	88	44	44	88	44	88
Spares				1670																
Tools				7388																
Inflation 1 Year @ 2.5%pa				12189																
Total				**499739**	**0**	**670**	**670**	**670**	**714**	**812**	**884**	**71848**	**791**	**822**	**900**	**890**	**927**	**1009**	**84044**	**1089**

Option 4: Single Busbar with Synchronizing (digital)

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Peak Load				27	23	24	25	26	27	28	30	31	32	33	35	36	38	39	41	43
Annual Electricity Sales	MWhpa			74	78	82	86	90	95	100	105	109	114	119	124	130	136	142	148	155
Number of Customers				127	130	132	134	136	139	141	143	145	146	147	149	150	151	153	154	156
	Unit	Size	Cost/Unit																	
Civil Works				171710																
Diesel Generator, Installed	kW	31	23681	47362								71044							23681	
	kW	40	29680																59359	
	kW	48	30077																	
Exhaust Systems				7829																
Daily fuel tank/ fuel lines				10325																
Governors/AVRs				7961																
Generator Control Panel				36673																
Generator Feeder Panel				3917																
Distribution System per kW			700	57295		175	175	175	175	218	239	215	225	234	244	255	266	277	289	301
Service Lines per customer	Each		407			407	407	407	407	506	556	501	522	544	567	592	617	644	671	700
Meters	Each		44			88	88	88	132	88	88	88	44	44	88	44	44	88	44	88
Spares				1670																
Tools				7388																
Inflation 1 Year @ 2.5%pa				9179																
Total				376325	0	670	670	670	714	812	884	71848	791	822	900	890	927	1009	84044	1089

7.5 Financial Summary of Generator Control Options

The analogue generator control options alone do not result in an affordable tariff in either island. See Appendix I and J, for detailed derivation of tariff from cumulative cash flow requirements, and the derivation of the FIRR See Appendix G and H.

Table 7.5: Financial Summary, Mukurimagu

FIRR		4.7%
Existing Tariff	$/kWh	0.42
***Option 1*: Single Busbar No Synchronizing**		
Required Tariff	$/kWh	0.65
Capital costs	$	$435,183
***Option 2:* Two Busbars, No Synchronizing, Split Load**		
Required Tariff	$/kWh	0.62
Capital costs	$	$439,163
***Option 3:* Single Busbar with Synchronizing (Analogue)**		
Required Tariff	$/kWh	0.63
Capital costs	$	$466,512

Note: Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island.

Table 7.6: Financial Summary, Maaeboodhoo

FIRR		4.7%
Existing Tariff	$/kWh	0.52
***Option 1*: Single Busbar No Synchronizing**		
Required Tariff		1.15
Capital costs		$487,799
***Option 2:* Two Busbars, No Synchronizing, Split Load**		
Required Tariff	$/kWh	1.11
Capital costs	$	$478,413
***Option 3:* Single Busbar with Synchronizing (Analogue)**		
Required Tariff	$/kWh	1.12
Capital costs	$	$499,739

Note: Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island.

7.6 Alternative Means of Synchronizing Generators

In both islands single busbar with synchronizing resulted in a marginally more expensive tariff than using two busbars to split the load at peak. However synchronizing has a number of benefits which have not been counted in the analysis. Synchronizing avoids twice daily interruptions to electricity supply required either to change generators or to split the load. Also sharing the load between two generators at peak would improve the stability and reliability of the system, factors which are always a major problem in small systems. However none of the analogue generator control systems are financially viable as they result in unaffordable tariffs.

From investigations by the ADB project engineers, there appears to be no acceptable means of reducing the cost of analogue generator controls. It is possible that digital control and synchronising may be financially viable. This is investigated below.

7.6.1 Microprocessors Based Synchronizing

An alternate cheaper means of synchronizing may be achieved using commercial available microprocessors which include monitoring, metering, control, and synchronizing systems. Together with electronic governors such microprocessors could also optimize diesel generator performance.

Typically these microprocessors include load sharing, control for real and reactive load when synchronized, engine and alternator protection, and advanced diagnostics and controls.

Normally such microprocessors are configured using a laptop computer and manufacturer's software. They can be configured over the internet.

There is a substantial market for microprocessors or generator controls in developed countries, for the control of multiple standby generators, and with multiple generators in small boats and pleasure craft. As a result the price for this equipment has been dropping rapidly.

7.7 PowerCommand Paralleling Generator Set Control

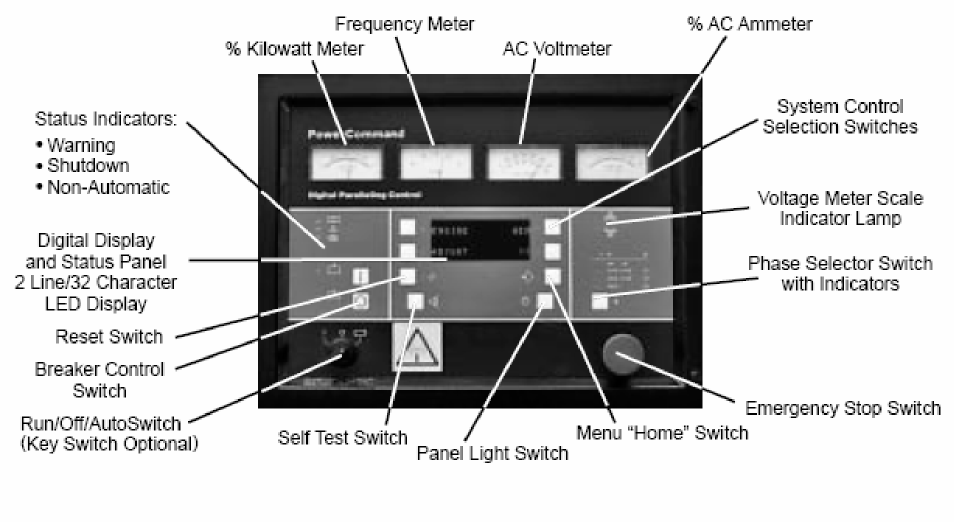
PowerCommand Control 3100 is a typical microprocessor based controller produced by Cummins Power Generation[45], which monitors, meters, controls and synchronizes generator sets. See Appendix F.

7.7.1 Controls and Adjustment Switches

PowerCommand Control 3100, includes load sharing, control for real and reactive load on the generator while synchronized, and alternator protection, and advanced diagnostics and controls, as well as a digital voltage regulation.

In addition to digital metering, analogue metering is included for easy viewing. The chart below shows the location of the standard controls and meters.

Chart 7.1: Labelling of Switches and Control on a PowerCommand Control 3100



7.7.2 Amp Sentry Protection for Paralleling

The Amp Sentry "add on" for the basic controller provides comprehensive protection for alternator and system loads and prevents nuisance tripping. In order to minimise manufacturing costs, microprocessor controls are designed and manufactured around standardized control blocks, which substantially reduces spare parts inventories, and

[45] Cummins Power Generation, design and manufacture of power generation systems.

maintenance training. For the Maldives such processors have the great advantage that their performance can be diagnosed over the internet from either the capital city Male' or indeed from Singapore or the manufacturer's works, and they can also be programmed over the internet. The savings in travel and time for future maintenance would be substantial.

7.7.3 Installation of Microprocessor Controllers

Microprocessor controllers can be supplied by the manufactures already mounted on the diesel generator units. The controllers are designed for reliability of operation in the environment of the engine room. Microprocessor control units are very much smaller than traditional analogue systems than traditional systems. For the two target islands 3 microprocessor systems (one mounted on each engine) would take up a total 1.2 m^3, compared to about 9 m^3 for analogue equipment.

As digital generator control units mount on the generator the need for very expensive main control panel and associated power station control room is eliminate. For the digital control unit the distribution control and protection panel (incorporating generator input MCCBs, would use a standard 300Amp MCCB panel mounted on the engine room wall. Thus in a small power station the construction costs of a new power station could be reduced by about one third as a control room is not be required See Table 7.7. For full detail on cost prices see Appendix K Table 6 and Appendix L Table 6.

Table 7.7: Capital Savings by Use of Digital Control Instead of Analogue Unit

Items	Cost (AUS$)
Analogue Generator Control	
Control equipment with synchronizing (Analogue)	$43,000
Distribution Panel, 5 feeders, 100Amps MCB (Freestanding in Control Room)	$3,907
Power station building	$146,199
Power station slab and foundations	$17,647
Digital Generator Control	
Control Equipment with synchronising (Digital)	$36,000
Distribution Panel, 5 feeders, 100Amps MCB (Wall mounted in Machine Room)	$2000
Power station building without control room	$124,269
Power station slab and foundations without control room	$15,000

Capital Costs Savings	$33,484

7.7.4 Financial Analysis of Microprocessors Controllers.

In both islands the use of digital generator controls will reduce the capital cost and reduce the required tariff. See Table 7.8. See Appendix G Table 4 and Appendix I Table 4 for Maaeboodhoo and Appendix H Table 4 and Appendix J Table 4 for Mukurimagu, for detailed derivation of tariff from cumulative cash flow requirements, and the derivation of tariffs.

Nevertheless, although standard digital microprocessor controls result in the lowest tariff of any of the options considered, the tariff is still not affordable. However tariffs will become affordable when digital generator controls are combined with improved distribution design.

Table 7.8: Financial Summary
Control Equipment with Synchronising (Digital) Option

Mukurimagu		
Required Tariff	$/kWh	0.57
Capital costs	$	$394,197
Maaeboodhoo		
Required Tariff	$/kWh	0.89
Capital costs	$	$376,487

Note: Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island.

7.8 Financial Analysis of Microprocessors and Improved Criteria for Distribution Design

The combination of both microprocessor control and reduced distribution design was able to reduce the capital cost dramatically, allowing for the project in both islands to become financial viable. The required average tariff has been reduced to a level which is accepted by the ADB Project as affordable, with the FIRR has exceeding the Weighted Average Cost of Capital.

As Mukurimagu and Maaeboodhoo were selected as typical small outer islands, the implication is that with designs incorporating improved distribution criteria and digital generator controls electricity supply of an internationally accepted quality can be afforded by small Maldivian outer islands.

In 2007, following a project based on power station digital control equipment and improved criteria for distribution, domestic customers in Mukurimagu would spend 8.6% of their income on electricity while in Maaeboodhoo they would spend 5.7%, which are within the affordability limits required for a loan from the ADB of commercial banks. This project would require an increase from the inadequate present tariff of 21% in Mukurimagu and 67% in Maaeboodhoo. It would be a community decision on each island to decide if they are willing to pay this higher tariff for an improved electricity supply.

Table 7.9: Financial Summary
Control Equipment with synchronising (Digital) plus reduced Distribution Design Option

Mukurimagu		
Required Tariff	$/kWh	0.51
Capital costs[1.]	$	$342,687
Maaeboodhoo		
Required Tariff	$/kWh	0.87
Capital costs[2.]	$	$363,954

Notes: 1. See Appendix L Table 9 4. See Appendix K Table 9
Tariffs for 2007 are adjusted to obtain a positive cumulative cash flow and a Financial Internal Rate of Return of 4.7% in order to exceed the weighted average cost of capital of 4.6% to the island. See Appendix H and I Table 6.

Table 7.10 Projected Capital Costs Mukurimagu AUS$
Control Equipment with synchronising (Digital) plus Reduced Distribution Design Option

SYNCHRONISING

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2022
Peak Load				50	44	46	48	51	54	56	59	62	66	69	73	77	81	85	89	94	99
Annual Electricity Sales	MWhpa			154	162	172	181	192	203	215	227	240	254	268	284	300	318	336	355	376	398
Number of Customers				142	145	148	150	153	156	159	162	165	168	172	175	178	182	185	189	192	196
	Unit	Size	Cost/Unit																		
Civil Works				156018																	
Diesel Generator, Installed	kW	18	15017																		
	kW	31	23681																		
	kW	40	29680	47482																	
	kW	48	30077						30077			30077									
	kW	68	30872									30872				30872			30872		
	kW	80	36715	2035															36715		
	kW	100	40331																		
Daily fuel tank / fuel lines				1551																	
Generator panels			17560	36673																	
Feeder Panel			187	3917																	
Governors/AVRs			23	7961														70		0	0
Distribution System per kW			700	60659		1591	1675	1764	1858	1957	2061	2171	2287	2409	2537	2673	2815	2966	3124	3291	3467
Service Lines per customer	Each		407	0	0	924	973	1025	1079	1137	1197	1261	1328	1399	1474	1553	1636	1723	1815	1912	2014
Meters	Each		44	0	0	100	105	111	117	123	130	136	144	151	159	168	177	186	196	207	218
Spares				2334																	
Tools	1330			7546																	
Inflation 1 years at 2.5%				16513																	
Total				**342687**	**0**	**2615**	**2754**	**2900**	**33131**	**3217**	**3388**	**64517**	**3759**	**3959**	**4171**	**35265**	**4628**	**4945**	**72722**	**5410**	**5700**

Table 7.11 Projected Capital Costs Maaeboodhoo AUS$
Control Equipment with Synchronising (Digital) plus Reduced Distribution Design Option

SYNCHRONISING

Year				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Peak Load				27	23	24	25	26	27	28	30	31	32	33	35	36	38	39	41	43
Annual Electricity Sales	MWhpa			74	78	82	86	90	95	100	105	109	114	119	124	130	136	142	148	155
Number of Customers				127	130	132	134	136	139	141	143	145	146	147	149	150	151	153	154	156
	Unit	Size	Cost/Unit																	
Civil Works				171710																
Diesel Generator, Installed	kW	18	13,210	15017																
	kW	31	18,485	47362								55454							18485	
	kW	40	20,298																40596	
	kW	48	20,617																	
Exhaust Systems				7829																
Daily fuel tank/ fuel lines				10325																
Governors/AVRs				7961																
Generator Control Panel				36673																
Generator Feeder Panel				3917																
Distribution System per kW			700	45226		175	175	175	175	218	239	215	225	234	244	255	266	277	289	301
Service Lines per customer	Each		407			407	407	407	407	506	556	501	522	544	567	592	617	644	671	700
Meters	Each		44			88	88	88	132	88	88	88	44	44	88	44	44	88	44	88
Spares				1670																
Tools				7388																
Inflation 1 years at 2.5%				8877																
Total				**363954**	**0**	**670**	**670**	**670**	**714**	**812**	**884**	**56258**	**791**	**822**	**900**	**890**	**927**	**1009**	**60084**	**1089**

Chapter 8:

Renewable Energy

8 RENEWABLE ENERGY

8.1 Introduction

This chapter introduces the topic of renewable energy, discusses the renewable energy resources in the Maldives, and considers the available design options for both solar and wind energy. It concludes that the most effective way of harnessing either wind or solar energy in hybrid with diesel generators. Hybrids are then specifically discussed in Chapter 9.

8.2 General

On Earth, sunlight is an incredibly important form of energy. Every day, the sun pours unimaginable amounts of energy into space. Some of it is in the form of infrared and ultraviolet light, but most of it is in the form of visible light. Some of this energy falls on the Earth, where it warms our planet's surface, drives ocean currents, rivers, and winds.

A number of different renewable energy technologies are technically feasible in the Maldives but most are not economically feasible. These include tidal energy, ocean thermal energy conversion (OTEC), wave energy, and gas from rubbish disposal and sewerage. Hydro is not technically possible because the islands are flat. Biomass is not possible because there are no forests, and not enough land to establish forests. The technologies which have immediate promise are solar and wind, which are considered further.

While the use of renewable energy has disadvantages and is higher in initial cost than is the use of fossil fuels, its use does have the clear advantages of minimal environmental damage and of being a source that is continually renewed. Over the past decades there have been many efforts made to use renewable energy for island public electricity generation use, especially in the Pacific. None of these projects have been viable in the medium term; however lessons can be taken from these experiences. In the small island situation, success with the use of photovoltaic (PV) has been limited to the telecommunication industry and for marine navigation lights[46].

For the development of renewable energy in the Maldives, it is important to take advantage of this large tropical atoll experience base.

8.3 Renewable Energy Technologies

8.3.1 Tidal Energy

Tidal Energy is produced by vast amounts of sea water shifting position with the tides. The movement of this water can be tapped for energy just as the movement of water can be tapped for hydro electric power. Several sites around the world commercially generate electricity by extracting energy from the tidal flow of the sea[47].

Such funnelling of huge masses of seawater moving with the tides cannot take place in the Maldives since the islands are small and the rising seawater simply flows around the islands with the land having little effect on the height of the tide. The islands of the Maldives have low tidal ranges, typically around 1.5 meters[48]. This small tidal range is typical of small islands around the world and makes it difficult to extract useful quantities of energy from the tidal flow for small island sites.

8.3.2 Ocean Thermal Energy Conversion (OTEC)

The surface of the ocean in the tropics is significantly warmer than the temperature of the sea at depth. This temperature differential can be the energy source for electrical generation.

Ocean Thermal Energy Conversion remains experimental and is not appropriate for consideration in the Maldives at this time for island electrification.

---

[46] *Solar Energy: Lessons from the Pacific Islands Experience.* Liebenthal, A., S. Mathur and H.A. Wade, World Bank Technical Paper No. 224, Energy Series, Washington, DC, May 1994.
[47] Source: www.actewagl.com.au/education /electricity/generation/ tidal.cfm
[48] Ministry of Communication Science and Technology 2005

8.3.3 Wave Energy,

Given the lack of commercially proven wave energy systems and their technical inappropriateness to supplement small energy flow grids, wave energy is not considered a practical electricity production approach for the outer islands of the Maldives at this time and is not analysed further in this study.

8.3.4 Renewable Energy from Biological Sources

For electricity generation, it is possible to operate engines by combustion, gasification or fermentation of biological materials. All these processes are inefficient for electrical production and require a large and continuous flow of the biological feedstock through the conversion system that generates the electricity. This in turn requires large areas of agricultural land for the production of the feedstock, areas which are not available on most islands of the Maldives.

8.4 Solar Power System

For some decades, solar photovoltaic (PV) systems have been used for rural electrification in remote areas. The great majority of systems that have been installed are low capacity, individual systems serving a family. In the last decade, an increasing number of PV panels have been connected to grid based systems to supplement conventional electrical generation systems. Although their capital cost remains high, their low cost of maintenance, lack of a fuel requirement and environmentally benign nature have made them increasingly attractive for both remote electrification and for supplementing conventional grid based electricity systems.

Solar power systems have been adopted by telecommunication companies' world wide to provide power for microwave repeaters and other equipment that must have the highest possible reliability of power supply. They are also widely used for navigation because of their reliability and relatively low cost.

The major problem with the use of photovoltaic for electricity generation is their cost and their variable output which is in proportion to the amount of solar energy available at any particular time. For most applications, some form of energy storage must be included, typically a storage battery, to accept the high energy levels when the sun is bright and to provide extra energy when the sun is weak or not present.

8.4.1 Photovoltaic (Solar Cell)

Photovoltaic cells are constructed by layering semiconductors into thin, flat sandwiches, called solar cells. These are linked by electrical wires and arranged on a panel of a stiff, non-conducting material such as glass. The panel itself is called a module. When sunlight is absorbed by these materials; the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the PV effect.

A single cell can produce only very tiny amounts of electricity-barely enough to light up a small light bulb or power a calculator. Nonetheless, single PV cells are used in many small electronic appliances such as calculators.

The performance of a solar cell is measured in terms of its efficiency at turning sunlight into electricity. Only sunlight of certain energies will work efficiently to create electricity, and much of it is reflected or absorbed by the material that makes up the cell. Because of this, a typical commercial solar cell has an efficiency of 15% about one-sixth of the sunlight striking the cell generates electricity. Low efficiencies mean that larger arrays are needed, and that means higher cost.

8.4.2 Storing Electricity

Photovoltaic panels make electricity in all kinds of conditions, from cloudy skies to full sunlight, in all seasons of the year. But they don't work at all during the night-time. To make electricity available after sundown, the energy must be stored during the day for later use. The usual storage device is a rechargeable battery.

The batteries used with PV arrays must be able to discharge and recharge again many times. They are also usually larger and more expensive than normal rechargeable battery.

Besides PV panels and rechargeable batteries, modern photovoltaic systems are usually equipped with some kind of electronic charge controller. The main job of the charge controller is to feed electricity from the PV panel to the battery in the most efficient manner and to prevent the solar panel from overcharging the battery. The charge controller also protects the solar panels from electrical damage

In many cases, people need the electricity stored in the rechargeable batteries for use with normal household appliances. The problem is that most of those appliances require 230 volts of alternating current (230V AC), whereas the battery output is always direct current (DC), usually at a much lower voltage. A device called a power inverter solves this problem by converting the battery's low-voltage direct current to 230volts of alternating current. Modern charge controllers often come equipped with their own built-in power inverters.

8.4.3 Solar Resource

There is little accurate measurement of the solar resource available in the Maldives, apart from the hours of sunlight for various locations.

However the US National Renewable Energy Laboratory (NREL) has simulated solar radiation figures for the various Maldivian islands contained in the data resource for their computer program HOMER[49].

[49] See Section 9.5

The NREL figures for average daily solar radiation and clearness index for the specified island were therefore used in this study. Details are given in Table 8.1 and illustrated in Chart 8.1.

Chart 8.1: Average Daily Solar Radiation and Clearness Index

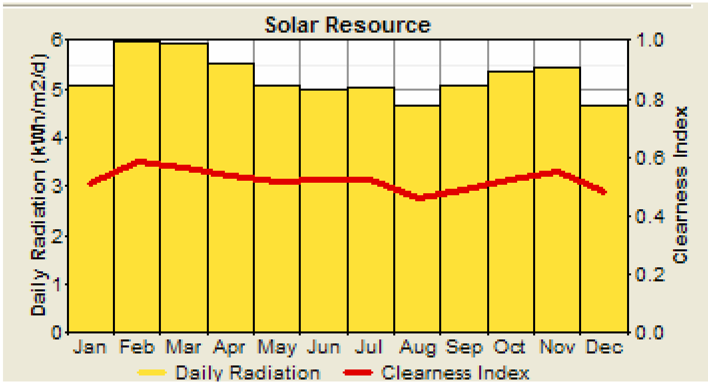


Table: 8.1: Solar Radiation Data

Month	Clearness Index	Daily Radiation (kWh/m²/day)
January	0.513	5.057
February	0.583	5.979
March	0.565	5.922
April	0.538	5.532
May	0.515	5.063
June	0.524	4.979
July	0.525	5.052
August	0.464	4.665
September	0.491	5.079
October	0.523	5.368
November	0.548	5.431
December	0.480	4.648
Average	0.522	5.225

Source: HOMER, US National Renewable Energy Laboratory (NREL)

8.4.3.1 Telecommunications Power in Maldives

While the use of photovoltaic for rural electrification has not been successful in the Maldives, Dhivehhi Raajieyge Gulhun Pvt. Ltd. (Dhiraagu), the Maldives telecommunications company, began using photovoltaics for powering outer island telephones in the 1980's[50]. They have continued increasing the scope and quality of their installations because they have provided a high reliability of service at an acceptable economic cost. Two classes of installations are presently in service. Small installations at island offices which have an

[50] Source www.dhiraagu.com

installed capacity of typically 30Wp of solar photovoltaic and large installations at nodes in the island microwave network.

8.4.4 Solar Power Options for Rural Electrification in the Maldives

It may be thought that the high availability of solar energy, the high cost of conventional electrical generation and the typically small loads may make PVs more economic in the small island situation than in urban areas.

8.4.4.1 Grid Distributed Photovoltaics

Grid distributed photovoltaics is the supply of electricity centrally generated by PVs. So far as the author is aware a PV grid system has only be tried once in an atoll situation. In the mid-80s the U.S. Department of Energy funded the installation of a 16kWp photovoltaic array, battery bank and 120V DC distribution grid as a central generation system for the main village on Utirik atoll. The system was seriously flawed technically and was not matched to the needs of the community. In particular the energy supplied to each customer was not metered, so as a result demand always exceeded supply. The scheme therefore never provided the desired level of service to the community and was instead the source of much frustration and disappointment. It has been decommissioned[51].

In 1994 a comprehensive ADB rural electrification study for the Marshall Islands concluded that the majority of the islands would be best electrified by individual solar systems, and that PV grids were not technically or economically viable on the Marshall Islands[49].

In any event the use of grid distributed photovoltaics generated electricity would be limited on most Maldivian outer islands by the lack of land to accommodate a central PV array.

Under the very best of conditions there is no more than 1kW of power falling per square meter of surface exposed to the sun and even under clear sky conditions the average power from the sun between sunrise and sunset is typically 500 Watts per square meter of exposed

[51] *Outer Island Electrification for the Marshall Islands,* Asian Development Bank, 1994.

surface. Since the sun does not shine at night, the clear day 24 hour average falls to around 250Watts per square meter. Thus to generate an average of 125kW with a 100% efficient system operating under a clear sky requires about 500 square meters of area. Since solar electrical conversion systems rarely exceed an overall efficiency of 10%, the actual area required for the 125kW solar power system would be more than 5000 square meters[52], a contiguous area difficult to find in the Maldives that has not already been assigned another use. The changing level of solar availability due to clouds, the area required for a reliable power system increases significantly, sometimes more than doubling. On the land starved Maldivian outer islands the allocation of 5,000 to 10,000 m^2 to accommodate a photovoltaic array would require relocation of a considerable number of families, and would be most unpopular with the communities.

8.4.4.2 Individual Stand-A –Lone Photovoltaic Units

An alternative to centralised PV generation is to located independent PV units at each residence. This has been the preferred method in the Pacific atolls, where photovoltaics have been installed. In rural areas of developing countries, the need for electrical energy is small with almost all households connected to an electrical grid consuming less than 1 kWh per day and most less than 0.3kWh per day. The cost of extending the grid for such small loads takes decades to recover if it is at all possible.

With a typical rural grid in a developing country, increased demand often results in unreliable service to all customers as the rated capacity of the grid to deliver power is exceeded. In some parts of India, many solar systems are sold to customers already connected to the grid because of the low quality and reliability of the rural grid power.

The experience with this form of PV based rural electrification is extensive with perhaps a half million homes electrified in the rural areas of developing countries by solar home systems. Despite this experience, most projects have been technical successes but

[52] *Renewable Energy for Outer Island Electrification, Republic of Maldives,* Asian Development Bank, December 2000

development failures in that the electricity supply has not been sustained more than a few years after its installation[64].

The reasons for these failures are almost universally institutional. Many projects carefully consider the technical aspects of the solar installations but virtually ignore the fact that they must be taken care of in order to operate in the long term[53].

What has yet to be well understood by aid donors when doing solar rural electrification project design is that what is being provided is not solar systems but electrical service. The institution managing the project must be organized around providing service for the long term and the technical design appropriate to that goal, not to the goal of maximum affordability, as is usually the case. To date the most successful solar rural electrification projects, i.e. those that have been able to provide a continuing and reliable electrical supply from solar generation over the long term without subsidy, have been those patterned after conventional power utility institutions. That is, the solar systems are treated simply as a source of generation which is owned, operated and maintained by the utility and users have no responsibility other than paying the fee for the electrical service provided and not abusing the installed systems.

Since the cost of diesel generated electricity falls as the load increases while solar power has little affected by scale, solar has the best comparative economics at low power levels. Also, the cost of installing a grid varies mainly according to distance between houses so in rural areas with widely separated houses installing a grid system may exceed the total capital cost of solar photovoltaic for each house. On the other hand, where houses are very dense, as in the Maldives, the grid cost is modest.

The economics of rural electrification solar systems can be good where all the following factors are present:

---

[53] World Bank, *Solar Energy: Lessons from the Pacific Islands Experience*

a) Where the average per household load is under one kWh per day;

b) Where there is little interest in owning refrigerators;

c) Where the systems are maintained by a professional organization; and

d) Where users are charged the real cost of operation and maintenance of the systems with the collected fees going directly and transparently into the support of the systems. If any of these factors are not present, either the life cycle cost of the solar becomes too high or customer satisfaction too low for the electrification to be considered a success.

In the Maldives, there are few, if any, locations where solar photovoltaic systems could be the preferred economic choice for further electrification. The majority of households in Maldives have refrigerators, irons, water pumps, television sets and other high demand appliances, and when used cause inverter failure and rapid discharge of the batteries.

8.4.4.3 Photovoltaic Generation in Hybrid with Diesel Generation

Given that neither centrally generated PVs or Stand-A-Lone PVs appear to be suitable to the conditions in the Maldives, see sections 8.3.4.1 and 8.3.4.2 above, the most likely application of PV generation for the outer islands appears to be in hybrid with diesel engines. This option is discussed in detail in Chapter 9.

8.5 Wind Power System

Wind energy has been around for hundreds of years. From old Holland to farms in Australia, windmills have been used for pumping water or grinding grain. Today, the windmill's modern equivalent, a wind turbine, can use wind's energy to generate electricity.

Stand-alone wind turbines are typically used for water pumping or communications. However, homeowners, and farmers, in windy areas also use wind turbines as a way to reduce their electric bills.

Small wind systems also have potential as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system.

8.5.1 Wind Turbine

Wind turbines, like windmills, are mounted on a tower to capture the most energy. At 10 meters or more above ground, they can take advantage of the faster and less turbulent wind. Turbines catch the wind's energy with their propeller-like blades. Usually, two or three blades are mounted on a shaft to form a rotor.

A blade acts much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the down wind side of the blade. The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn, this is called lift. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity.

Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or even combined with a photovoltaic (solar cell) system. For utility-scale sources of wind energy, a large number of wind turbines are usually built close together to form a wind plant.

8.5.2 Wind Power for Rural Electrification in the Maldives

Most tropical island sites, including the Maldives, have variable, seasonal winds with many months of the year having a low-speed wind regime which requires one type of wind turbine design for efficient electricity production followed by months of moderate winds which require a different turbine design. This makes system design a compromise that cannot be highly efficient in converting wind energy to electricity all year round.

The second, perhaps more serious, problem faced by installations in tropical islands is the high maintenance requirement resulting from the high humidity, high temperature, salt laden climate. It has mainly been this aspect that has prevented wind energy from being successfully used in tropical islands. For wind systems located in remote islands with little technical infrastructure, the maintenance needs of the wind systems tend to exceed the capacity of the support infrastructure and there are usually long periods between failure and when a repair is effected—if they ever are effected. An alternator failure which may take a week to repair in Australia may typically take months to repair in an isolated island.

8.5.3 Wind Resource in the Maldives

Wind data is available from three islands only, two airport islands and the island of Villingili. The data for Villingili is more detailed than for the airport islands, and has been used as surrogate data for the target island of Mukurimagu.

A simple wind classification with small wind power intervals scheme is used to represent the wind resource is presented in Table 8.2. The Maldives is moderately technically suited for outer island small wind turbine applications provided trees or other obstacles do not shelter the particular site.

Table 8.2: Wind Power Classification

Resource	Potential	Wind Power Density (W/m2)	Wind Speed (a) (m/s)
Large	**Small**	**@ 50 m agl**	**@ 50 m agl**
Fair	Moderate	225 – 250	5.8 – 6.0
Fair	Moderate	250 – 275	6.0 – 6.2
Fair	Moderate	275 – 300	6.2 – 6.4
Moderate	Good	300 – 325	6.4 – 6.5
Moderate	Good	325 – 350	6.5 – 6.7

(a) Mean wind speed is estimated assuming a sea level elevation and a Weibull distribution of wind speeds with a shape factor (k) of 2.0. The actual mean wind speed may differ from these estimated values by as much as 20 percent, depending on the actual wind speed distribution (or Weibull k value) and elevation above sea level.
(b) m agl is meters above ground level.

Data was collected on towers range from 20 metres, 30 meter and 40 metres high on the island of Villingili. The higher the tower is the mean speed of the month increase slightly as shown in the Tables 8.3, 8.4 and 8.5.

Table 8.3: Monthly Mean Values of Wind Speed in m/s for Villingili, Meteo Data report, Height: 20.0m

Month	2003	2004	2005	Mean	Mean of Months
Jan		5.2	4.0	4.7	4.6
Feb		3.7	5.1	4.4	4.4
Mar		3.0		3.0	3.0
Apr		3.3		3.3	3.3
May		6.8		6.8	6.8
Jun		5.5		5.5	5.5
Jul	3.2	4.9		4.1	4.1
Aug	4.6	3.8		4.2	4.2
Sep	4.3	5.0		4.7	4.7
Oct	5.1	3.7		4.4	4.4
Nov	2.7	3.0		2.8	2.8
Dec	4.2	4.7		4.4	4.4
mean, all data	4.1	4.4	4.6	4.3	
mean of months	4.0	4.4	4.6		4.4

Source: Ministry of Communication, Science and Technology 2005

Table 8.4: Monthly Mean Values of Wind Speed in m/s for Villingili, Meteo Data Report, Height: 30.0m

Month	2003	2004	2005	Mean	mean of months
Jan		7.0	5.1	6.2	6.1
Feb		5.0	6.5	5.7	5.7
Mar		3.7		3.7	3.7
Apr		3.7		3.7	3.7
May		7.6		7.6	7.6
Jun		6.1		6.1	6.1
Jul	4.0	5.6		4.9	4.8
Aug	5.4	4.4		4.9	4.9
Sep	5.1	5.6		5.3	5.3
Oct	5.7	4.2		4.9	4.9
Nov	3.6	3.9		3.7	3.7
Dec	5.8	6.3		6.0	6.0
mean, all data	5.0	5.3	5.8	5.2	
mean of months	4.9	5.3	5.8		5.2

Source: Ministry of Communication, Science and Technology 2005

Table 8.5: Monthly Mean Values of Wind Speed in m/s for Villingili, Meteo Data Report, Height: 40.0m

Month	2003	2004	2005	Mean	mean of months
Jan		7.2	5.3	6.3	6.3
Feb		5.2	6.8	5.9	6.0
Mar		3.9		3.9	3.9
Apr		3.9		3.9	3.9
May		8.1		8.1	8.1
Jun		6.4		6.4	6.4
Jul	4.4	6.0		5.3	5.2
Aug	6.0	4.7		5.4	5.3
Sep	5.4	6.0		5.7	5.7
Oct	6.0	4.4		5.2	5.2
Nov	3.9	4.1		4.0	4.0
Dec	6.0	6.5		6.3	6.3
mean, all data	5.3	5.6	6.0	5.5	
mean of months	45.3	5.5	6.1		5.5

Source: Ministry of Communication, Science and Technology 2005

8.5.4 Wind Direction Frequency Distribution

The diurnal wind speed distribution (or wind speed versus time of day) is influenced by site elevation, topography, and direct exposure to the monsoon flow.

The seasonal climate is depicted for four major regimes:

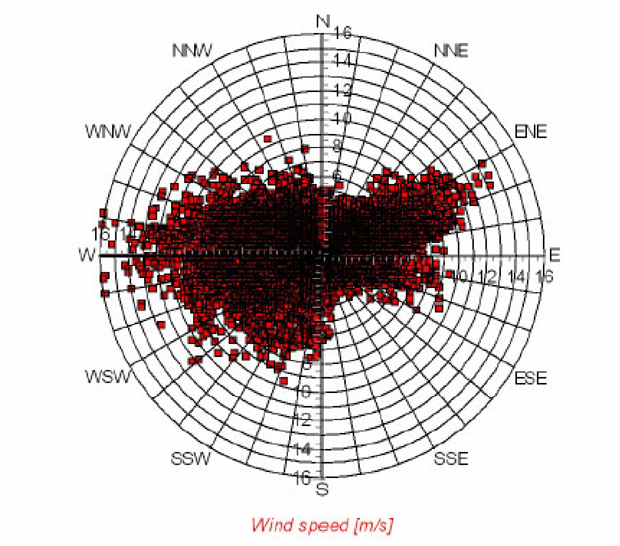
- The Northeast Monsoon (December through February),
- The Southwest Monsoon (May through September), and
- The inter-Monsoonal period March through April and
- The inter-Monsoonal period, October through November.

The prevailing wind directions throughout Maldives are directly related to the two monsoon flows. The prevailing directions during the southwest monsoon vary from south westerly along the western and northern coast to just south of due westerly along the south coast. See Charts 8.2 and 8.3.

The directions from the northeast monsoon are generally from the northeast throughout Maldives, though at some locations along the southern coast, the prevailing wind direction is more east-northeast.

The monsoon flows are remarkably persistent with exposed locations showing little or no variation in wind direction during the monsoon periods. The transition months of March, April, October, and November generally feature winds from both the west and northeast.

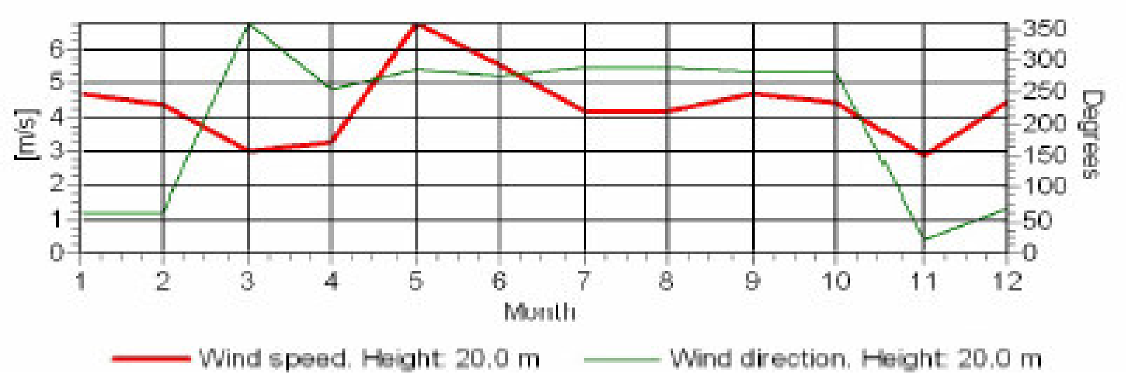
Chart 8.2: Wind Directions for a Twelve Month Period in Villingili

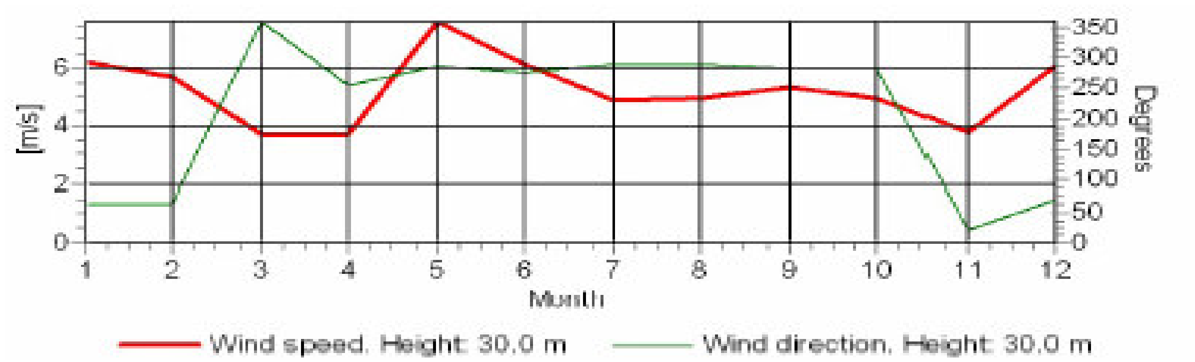


Source: Ministry of Communication, Science and Technology 2005

Chart 8.3: Wind Speed and Degree Distribution

(At heights of 20, 30, and 40 meters for a twelve month period for Villingili)





Source: Ministry of Communication, Science and Technology 2005

8.5.5 Application for the Maldives

Stand-A-Lone wind generators supplying individual customers, given the high density of housing is not an option. Using a wind farm to supply an island without assistance from diesels is also not an option given the variability of wind, and the long periods of no wind. As such periods can and do last many days at a time the use of storage batteries would not be practical.

Thus the application of wind generators in the outer islands will be as hybrid with diesel generators. As the existing distribution in the Maldives is alternating current, and all the privately owned appliance stock is suitable only to alternating current, the output of the wind turbine generator would need to be either alternating current or direct current converted to alternating current using an inverter. As wind generators are readily available for the generation of alternating current, the need for a costly inverter, and the electrical losses associated with an inverter, can be avoided.

Chapter 9:

Hybrid Systems

9 HYBRID SYSTEMS

9.1 Introduction

From the previous Chapter the only renewable energy/diesel hybrids considered suitable for application in the Maldivian outer islands are photovoltaic/diesel and wind/diesel.

This Chapter discusses the possible benefits of hybrid systems, the preference for centralised schemes. It then discuses the preferred manner in which the hybrids would be operated and the methodology of the design of each hybrid. Specific design of the hybrids is considered in Chapter 10.

9.2 Benefits

Renewable based generation technology used in hybrid with diesel generators saves diesel fuel. Where PVs are sufficient to supply the day load, with battery assistance, the scheme may extend the diesel engines' useful life, may improve diesel fuel efficiency and reduce diesel engine maintenance[54]. For the most part, the values of these factors are dependent on the load structure and the size of the installed diesel system. The relative size of the renewable and the diesel component is a critical design variable.

Hybrid systems provide the greatest benefit where there is little change from day to day in the pattern of electricity use. For the best long term benefit the load growth over the year should not be large.

A small economic advantage gained by the use of renewable based generation technology is the reduction of greenhouse gas emissions valued in carbon credits. Diesel generators exhaust carbon dioxide to the atmosphere in proportion to the fuel consumed. The fuel consumed depends on the load and the fuel efficiency of the diesel generator. In some countries carbon credits are tradable, however there is no carbon trading scheme in Maldives for the rural outer islands, thus there is not financial gain to the islands in conserving the amount of carbon emitted to the atmosphere.

[54] Battery charging from midnight to 5am may reduce inefficient diesel engine part load.

A generous economic value of carbon credits is $45.95 per 1000kg of diesel saved, which for a small outer island would result in the small amount of around $1500 a year. However for this project the economic return of the project is not counted[55].

9.3 Distributed Hybrid Systems

In some countries distributed hybrids have the benefit of relieving transmission and distribution lines of load, and thus reducing losses. Given the close domestic settlement on all Maldivian islands, and thus the compact geographic nature of the electrical load, it would seem better to centralise the equipment, thus saving on maintenance, and take advantage of economies of scale. Distributed hybrid systems are not further considered.

9.4 Centralised Hybrid Systems

Given the lack of land area and the type of housing, the hybrid system most suitable for the majority of the outer islands is the integrated type that locates all components together and includes a battery for storage and load levelling.

9.4.1 Diesel Generator Operation

As neither solar nor wind resources are constant they do not contribute to system reliability. For reliability reasons three diesel engines are required for each island with 80% of the capacity of the two smallest engines sufficient to meet the peak load[56]. It is an advantage if the hybrid schemes permits the diesel generators to operate in their efficient load range.

9.4.2 Photovoltaic Generation Operation

It is proposed that for the PV/Diesel hybrid, that the generation of the PVs, together with a possible contribution from batteries. The batteries would be charged by diesel generators from about midnight to 5am, thus providing a base load which should improve their efficiency. From calculations on HOMER, there is little financial benefit in storing the PV output in batteries to reduce the evening peak, as the diesel engines would in any event be

[55] The project investigates the value to the individual island of electricity options, not the value to the country as a whole.
[56] One engine must be available for service, or allowed to be faulty. Assuming synchronization the remaining engines are required to meet peak with a 20% margin, in order to provide sufficient capacity to clear faults at peak.

sized to meet the peak, and the cost of the additional batteries to reduce peak load would be high. On an average day[57], the project assumes that two thirds of the daytime energy load will be met by PVs, with the energy deficit met from the batteries. As the diesel engines would not be running, a battery bank is required to contribute to the load should a cloud pass over the sun on an otherwise fine day. When the day has less sunlight than an average day the diesel generators will be required to contribute to the PV/Battery deficit by commencing generation when the battery level falls to 60%. See Section 9.7.3.

Benefits are reduced diesel fuel consumption due to reduced load, and also higher diesel fuel efficiency by increasing the loading on the diesel generators during off-peak night periods, extended diesel generator lifetime and reduced maintenance due to diesel shutdown during most days.

9.4.3 Wind Generation Operation

The wind resources in the Maldives are very modest, with long periods of calm weather. While in theory it would be possible to operate wind generators as on the same regime as outlined for PVs above, a computer simulations, HOMER[58] indicates, that the optimum economics for wind technology in the Maldives occurs when the wind turbine feeds directly into the grid and offsets fuel requirements of the diesel engines, See section 9.8. This means that the costs associated with a battery, battery controller, and battery charger are avoided. The primary disadvantage of this approach is that the power input to the grid by the wind system should generally not exceed about 15% of the power level of the diesel generation[59].

Benefits are limited to fuel savings from reduced diesel load, but this is somewhat offset somewhat by reduced fuel efficiency of the diesel generators, which are pushed into operating into lower loads than optimal.

[57] An average solar combined with an average load day, at mid project duration in 2011.
[58] NREL, *HOMER*
[59] ADB, Renewable Energy for Outer Island Electrification, Republic of Maldives.

9.5 Operation and Maintenance

While there are certainly attractions to renewable based generation technology for rural electrification it is technically complex and the long term reliability of the system as a whole is not good unless a technician well trained in the troubleshooting and maintenance of the system is present and preventive maintenance measures are properly carried out. There will not be a sufficiently well trained technician on the outer islands and it would be expensive to transport a technician from the capital, Male'[60].

Since virtually all hybrid systems are special designs provided by distant companies with every installation unique, obtaining technical advice, spare parts and service for the specific control system installed is usually difficult and expensive, bordering on close to impossible for an outer island where technical expertise is usually limited to the repair of diesel engines[61], and where those who some technical ability rarely speak English.

As experience with operating hybrid systems is gained, increasing their complexity and level of automatic control may become reasonable but in the beginning, simplicity of design, operation and maintenance needs to be primary design criteria.

9.6 Hybrid Technical Design Using HOMER

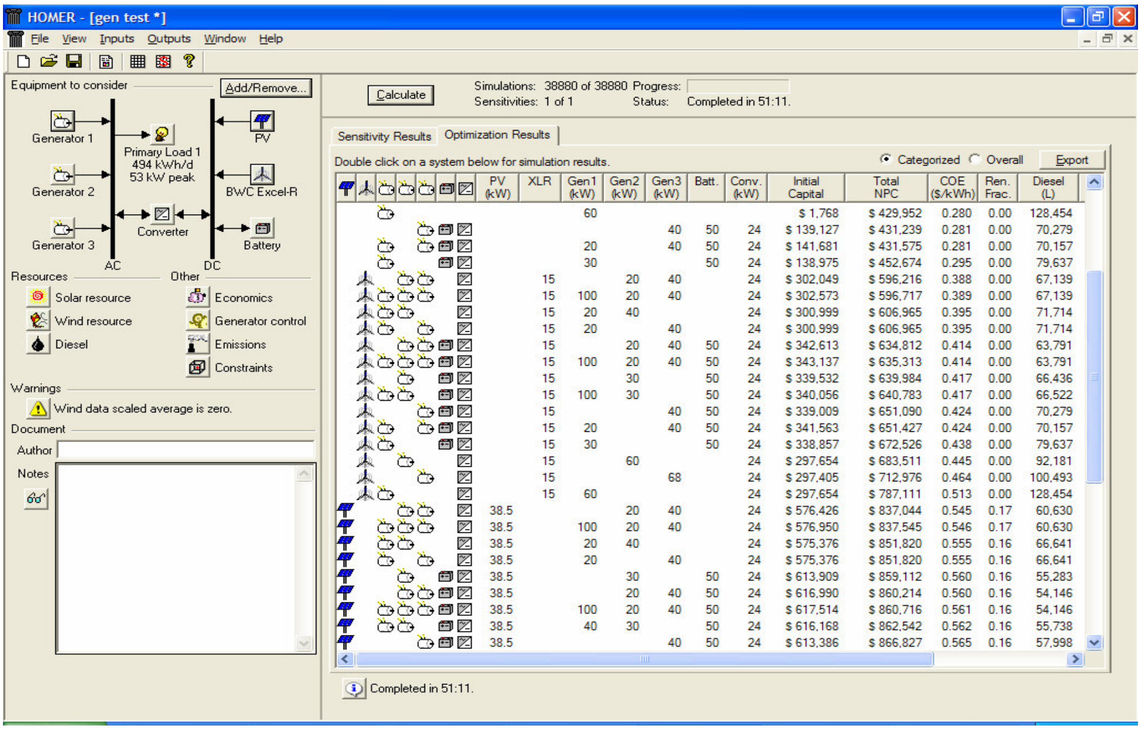
On most rural islands in the Maldives there are a large number of variables to be considered in designing a hybrid system, including the size of each major component, the solar and wind resource, the operating pattern and the load structure.

A computer simulation program, HOMER[62], developed and distributed by the US National Renewable Energy Laboratory (NREL) specifically for hybrid optimization, was used, by inputting the load patterns of the study island generation systems, and running the simulation resulting in an optimized hybrid system. While varying component sizes and characteristics,

[60] Cargo/passenger boats from the outer islands to Male' are irregular and slow, a round trip often taking two weeks. For most islands it is possible to do the round trip in two days using a speedboat, but they are expensive, of the order of AU$1,500 a day.
[61] Diesel engines are commonly used in fishing boats.
[62] NREL, *HOMER*

HOMER will produce hundreds of simulation for all possible system configurations. HOMER displays a list of configurations, sorted by net present cost that can use to compare system design options shown in Charts below.

Chart 9.1: From HOMER program for Mukurimagu



The island daytime loads are not static and change over time, often quite significantly, making, specific optimum design in HOMER for the present load pattern not practical.

Chart 9.2: Tabular Sensitivity Results From HOMER for Mukurimagu

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. ◉ Categorized ○ Overall Export

PV (kW)	XLR	Gen1 (kW)	Gen2 (kW)	Gen3 (kW)	Batt.	Conv. (kW)	Initial Capital	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)
		60					$ 1,768	$ 429,952	0.280	0.00	128,454
				40	50	24	$ 139,127	$ 431,239	0.281	0.00	70,279
		20		40	50	24	$ 141,681	$ 431,575	0.281	0.00	70,157
		30			50	24	$ 138,975	$ 452,674	0.295	0.00	79,637
	15		20	40		24	$ 302,049	$ 596,216	0.388	0.00	67,139
	15	100	20	40		24	$ 302,573	$ 596,717	0.389	0.00	67,139
	15	20	40			24	$ 300,999	$ 606,965	0.395	0.00	71,714
	15	20		40		24	$ 300,999	$ 606,965	0.395	0.00	71,714
	15		20	40	50	24	$ 342,613	$ 634,812	0.414	0.00	63,791
	15	100	20	40	50	24	$ 343,137	$ 635,313	0.414	0.00	63,791
	15		30		50	24	$ 339,532	$ 639,984	0.417	0.00	66,436
	15	100	30		50	24	$ 340,056	$ 640,783	0.417	0.00	66,522
	15			40	50	24	$ 339,009	$ 651,090	0.424	0.00	70,279
	15	20		40	50	24	$ 341,563	$ 651,427	0.424	0.00	70,157
	15	30			50	24	$ 338,857	$ 672,526	0.438	0.00	79,637
	15		60			24	$ 297,654	$ 683,511	0.445	0.00	92,181
	15			68		24	$ 297,405	$ 712,976	0.464	0.00	100,493
	15	60				24	$ 297,654	$ 787,111	0.513	0.00	128,454
38.5			20	40		24	$ 576,426	$ 837,044	0.545	0.17	60,630
38.5		100	20	40		24	$ 576,950	$ 837,545	0.546	0.17	60,630
38.5		20	40			24	$ 575,376	$ 851,820	0.555	0.16	66,641
38.5		20		40		24	$ 575,376	$ 851,820	0.555	0.16	66,641
38.5			30		50	24	$ 613,909	$ 859,112	0.560	0.16	55,283
38.5			20	40	50	24	$ 616,990	$ 860,214	0.560	0.16	54,146
38.5		100	20	40	50	24	$ 617,514	$ 860,716	0.561	0.16	54,146
38.5		40	30		50	24	$ 616,168	$ 862,542	0.562	0.16	55,738
38.5				40	50	24	$ 613,386	$ 866,827	0.565	0.16	57,998

Therefore, using the information developed from the simulation runs in HOMER and with help from engineers with experience in these areas, a general outline design was developed for the majority of Maldives outer islands, which are, comprised of domestic and commercial users. The island power systems that have industrial users do not fit this design as the day peak load would be too large.

9.7 Photovoltaic Generation Design

9.7.1 Use of HOMER

HOMER[60], was used, by inputting the load patterns of the study island generation systems and making hundreds of simulation runs while varying component sizes and characteristics. However while most useful in determining available component sizes and their unit prices HOMER was unable to optimize the battery size for meeting day load only. However it was able to confirm that our selection of PV panel size was optimal.

Given the approximate nature of the estimates of load growth for a particular island, any attempt to closely optimize the hybrid system more of an academic than a practical exercise.

9.7.2 Solar Panels

The area of solar panels was optimised using by varying the PV input on an interactive Excel sheets and observing which size of array gave the best financial internal rate of return. This was also checked on the HOMER program and identical solar array sizes were calculated.

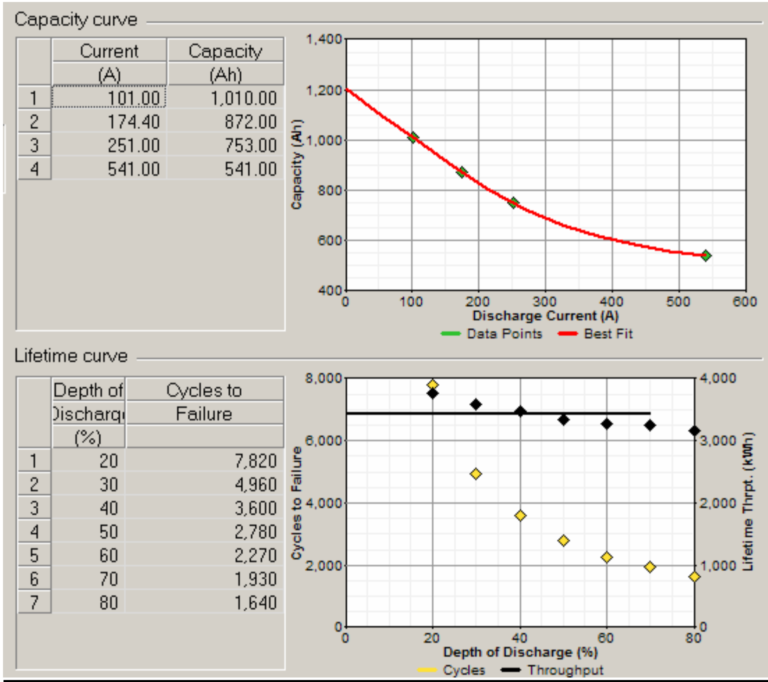
Conditions required to optimise the use of PVs also include:

- A daytime system load curve with reasonably level power requirements so the power converter can be optimized in capacity
- Sufficient area within 50 meters of the power station for installing the amount of solar panels to provide for all daytime power needs.
- No requirement for increased power station size to accommodate batteries and other balance of system components
- No expectation of rapid population increase on the island with associated unpredictable load growth.
- A system which uses a separate diesel engine for daytime operation that can be removed from operation.

9.7.3 Batteries

The chart below gives details of the Hoppecke 10OPzS1000 battery, typical of the stationary lead acid battery which would be used with a hybrid PV/diesel. A cycle of discharge is required daily, therefore for a projected 5years lifetime the battery should not generally exceed a design depth of discharge of 60%.

Chart 9.3: Properties of a Hoppecke 10OPzS1000



Source: HOMER

Battery lifetime depends on having a charger control devices that insures that neither the renewable energy generator nor the diesel generator will overcharge the battery

The major part of the recurring cost associated with the renewable component is the replacement of batteries.

Batteries need to be manually checked periodically to compare specific gravity of the electrolyte with terminal voltage to judge the internal condition of the plates.

An unexpected increase in the capacity of the electrical system will cause a dramatic increase in the cost of maintenance for the batteries, as it will increase the depth of discharge.

9.7.4 Inverter

A synchronizing inverter is required to convert the battery power to mains power and to share the load with the diesel engine.

For an atoll installation, the inverter is the weakest component as it is the most sensitive to heat, humidity and salt laden air. It is recommended that in the detailed design a rotary inverter be considered instead of the usual static inverter. Trials in Hawaii and Fiji indicate that a rotary inverter has lower maintenance costs and higher reliability of service than a static inverter in tropical marine climate applications though further trials are needed to confirm this preliminary conclusion. A static inverter provides the easiest interface for computer control and is the type usually used for integrated hybrid systems. Where computer optimized control is not used, that capability is not needed. A rotary inverter usually has a slightly lower efficiency of operation than the best static inverters but since the efficiency of an inoperative inverter is zero, the average lifetime efficiency of a more reliable rotary inverter can easily be better than that of a static inverter.

9.7.5 Computer Control System

A computer control system would determine how the load is divided between the battery bank and PVs, controls the charging of the battery, the loading on the diesel and the timing of load shifting from diesel to battery and back. The computer can automatically start the diesel and shift load to it when the battery comes near to the limit of its depth of discharge.

9.7.6 Solar Hybrid System Operation

The proposed solar hybrid operating pattern is similar to that observed in the power stations visited. The main difference would be that instead of bringing a small diesel on line for the day load, an inverter would be synchronised on line. Essentially, the cost benefit for the hybrid lies in the elimination of the use of the smaller diesel during the day though that will be partly offset by increased use of fuel at night when charging the battery, the amount depending on the level of charge received from the solar array on the previous day.

In theory some additional saving can be achieved by shifting to a smaller diesel after battery charging is complete and before sunrise, however that would require the attendance of an operator, so labour costs may exceed fuel savings.

9.8 Wind Generator Design

9.8.1 Use of HOMER

As with PV design, discussed above, the HOMER computer simulation program was used, inputting the load patterns of the study island generation systems and making hundreds of simulation runs while varying component sizes and characteristics.

For wind generation this was most useful as HOMER was able to optimize the turbine size against the load and wind resource and determine available component sizes and their unit prices.

9.8.2 Size Selection

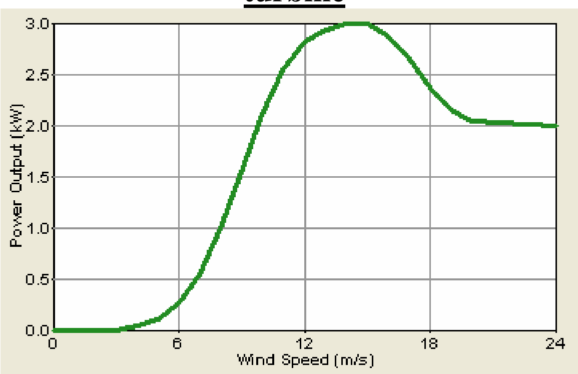
Unlike photovoltaics, which do not provide a significant reduction in generation costs with increasing size of the panels, different sizes of wind turbines do produce power at different rates. The larger the turbine, the lower the unit capital cost up to a level of about a megawatt. Most high quality wind sites in industrialized countries with high quality technical support, groups of individual turbines in the range of 150-250kW are considered the economic optimum for wind farms, with larger sizes expected to be the optimum for the future as designs evolve and experience with the larger systems is gained.

In the smaller Maldivian outer where the peak load is less than 100kW, it will not be practical to install wind turbines larger than 3 to 15kW, well under what would be considered an optimum size for a wind generator in a developing country.

9.8.3 Wind Turbine Selection

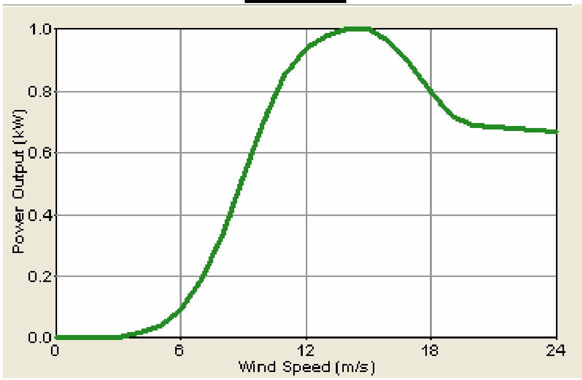
An important aspect of wind power is the nature of the resource. While solar power is a linear resource, that is, a doubling of solar energy results in a doubling of the electricity produced by solar panels, no matter what their design, wind power is non-linear. Doubling the wind speed results in an eight-fold increase in wind energy content but all that energy cannot be extracted from the wind. The actual relationship between wind speed and electricity output from a wind machine depends on the turbine design. For this reason, wind power economics are much more resource and device specific than solar energy. See Chart 9.4A and Chart 9.4B are properties of two wind turbines taken from HOMER.

Chart 9.4A: Power curve for 3 kW wind turbine



Source: HOMER

Chart 9.4B: Power curve for 1kW wind turbine



To complicate matters, wind resources are very site specific. Sites only a hundred meters apart may have very different wind resource characteristics due to interference with wind flow by trees or hills or due to concentration by landforms. For these reasons, resource surveys are much more important to the success of wind energy than for solar energy. Further, given the exponential nature of the energy in the wind, long term averages do not suffice to give a useful picture of the wind energy content. Hourly wind data or even better, continuous analysis of energy content, is needed to properly design and predict the performance of wind energy systems.

9.8.4 Components

Computer simulations indicate that the optimum economics for wind technology in the Maldives occurs when the wind turbine feeds directly into the grid and offsets fuel requirements of the diesel engines. This means that batteries, battery controller, and inverters are not required.

Chapter 10:

Proposed Diesel/Photovoltaic Hybrid System for Mukurimagu

10 PROPOSED DIESEL/PHOTOVOLTAICS HYBRID SYSTEM FOR MUKURIMAGU

10.1 Introduction

Following the methodology of design outlined in Chapter 9, a detailed design of the PV/diesel hybrid for the island of Mukurimagu is described. The design is then costed using international prices for PV and control equipment, and equipment and island prices for labour. International expertise is costed for installation, commissioning and training.

A financial internal rate of return analysis is carried out on the project comparing the benefits and costs of adding a PV hybrid to the existing diesel generation. The result was an FIRR of – 22%. The project would only be of benefit if the price of fuel rose eight fold from the present level, though at that price the island could not afford electricity at anything like its present rate of consumption.

A PV/Diesel hybrid is proven to be not financially viable.

10.2 Island Selection

The two target islands for this project are Mukurimagu and Maaeboodhoo. Of the two Mukurimagu is more suited to renewable applications because it has:

- A daytime system load curve with reasonably level power requirements so the inverter converter can be optimized;
- Sufficient area within 50 meters of the power station for installing the solar panels to provide for daytime power needs;
- No requirement for increased power station size to accommodate batteries and other balance of system components;
- No expectation of rapid population increase on the island with associated unpredictable load growth;
- A system which uses a separate diesel engine for daytime operation that can be removed from operation.

10.3 PV Hybrid Operation Design

The existing electricity system on Mukurimagu operates both during the day and night with a brief interrupt to change over the generators. The addition of the PV component would provide daytime power and eliminate the need either to operate the existing diesel at low power levels during the day.

- The diesel engine would run from commencement of the evening peak, typically 1800, to sunrise when street lighting is extinguished, typically 0700.
- The solar array supplemented by the battery array with a total capacity of 360kWh would provide all power demand from sunrise to the commencement of the evening peak
- All the photovoltaic array power will be used either directly for the load or for battery charging.
- The period of diesel operation from the end of the evening peak, from about midnight until sunrise would be used for battery charging as well as supplying the moderate night time load thereby insuring that the battery starts the day with a full charge.

10.3.1 Solar Climate

There are no suitable long term solar radiation data available for the Maldives. From HOMER[63] an estimate of average global solar radiation in the Maldives of 5.22kWh/m^2/day is used for the design. This value is equivalent to 5.22 hours per day of solar radiation at the panel's rated input of 1000W/m^2 shown in table below.

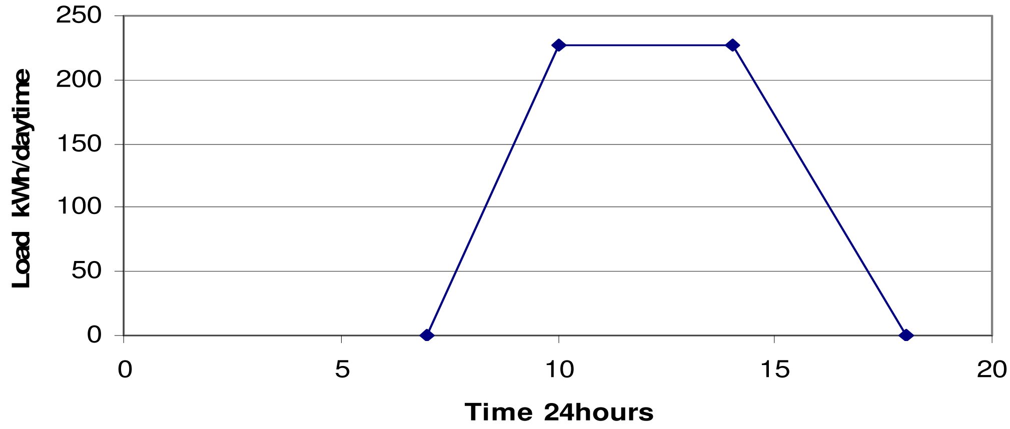
10.3.2 Operation of Photovoltaic Panel

On a clear day, the morning load from about 0700 to about 1000 would be partially met by the battery and partially by the solar array. Between about 1000 and 1400 the photovoltaic array would meet the full electrical load and recharge the battery, See chart 10.1. Between about 1400 and sunset, the load would be split between the photovoltaic array and the battery

[63] NREL, *HOMER*

resulting in an end of the day battery charge of about 90% which would be topped up to full charge by the diesel early the next morning.

Chart 10.1: Load Produced by the PV Array during the Day (0700 to 1800)



On overcast days, the daytime load would be carried mainly by the battery with the solar array providing less than 20% of the load. At the end of the day, the battery charge level would be 60% according to the level of cloudiness. The battery would be brought back to full charge by the diesel early in the following morning. Should the battery charge fall below about 50%, the operator should start the diesel early in the afternoon to insure that the battery life is not reduced by an excessively deep discharge level.

The result is to reduce the hours of operation of the diesel engine, thereby increasing its operational life and reducing maintenance as well as reducing fuel use.

The photovoltaic panel energy is fully utilized either by charging the battery or by meeting the daytime system load. The difference between the photovoltaic panel output and the daytime load, if any, is met by the diesel through battery charging. While the energy from the diesel through the battery has a 20% loss due to battery efficiency, this is at least partly offset since the fuel efficiency of the engine is improved by its higher loading while charging the battery.

From HOMER, given the typical Mukurimagu daytime load, the PVs supported by the battery, can be expected to deliver approximately 411kWh between 0700 and 1800, if the generator is not started. Using the above design criteria, this indicates a total battery design capacity requirement of approximately 135kWh. To minimize charger and controller amperages while keeping the total number of series connected battery cells manageable, a battery bank voltage of 240V (120 cells) is assumed.

Sufficient battery capacity to carry the system through cloudy periods is required. Therefore a base capacity of five times the daily requirement was used in the design. This results in an average discharge depth of about 60% which optimizes battery life.

10.4 PV Hybrid Design

10.4.1 General

The general design for Mukurimagu is outlined below:

- A battery array with a total capacity of 360kWh was assumed which approximately equals the energy required by the load during the daytime hours.

- An inverter with a peak capacity of 20kW.

- A panel array totalling 106kWp which under conditions at the site could be expected to produce an average of about 273kWh per day which is essentially 100% of the daytime energy requirement.

The load forecast developed for Mukurimagu in 2007 estimates generated energy growth from 242MWhpa to 311MWhpa by 2011. The annual night peak is calculated by dividing the generator units by the annual load factor.

A ratio of the average night peak to day peak was calculated at 1.93, from the daily load chart recorded by the portable data logger connected on Mukurimagu in March 2003. During Ramadan, in November, the night load is high compared to other months due to the use of refrigeration by most households, and because of house lighting left on throughout the night. Therefore an estimated ratio of the average night peak to day peak on annual peak day is 2.25 assumed.

The annual day peak load grows is the annual night peak divided by 2.25. The estimated day peak load that the renewable energy component would have to meet is expected to grow from 18kW to approximately 22kW by 2011.

The load critical component is the inverter, since the diesel can operate longer periods at full load in charging the battery to make up a lack of battery storage. However, if the inverter capacity is inadequate, the system will trip and the diesel will have to operate inefficiently at low load levels, offsetting much of the expected benefits from the renewable system. Therefore an inverter of at least 45kW should be installed. To provide operational flexibility and a lower cost spare parts inventory (at least one spare inverter should be on hand at all times), four 12kW inverters are proposed. To provide for motor starting and short term switching loads, the inverters should be capable of providing a 25% overload current for at least 5 minutes without overheating.

10.4.2 Panel Sizing

The amount of energy delivered to a lead-acid battery from a solar panel is determined by the level of solar radiation falling on the panel and losses in the panel/sun and panel/battery interface.

The panel manufacturer states for each panel its output in Watts when irradiated at 1000 W/m^2, with energy entering the panel at right angles to its clean surface, at a temperature of 25°C and loaded at an impedance matching that of the maximum power point of its voltage-current characteristic. As these conditions are rarely met in practice, actual panel output will be lower. The following output reductions were used for the project designs.

- Temperature above 25°C 10% loss

Panel power falls as cell temperature rises. In the hot, high sunlight environment of the tropical environment of the Maldives, cell temperatures of 40-60 degrees are likely.

- Increased surface reflection 3% loss

Glass surfaces have increased reflective losses at light incident angles less than 90 degrees. Most of the time, the sunlight will not be received at a right angle to the glass surface.

- Surface dirt 3% loss

Though dirt collection on solar panels in the Maldives is not a serious problem, it is sufficient to warrant a reduction in panel output of 3%.

- Battery/Panel impedance mismatch 5% loss

In order to achieve rapid battery recharge, 36 cell panels are specified. The maximum power point of a 36 cell panel usually is at a voltage higher than the average battery voltage and a typical mismatch of 4% to 6% occurs.

- General degradation of panel output with time 5% loss

Manufacturers consider long term degradation of less than 10% to be acceptable under their warranty terms. A degradation of 5% from the Wp specified is not unusual.

- Early morning and late afternoon shading 10% loss

Almost all sites in the Maldives have coconut trees or breadfruit trees which block early and late solar radiation from reaching the panel.

- Wiring and Battery Losses 30% loss

Losses in the controller and wiring amounting to 10% of panel input are assumed. Battery internal losses of 20% are assumed. Therefore the total wiring and battery losses are assumed to be 30%. This is equivalent to saying that only 70% of panel power can be used at the appliance. The panel must therefore provide 1/70% = 143% of the Watt hours as required at the load.

- Total power reduction from manufacturer's specification 50%

Total de-rated capacity = 0.80×0.97×0.97×0.95×0.95×0.90×0.70 = 50% of the panel Wp rating.

Under those conditions, daily output of the panel in Watt hours will be equal to the corrected panel peak Watts (Wp) times 5.22. So a 100 Wp panel reduced by 50% to a 64 Wp equivalent will provide 5.22 X 50% = 2.59 Wh/day under the design conditions. Thus for every 1 Wp of panel rated capacity, an actual output of 2.59 Wh/day will become available to the battery.

To produce an average of 274kWh per day, a total panel capacity of 274/2.59 = 106kWp rated capacity is needed. At 240V, this represents approximately 160A of maximum current that will need to pass through the charge control system. As with the inverter, a pair of 100A controllers is proposed to provide maximum flexibility and lower spare parts inventory costs.

The battery charger specification should be based on the maximum allowable rate of charge of the cells. With a total battery capacity of 360kWh at 240V, the Ah capacity is 1500Ah. Since deep discharge cells should not be continuously charged at a rate greater than C/10, a continuous battery charging capacity of 60 Amperes is adequate.

To summarize the components assumed for the solar system:

- **Panel Array** – 106kWp arranged to charge a nominal 240V battery bank;
- **Battery** – 120 deep discharge, open cell units at 560Ah or greater;
- **Charge Control** – Two 100A units;
- **Diesel powered charger** – 60A continuous capacity to charge a 240V battery;
- **Three Phase Inverter** – Four units having 240V DC in and 3 phase mains AC power out with each unit capable of 12kW continuous operation and 15 kW for five minutes.

The PV array can be developed immediately next to the power house it would require an open land area of approximately 925m^2, therefore some of the coconut trees would need to be removed.

10.5 PV Hybrid Base Cost Estimate

Cost estimates are based on figures published by the National Renewable Energy Laboratory of the US within the HOMER hybrid simulation program and are confirmed by prices published by manufacturers.

Currently solar panel prices are somewhat higher than in previous years due to a short term spike in demand caused by high demand resulting from huge subsidies in Europe. Very recent quotes have been around $5 per Wp, up from a low of $2.80 a year or so ago. Panel prices are expected to fall again when new manufacturing capacity now under construction comes on line. The real cost in the developing countries tends to be significantly higher, however, because

(1) Purchase quantities are usually too small to get top prices;

(2) Companies in the developing countries usually do not have access to manufactures due to small quantities of sales and must go through a middle-man to buy the equipment adding at least 15% to the manufacturer's wholesale price;

(3) Shipping and insurance is a significant cost and

(4) Installation costs may be high due to the cost of access to the remote sites (though that is somewhat offset by lower labour costs) and

(5) Often in developing countries, high cost specialists have to be brought in from outside to manage the installation work.

Costs in most cases were estimated using a number of comparative sources and on manufacturer’s list prices.

Because the design is preliminary with a detailed site survey required before a final design can be prepared, there is an estimated cost uncertainty of ±15% in the base cost estimate figures. However for financial analysis a 10% physical contingency is adopted to preserve consistency in the analysis with the diesel capital costs.

10.6 PV Hybrid Project Cost

The total cost of the project is $643,014, See Table 10.1. This includes the estimated capital costs of the proposed project, associated civil works, consulting engineering design and contract supervision, contingencies, interest during construction, monitoring for 30 months as well as including both physical and price contingencies and interest during construction.

Table 10.1 Base Cost Estimate Mukurimagu PV Hybrid (AUS$)

Item	Unit	Unit Cost	Quantity	Cost	Assumed Lifetime (years)
PV Component					
Solar Panels (106kWp @165Wp)	Panel	$462	322	$149,049	20
Ground level panel mounting racks (m^2)	m^2	$67	464	$30,873	20
Connection to power house	Meter	$13	150	$1,995	20
Battery (industrial grade cell at 1500Ah)	Cell	$904	120	$108,528	5
Battery Rack	Rack	$734	3	$2,202	20
Charge Controller	Each	$1,036	2	$2,072	10
Mains Charger	Each	$1,463	1	$1,463	10
Inverter and Load Controller	Each	$18,953	2	$37,905	10
Metering and Panel Controls	Each	$3,325	1	$3,325	20
Solar still for battery water	Each	$1,197	1	$1,197	10
Tools and Test Equipment	Kit	$3,059	1	$3,059	10
Installation, Commissioning and training		*Panel*	*Battery*	*Inverter*	
Site Survey		$4,877	$4,877	$4,877	$14,630
Detailed Design		$4,877	$4,877	$4,877	$14,630
component specification and purchasing		$4,877	$4,877	$4,877	$14,630
Assembly, supervision and Commissioning		$10,862	$10,862	$10,862	$32,585
Civil Works (footing for panel racks)		$11,970			$11,970
Civil Works (Trenching for connection cable)		$9,310			$9,310
(a) Per Diem		$4,389	$4,389	$4,389	$13,167
(b) International Travel		$3,547	$3,547	$3,547	$10,640
(c) Local Travel		$1,596	$1,596	$1,596	$4,788
(d) Communication		$665	$665	$665	$1,995
Sub Total Installation		$56,968	$35,688	$35,688	$128,345
Sub Total Purchase		$188,300	$115,462	$37,905	$341,667
Spare Parts @ 10%		$18,830	$11,546	$3,791	$34,167
Shipping and Insurance @10%		$18,830	$11,546	$3,791	$34,167
Local shipping, Warehousing and Wharfing @10%		$18,830	$11,546	$3,791	$34,167
Physical Contingency 15%		$36,790	$22,673	$11,039	$70,502
Total Solar		$338,549	$208,462	$96,004	**$643,014**

10.7 Financial Analysis

The approach used in determining whether PVs should be hybrid with diesel generators can be justified, was to perform a financial internal rate of return (FIRR) analysis for the addition of a PV system to the diesel generator. This analysis compares the benefits against the costs of the proposal. If the FIRR exceeds the WACC of 4.6% the PV hybrid is justified, that is the benefits justify the costs.

The following data are used in the analysis:

Table 10.2: Island Cost Data Used in Financial Analysis, AUS$

Item	Unit	Price
Fuel Cost	$/l	0.49
Lube Cost	$/l	2.59
Variable R & M @ AUS$ 0.0133 per kWh	$/MWh	13.30
Diesel Generator Efficiency Improvement @ 0.02l/kWh	l/MWh	20.00
Lube Consumption	l/MWh	5.14
Deferred Engine Purchase	Years	3
Increase in Fuel Efficiency due to Hybrid	%	5.0%
Carbon Credits per 1000kg of fuel	$	45.95

Credits were given for the reduction in diesel fuel and the extension of operating life for the diesel provided by the solar system allowing the diesel to be shut down during the day. Credit was given for the reduction of greenhouse gas due to lower fuel consumption. Greenhouse gas credit was included at $45.95 per 1000kg of fuel consumed.

The hybrid system has a generation cost much higher than the standalone diesel system. Considering only the incremental economic costs and benefits of the PV system, the financial Internal Rate of Return is calculated at -22%. A sensitivity analysis with respect to fuel indicated that the hybrid system would only become financially feasible when the cost of fuel is increased by eight fold. However under that scenario the consumption of electricity by the island would be greatly curtailed.

It is clear from this analysis that the costs of the project greatly exceed the potential benefits.

Table 10.3: Summary of Financial Analysis for photovoltaic hybrid proposals at Mukurimagu

Project		Capital Cost	Average Tariff	FIRR
	unit	$	$/kWh	%
Solar Investment (Renewable Only)		$643,014	Not applicable	-22%

Table 10.4 Financial Analysis solar Diesel Hybrid for Mukurimagu

Year		Mtce %	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total Number of Customers				145	148	150	153	156	159	162	165	168	172	175	178	182	185	189
Generated units	MWhpa			171	9	10	10	11	11	12	13	13	14	15	16	17	18	19
Annual Peak Load	kW			44	46	48	51	54	56	59	62	66	69	73	77	81	85	89
Daytime Peak Load	kW			18	19	20	21	22	23	24	25	26	27	29	30	32	33	35
Nighttime Peak Load				40	42	44	46	48	51	53	56	59	62	65	68	71	75	79
Photovoltaic Generation	MWhpa			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Photovoltaic Generation Cost																		
Solar Panels (106kWp @165Wp)	AUS$	0.05%	$149,049	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Ground level panel mounting racks (926m²)	AUS$	0.50%	$30,873	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154
Connection to power house	AUS$	0.00%	$ 1,995															
Battery (industrial grade cell at 560Ah)	AUS$	1.50%	$108,528	1,628	1,628	1,628	1,628	1,628	108,528	1,628	1,628	1,628	1,628	108,528	1,628	1,628	1,628	1,628
Battery Rack	AUS$	1.00%	$2,202	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
Charge Controller	AUS$	1.50%	$2,072	31	31	31	31	31	31	31	31	31	31	2,072	31	31	31	31
Mains Charger	AUS$	1.50%	$1,463	22	22	22	22	22	22	22	22	22	22	1,463	22	22	22	22
Inverter and Load Controller	AUS$	1.50%	$37,905	569	569	569	569	569	569	569	569	569	569	37,905	569	569	569	569
Metering and Panel Controls	AUS$	1.00%	$3,325	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Solar still for battery water	AUS$	0.50%	$1,197	6	6	6	6	6	6	6	6	6	6	1,197	6	6	6	6
Tools and Test Equipment	AUS$	1.00%	$3,059	31	31	31	31	31	31	31	31	31	31	3,059	31	31	31	31
Installation	AUS$		$128,345	2,341														
Spare Parts @ 10%	AUS$		$34,167															
Shipping and Insurance @10%	AUS$		$34,167															
Local shipping, Warehousing and Wharfing @10%	AUS$		$34,167															
Physical Contingency 15%	AUS$		$70,502															
Battery Losses (Cost of Diesel Fuel to Supply)	AUS$			4	4	5	5	5	10	10	10	10	10	10	10	10	10	10
Inverter Losses (Cost of Diesel Fuel to Supply)	AUS$			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total	AUS$		$643,014.20	4,918	2,576	2,577	2,577	2,577	109,483	2,583	2,583	2,583	2,583	154,520	2,583	2,583	2,583	2,583
Benefits																		
Saving in Fuel Cost @ 0.35l/kW for day time running	AUS$	0.35		14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546	14,546
Lub Cost @ 0.0023l/kWh	AUS$	0.0023		538	538	538	538	538	538	538	538	538	538	538	538	538	538	538
Variable R & M @ US$ 0.01 per kWh	AUS$	0.013		668	668	668	668	668	668	668	668	668	668	668	668	668	668	668
Deferred Engine purchase	AUS$			27,911						27,911							27,911	
Efficiency Improvement @ 0.02l/kWh	AUS$	0.02		1,999	-682	-673	-664	-654	-654	-654	-654	-654	-654	-654	-654	-654	-654	-654
Carbon Credits	AUS$			658	658	658	658	658	658	658	658	658	658	658	658	658	658	658
Total	AUS$		0	46,320	15,728	15,736	15,745	15,755	15,755	43,666	15,755	15,755	15,755	15,755	15,755	15,755	43,666	15,755
	AUS$		(643,014)	41,402	13,151	13,159	13,168	13,178	(93,728)	41,084	13,172	13,172	13,172	(138,765)	13,172	13,172	41,084	13,172
Cumulative Cash Flow			(643,014)	(601,612)	(588,461)	(575,301)	(562,133)	(548,955)	(642,683)	(601,599)	(588,427)	(575,255)	(562,083)	(700,848)	(687,676)	(674,503)	(633,420)	(620,247)
FIRR			-22%															

Chapter 11:

Proposed Diesel/Wind Hybrid System

For Mukurimagu

11 PROPOSED DIESEL/WIND HYBRID SYSTEM FOR MUKURIMAGU

11.1 Introduction

Following the methodology of wind design outlined in Chapter 9, a detailed design of the wind/diesel hybrid for the island of Mukurimagu is described. The design is then costed using international prices for wind turbine, tower, control equipment and installation. PV and, and equipment and island prices for labour. International expertise is costed for installation, commissioning and training.

A financial internal rate of return analysis is carried out on the project comparing the benefits and costs of adding a wind/diesel hybrid to the existing diesel generation. The result was an FIRR of – 13%. The project would only be of benefit if the price of fuel rose five fold from the present high level, though at that price the island could not afford electricity at its present rate of consumption.

A wind/diesel hybrid is proven to be not financially viable. As Mukurimagu is typical of the smaller outer islands, the indication is that wind/diesel hybrids will not be financially viable on any of the smaller islands.

11.2 Island Selection

Mukurimagu appears to be a suitable location for a wind hybrid as there is a large expanse of shrub covered land are not far from the proposed power station site which is well removed from residences. Also this location would not need tree clearing. On the other hand, it would be difficult to find a suitable location for a wind generator at Maaeboodhoo. Other than for the availability of a suitable site the two island present similar advantages and disadvantages for wind generation. Therefore the analysis is carried out for Mukurimagu, and the results would be broadly similar for Maaeboodhoo.

11.3 Design

It would appear to be financially advantageous to size the wind generator to operate directly in parallel with the diesel generators, rather than operating the wind generator with batteries. The HOMER program (See Section 9.6) confirms that operation of the wind turbine in parallel with the diesel generators without batteries is the least cost system. As the wind is not steady, fluctuation of wind turbine output must be taken up by the diesel generator without excessive system disturbance. This limits the maximum capacity of the wind contribution to around 15% of the minimum system load. See Section 9.4.3

In Mukurimagu the projected system maximum demand for 2011 is 54kW. Currently the ratio of peak to minimum load is 4 to 1, and this is expected to remain reasonably constant as the nature of the system load is not expected to change. Thus the projected minimum load in 2011 is expected to be around 13.5kW, while the maximum designed turbine output would be around 15% of that, or about 2 kW.

After entering daily load patterns of Mukurimagu and expected wind speed distributions into HOMER, and by varying the proposed sizes of the wind turbine, it was determined that 3kW wind turbine was the most cost effective size of wind turbine. Given the wind conditions assumed for Mukurimagu, HOMER calculated the average daily output of this turbine at 6.375kWh.

As wind turbines are generally rated for a wind speed of 10 m/s and as the expected monthly mean wind speed in Mukurimagu is 4.4 m/s, it is not surprising that HOMER selected an oversized turbine. However a 3kW turbine may require some load dumping in the year leading up to 2011. Fortunately the wind patterns in the Maldives do not include very high winds and when higher than average winds do occur they tend to be steady and without the rapid fluctuations that can lead to system stability problems.

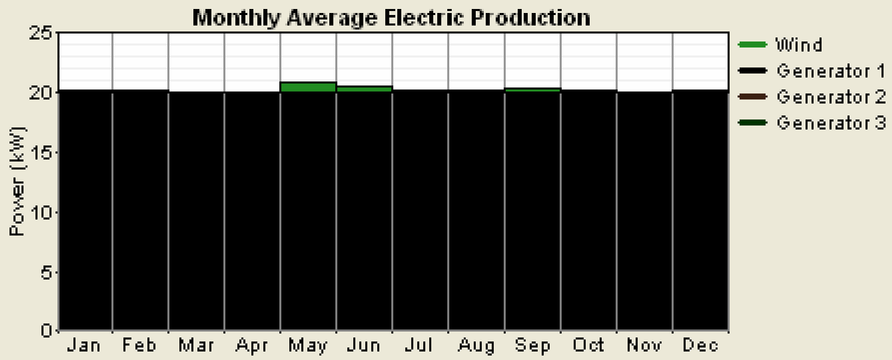
Because there is no battery storage, the only significant components for wind supplementation of the diesel system on Mukurimagu is the wind power unit and the synchronizing controls.

HOMER optimization studies indicate that such a turbine would generate about 1% of Mukurimagu's electrical energy needs, and that most of the energy generated would be in May and June. See Chart 11.1 below. This may be considered a disappointing result, as 1% is not significant. It would be difficult to persuade the local community to invest in this technology for such a reward. However the base problem is one of resource, the wind in the Maldives is intermittent and of generally low speed. In a number of months there is almost no wind.

Independently of this project a new power house is required on Mukurimagu and would be placed way from the residential area on the island. This allows a wind tower height of 20 meters. Preliminary estimates indicate that the western site may produce a higher level of energy generation over the course of a year; however a more uniform input from the wind system would be likely from the eastern site. A survey will need to be made to estimate the wind velocity lost in crossing the island and a detailed simulation of system performance over the course of a year will be necessary before the best site can be selected. Neither site will require major land clearing since the dominant vegetation in both areas are shrubs under three meters tall.

Chart 11.1: Annual Electrical Energy Production Calculated by HOMER

Annual electrical energy production			Annual electric loads served		
Wind turbine:	2,327 kWh	(1%)	AC primary load served:	89,060 kWh	
Generator 1:	175,398 kWh	(99%)			
Generator 2:	0 kWh	(0%)			
Generator 3:	0 kWh	(0%)			
Total production:	**177,725 kWh**		**Total load served:**	**89,060 kWh**	
Renewable fraction:	0.013		Excess electricity:	88,663 kWh	(50%)
			Unmet electric load:	0 kWh	(0%)
			Capacity shortage:	0 kWh	(0%)



11.4 Base Cost Estimate

Cost estimates, shown in Table 11.1, are based on figures published by the National Renewable Energy Laboratory of the US within the HOMER hybrid simulation program and are confirmed by list prices published by manufacturers, and by emailing a renewable engineer with experience in implementing renewable energy projects in Africa and the Pacific in the period 1997-2005.

No component escalation cost is included since for more than a decade the overall cost of wind systems have been constant in monetary terms and their real cost has been declining. Because the design is preliminary, with a detailed site survey required before a final design can be prepared, there is an estimated cost uncertainty of ±15% in the base cost estimates. However, to preserve consistency with the diesel capital costs a 10% physical contingency is used in the financial analysis. However the majority of costs are in installation, commissioning and training, not surprising considering the extreme isolation of the island.

Table 11.1 Base Cost Estimate Mukurimagu Wind Hybrid (AUS$)

Item	Unit	Unit Cost	Quantity	Cost $	Assumed Life (years)
Materials					
Wind Machine and control (Generic 3kW)	$/watt	$3.43	3000	10,289	10
Tower	m	$527	1	527	20
Connection	Meter	$13	120	1,596	20
Inverter and Load Controller	Each	$1,463	1	1,463	10
Tools and Test Equipment		$2,660	1	2,660	
Shipping and Insurance	$1,866	$146		2,013	
Local shipping, Warehousing and Wharfing	$1,866	$146		2,013	
Sub-Total Materials				**20,561**	
Installation, Commissioning and Training	*Wind*	*Inverter*			
Site Survey	$7,315	$7,315		14,630	
Detailed Design	$7,315	$7,315		14,630	
Component specification and purchasing	$7,315	$7,315		14,630	
Assembly, supervision and commissioning	$16,293	$16,293		32,585	
Civil Works (footing for panel racks)	$11,970			11,970	
Civil Works (trenching for connection cable)	$9,310			9,310	
(a) Per Diem	$6,584	$6,584		13,167	
(b) International Travel	$5,320	$5,320		10,640	
(c) Local Travel	$2,394	$2,394		4,788	
(d) Communication	$998	$998		1,995	
Sub-Total Installation	$74,813	$53,533		128,345	
Total Materials and installation				148,906	
Spare Parts				5,603	
Physical Contingency 15%	$14,021	$8,249		22,271	
Total Wind	$113,096	$63,684		176,780	

11.5 Financial Analysis

The approach used in determining whether there is financial justification for wind generation to be in hybrid with diesel was to perform a financial internal rate of return analysis comparing the costs of installing and maintaining a wind turbine against the benefit of fuel savings and carbon credits for reduction of greenhouse gases.

Greenhouse gas credit was included at $45.94 per 1000kg of fuel consumed, although it is noted that such greenhouse gas credits would not be returned to the island community, and perhaps more properly should be used in an economic analysis. However the credit was included to illustrate that it is not significant for this project.

It is clear that under the current cost conditions for capital investment, maintenance and fuel, that the addition of wind turbines to an island electrification project is not financially appropriate for Mukurimagu. When considering the incremental cost and benefit of the wind investment, the FIRR was negative at -13.0%. See Table 11.2

The hybrid system would only become financial feasible if the cost of fuel is increase by five times over its current very high cost, at which level the FIRR would exceed the island's WACC.

At current costs wind turbine hybrid is clearly not financially viable for Mukurimagu. It is almost certain that this conclusion would hold for Maaeboodhoo, or any other similar small outer island in the Maldives.

Table 11.2 Financial Analysis Wind Diesel Addition of Hybrid Wind for Mukurimagu

Year		Mtce %	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total Number of Customers				145	148	150	153	156	159	162	165	168	172	175	178	182	185	189
Generated units	MWhpa			145	148	150	153	156	159	162	165	168	172	175	178	182	185	189
average daytime energy	kW/day			165	169	172	175	178	182	185	189	192	196	200	203	207	211	215
Annual Peak Load	kW			44	46	48	51	54	56	59	62	66	69	73	77	81	85	89
Wind Generation (for Generic 3kW)	kWhpa			2327	2327	2327	2327	2327	2327	2327	2327	2327	2327	2327	2327	2327	2327	2327
Photovoltaic Generation Cost																		
Wind Machine and control	AUS$	1.80%	$10,289	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185
Tower	AUS$	1.20%	$527	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Connection	AUS$	0.00%	$1,596															
Spare Parts	AUS$	1.00%	$3,591	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Inverter and Load Controller	AUS$	1.50%	$1,463	22	22	22	22	22	22	22	22	22	22	1,463	22	22	22	22
Tools and Test Equipment	AUS$	2.00%	$2,660	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
Installation	AUS$		$128,345	303														
Spare Parts @ 10%	AUS$		$2,013															
Shipping and Insurance @10%	AUS$		$2,013															
Local shipping, Warehousing and Wharfing @10%	AUS$		$2,013															
Physical Contingency 15%	AUS$		$22,271															
Total	AUS$		$176,780	605	303	303	303	303	303	303	303	303	303	1,744	303	303	303	303
Benefits																		
Saving in Fuel Cost @ 0.35l/kW for day time running	AUS$	0.35		674	674	674	674	674	674	674	674	674	674	674	674	674	674	674
Lub Cost @ 0.0023l/kWh	AUS$	0.0023		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Variable R & M @ US$ 0.01 per kWh	AUS$	0.013		31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Efficiency Improvement @ 0.02l/kWh	AUS$	0.02		2,361	2,407	2,453	2,500	2,549	2,598	2,648	2,699	2,751	2,804	2,858	2,913	2,969	3,026	3,085
Carbon Credits	AUS$			0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431	0.431
Total	AUS$		0	3,092	3,137	3,184	3,231	3,279	3,329	3,379	3,430	3,482	3,535	3,589	3,644	3,700	3,757	3,815
	AUS$		(176,780)	2,487	2,835	2,881	2,929	2,977	3,026	3,076	3,127	3,179	3,232	1,845	3,341	3,397	3,454	3,513
Cumulative Cash Flow			(176,780)	(174,293)	(171,458)	(168,577)	(165,648)	(162,671)	(159,646)	(156,569)	(153,442)	(150,263)	(147,031)	(145,186)	(141,845)	(138,447)	(134,993)	(131,480)
FIRR			**-13%**															

Chapter 12:

Conclusion

12 CONCLUSION

12.1 Introduction

The ADB Outer Islands Electrification Project has adopted for the smaller islands the design and criteria used for the larger islands. This has seriously disadvantaged the smaller electrical utilities. The design for Mukurimagu resulted in a tariff which was not affordable by households, so the proposal was rejected by the ADB. In Maaeboodhoo the design resulted in a very sharp increase in tariff, which while affordable, was not acceptable to the island community.

The aim of this project is to investigate engineering means of providing an improved quality of electricity supply (to international standards) in these two islands at acceptable and affordable tariffs.

The project determined that a combination of improved distribution criteria and the adoption of digital control, protection, monitoring and synchronizing equipment will achieve that objective.

The use of wind and solar hybrids with diesel generators were investigated, and although technically practical, were not financially feasible

12.2 Review of Design Criteria

The distribution criteria used in the ADB Outer Islands Electrification Project required the immediate installation of equipment which would not be fully utilized for many years. Capital costs, and therefore tariffs, can be lowered by redesigning underground reticulation for a ten year projected load, by removing the constraint of 40% spare capacity of distribution boxes at commissioning, and by allowing for additional cable augmentation to meet increasing load beyond 10 years. However this alteration alone does not reduces costs sufficiently to make the provision of electricity to the smaller islands financial feasible.

12.3 Digital Metering, Control, Protection and Synchronizing Equipment

The study determined that the use of digital control equipment instead of analogue equipment would significantly lower capital costs, and thus lower tariffs. Such digital equipment is readily available from the major diesel-generator manufacturers for the size of diesel-generators used on the smaller outer islands.

The reduction in the capital cost by the use of digital control equipment on the two islands was sufficient to substantially reduce tariffs over that proposed by the ADB Project design, however the resulting tariffs, though affordable, and probably acceptable to the communities, could be lowered further by the combination of digital control equipment in the power station and improved underground cable distribution design.

12.4 Renewable Energy Hybrid

The lifetime generation cost[64] of the solar and wind hybrids examined were much higher than a stand-a-lone diesel system. The solar/hybrid system will only become financially feasible if the cost of fuel is increased eight times over the present very high price. A diesel/wind hybrid would only become financially feasible if the cost of fuel increased five times.

12.5 Recommendation for Improvement

The benefit of improved fuel efficiency with the improved load matching possible with synchronizing were not counted. This would further reduce required tariffs. Additional fuel efficiency improvements can be achieved by improved operation and monitoring the performance of diesel-generators. It would be an interesting project to investigate the practicability of real time motoring of diesel engine fuel efficiency using digital monitoring equipment.

[64] This includes all capital costs and operation and maintenance over a period of 15 years

References

List of References

Internet

- Ministry of Atolls Development website Accessed 5th April 2005, *www.atolls.gov.mv.*
- Chapter 2. PV Solar Electricity website Accessed 5th April 2005 *www.arts.unsw.edu.au/tsw/D87.RE.Ch.2PV.html*
- Maldives Information – Country Reports website, Accessed 5th April 2005 *www.countryreports.org/country.asp?countryid=151&countryName= Maldives.*
- Country Reports – Maldives Renewable Energy in South Asia Accessed 28th April 2005, *www.worldenergy.org/wec-geis/publications/reports/.../chap_2_4.asp*
- Cumin website Accessed 6th May 2005, *www.cummins.com/au/pages/en/index.cfm*
- Onan website Accessed 6th May 2005, *www.onan.com*.
- Universal Currency Converter, Accessed 11th May 2005, *www.xe.com/ucc.*
- ActewAGL website Electricity/ Generation/ Tidal, Accessed 21st February 2005, *http://www.actewagl.com.au/education/electricity/generation*
- US National Renewable Energy Laboratory (NREL) website "HOMER" Accessed 10th July 2005. *www.nrel.gov.*
- Dhiraagu website Accessed 28th May 2005, *www.dhiraagu.com.*

Renewable Energy Costs Internet Sites

- Trojan Deep Cycle Solar Batteries website. Accessed 14th July 2005, *www.store.yahoo.com/affordablesolar/Trojan.*
- Discount Solar website Accessed 5th April 2005 *www.discountpv.com*
- SolarBuzz website Accessed 14th July 2005, *www.solarbuzz.com*
- Go Power.com website Accessed 14th July 2005, *www.gopower.com/index.php*
- OutBack Power System website Accessed 15th July 2005 *www.outbackpower.com*

- Morningstar Corporation, the world's leading solar controllers website Accessed 15th July 2005, *www.morningstarcorp.com*

Reports

- *Solar Energy: Lessons from the Pacific Islands Experience.* Liebenthal, A., S. Mathur and H.A. Wade, World Bank Technical Paper No. 224, Energy Series, Washington, DC, May 1994.

- *Appraisal Report, Batch 1, Appendix 15, Mukurimagu*, *Republic of Maldive*s, Asian Development Bank. August 2003.

- *Draft Appraisal Report, Batch 2, Appendix 32, Maaeboodhoo*, *Republic of Maldive*s, Asian Development Bank, October 2005.

- *Renewable Energy for Outer Island Electrification, Republic of Maldive*s, Asian Development Bank, December 2000.

- *Appraisal Report, Batch 2, Outer Island Electrification, Republic of Maldive*s, Asian Development Bank. December 2005

- *Preparing the Outer Islands Electrification Study, Republic of Maldives*, Asian Development Bank TA3232 MLD, December 2000

- *Outer Island for the Marshal Island,* Asian Development Bank. 1994

- *Renewable-Energy-Based Rural Electrification in Pacific Island Nations*, Luis A.Vega, Ph.D. Pacific International Centre for High Technology Research 2800 Woodlawn Dr., Suite 180, Honolulu, Hawaii, June 1999.

- *Renewable Energy Training in Pacific Island Developing States*, United Nations, November 2004.

- *The Statistical Yearbook of Maldives,* Ministry of Planning and National Development, Male', Republic of Maldives

- *Vulnerability and Poverty Assessment, Republic of Maldive*s, United Nations Development Program, 1998.

Data

- Ministry of Communication, Science and Technology, 5th. Floor, BML Building Boduthakurufaanu Magu, Henveyru MV-MALE 20-05, WindPRO version 2.3.0.2, April 2003.

- Ministry of Atolls Development, 3rd Floor, MTCC Tower, Boduthakurufaanu Magu, Male' Republic of Maldives

Appendices

APPENDIX A:

Project Specification

PROJECT SPECIFICATION

FOR:	**Nofoaluma Isabel WORRALL**
TOPIC:	Analysis of Providing Affordable Electricity Supplies for the Outer Islands in the Maldives.
SUPERVISOR:	Ron Sharma
SPONSORHIP:	John Worrall Pty Ltd, Consultants Outer Islands Electrification, Republic of Maldives.
PROJECT AIM:	The project investigates the possibility of improving the affordability of electricity systems for the most vulnerable of the Maldivian Outer Islands by examination of the applicability of design and reliability criteria and the use of low cost digital control and synchronizing equipment. The project also investigates if renewable energy sources used in hybrid with the diesel generation equipment would be affordable.
PROGRAMME:	**Issue A, 17 November 2005**

1. Review and describe the exiting electricity systems in the outer islands of Maldives.

2. Select two typical poor and small outer islands as the basis of this study.

3. Describe the existing electricity supply on the two selected islands including the availability of electricity, existing electricity tariffs, stakeholder issues with electricity, the nature of the electrical demand and the condition and operating efficiency of existing electrical equipment.

4. Consider if the engineering methodology used in existing engineering planning, design and costing are appropriate for a poor community.

5. Methodology of Measurement of Lifetime Costs

6. Consider if the design and reliability criteria required are appropriate for a poor community.

7. Consider if digital control and synchronizing of diesel generators can significantly lower the lifetime cost of providing electricity to venerable island communities.

8. Consider if renewable energy sources such as photovoltaic or wind power can be used in hybrid with the diesel generation equipment to reduce fuel costs.

AGREED

______________________________ (student) __________________________ (supervisor)

(Dated) ___ / ___/ 2005

Appendix B:

Underground Cables Detail for Mukurimagu

(Under existing design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Table B.1: Power Cable Requirements for Mukurimagu

(Under existing design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Feeder A		PH1-A1	A1-A2	A2-A3	A3-A4	A4-A5	A5-A6	A6-A7	A7-A8
Sections		1	2	3	4	5	6	7	8
Length (m)		***289***	***148***	***70***	***77***	***113***	***77***	***96***	***119***
Cab. Size	16sq.mm	85.88	38.48	15.60	14.30	16.79	8.58	7.13	4.42
Cab. Size	25sq.mm	52.85	23.68	9.60	8.80	10.33	5.28	4.39	2.72
Cab. Size	35sq.mm	39.64	17.76	7.20	6.60	7.75	3.96	3.29	2.04
Cab. Size	50sq.mm	28.74	12.88	5.22	4.79	5.62	2.87	2.39	1.48
Cab. Size	70sq.mm	20.15	9.03	3.66	3.36	3.94	2.01	1.67	1.04
Cab. Size	95sq.mm	14.86	6.66	2.70	2.48	2.91	1.49	1.23	0.77
Cab. Size	120sq.mm	11.89	5.33	2.16	1.98	2.32	1.19	0.99	0.61
Cab. Size	150sq.mm	9.91	4.44	1.80	1.65	1.94	0.99	0.82	0.51
Max.A.Vd	40V								
PH-A8	39.57								

Feeder A	**Terminal Voltage**		**Current (A) at**		**Load (KW)**			**Power Loss**	
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Current (A)**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (KW)**
8	309	A8	I8	14.29	8.61	A8	8	0.000727	0.01766
7	311	A7	I7	28.57	8.61	A7	7	0.000727	0.05698
6	316	A6	I6	42.86	8.61	A6	6	0.000727	0.10282
5	321	A5	I5	57.14	8.61	A5	5	0.000727	0.26826
4	329	A4	I4	71.43	8.61	A4	4	0.000727	0.28562
3	335	A3	I3	85.72	8.61	A3	3	0.000727	0.37391
2	343	A2	I2	100.00	8.61	A2	2	0.000727	1.07603
1	360	A1	I1	114.29	8.61	A1	1	0.000727	2.74437
	Total			114.29	68.85				4.92565

Feeder B		FP1-B1	B1-B2	B2-B3	B3-B4	B4-B5	B5-B6	B6-B7	B7-B8
Sections		1	2	3	4	5	6	7	8
Length (m)		***253***	***158***	***116***	***97***	***82***	***109***	***96***	***82***
Cab. Size	16sq.mm	57.18	32.44	21.20	15.35	10.80	11.20	6.85	3.05
Cab. Size	25sq.mm	35.19	19.96	13.05	9.45	6.64	6.89	4.21	1.87
Cab. Size	35sq.mm	26.39	14.97	9.79	7.09	4.98	5.17	3.16	1.41
Cab. Size	50sq.mm	19.13	10.85	7.09	5.14	3.61	3.75	2.29	1.02
Cab. Size	70sq.mm	13.42	7.61	4.97	3.60	2.53	2.63	1.61	0.71
Cab. Size	95sq.mm	9.90	5.61	3.67	2.66	1.87	1.94	1.18	0.53
Cab. Size	120sq.mm	7.92	4.49	2.94	2.13	1.50	1.55	0.95	0.42
Cab. Size	150sq.mm	6.60	3.74	2.45	1.77	1.25	1.29	0.79	0.35
Max.A.Vd	40V								
PH-B8	35.67								

Feeder B	**Terminal Voltage**		**Current (A) at**		**Load (KW)**			**Power Loss**	
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Current (A)**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (KW)**
8	346	**B8	I8	14.29	8.61	B8	8	0.000727	0.01217
7	347	B7	I7	27.43	8.61	B7	7	0.000727	0.05251
6	350	*B6	I6	39.52	8.61	B6	6	0.000727	0.12377
5	354	B5	I5	50.65	8.61	B5	5	0.000727	0.15291
4	358	B4	I4	60.88	8.61	B4	4	0.000727	0.26137
3	363	B3	I3	70.30	8.61	B3	3	0.000727	0.41673
2	370	B2	I2	78.96	8.61	B2	2	0.000727	0.71612
1	381	B1	I1	86.93	8.61	B1	1	0.000727	1.38987
	Total			86.93	68.85				3.12545

*Friday Mosque

** School/Lab

Feeder C		PH-C1	C1-C2	C2-C3	C3-C4	C4-C5	C5-C6	C6-C7	C7-C8
Sections		1	2	3	4	5	6	7	8
Length (m)		***210***	***141***	***96***	***85***	***82***	***120***	***110***	***93***
Cab. Size	16sq.mm	54.52	32.84	19.66	14.89	11.81	13.35	8.44	3.75
Cab. Size	25sq.mm	33.55	20.21	12.10	9.16	7.27	8.21	5.19	2.31
Cab. Size	35sq.mm	25.16	15.16	9.07	6.87	5.45	6.16	3.89	1.73
Cab. Size	50sq.mm	18.24	10.99	6.58	4.98	**3.95**	**4.47**	**2.82**	**1.26**
Cab. Size	70sq.mm	12.79	**7.70**	**4.61**	**3.49**	2.77	3.13	1.98	0.88
Cab. Size	95sq.mm	**9.44**	5.68	3.40	2.58	2.04	2.31	1.46	0.65
Cab. Size	120sq.mm	7.55	4.55	2.72	2.06	1.64	1.85	1.17	0.52
Cab. Size	150sq.mm	6.29	3.79	2.27	1.72	1.36	1.54	0.97	0.43
Max.A.Vd 40V									
PH-C8	37.74								

Feeder C	Terminal Voltage		Current (A) at		Load (KW)		Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Current (A)**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (KW)**
8	336	C8	I8	15.53	8.61	C8	8	0.000727	0.01630
7	338	C7	I7	29.50	8.61	C7	7	0.000727	0.06961
6	343	C6	I6	42.78	8.61	C6	6	0.000727	0.15967
5	349	C5	I5	55.39	8.61	C5	5	0.000727	0.18292
4	355	C4	I4	67.38	8.61	C4	4	0.000727	0.28052
3	362	C3	I3	78.76	8.61	C3	3	0.000727	0.43292
2	371	C2	I2	89.57	8.61	C2	2	0.000727	0.82245
1	382	C1	I1	99.85	8.61	C1	1	0.000727	1.52202
	Total			**99.85**	**68.85**				**3.48642**

Feeder D		PH-D1	D1-D2	D2-D3	D3-D4	D4-D5
Sections		**1**	**2**	**3**	**4**	**5**
Length (m)		***105***	***227***	***103***	***142***	***129***
Cab. Size	16sq.mm	18.39	32.69	11.46	10.89	5.21
Cab. Size	25sq.mm	11.32	20.12	7.05	6.70	3.21
Cab. Size	35sq.mm	8.49	15.09	5.29	5.03	2.40
Cab. Size	50sq.mm	6.15	**10.94**	**3.83**	**3.64**	**1.74**
Cab. Size	70sq.mm	**4.32**	7.67	2.69	2.56	1.22
Cab. Size	95sq.mm	3.18	5.66	1.98	1.89	0.90
Cab. Size	120sq.mm	2.55	4.53	1.59	1.51	0.72
Cab. Size	150sq.mm	2.12	3.77	1.32	1.26	0.60
Max.A.Vd	**40V**					
PH-A8	24.48					

Feeder D	Terminal Voltage		Current (A) at		Load (KW)		Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Current (A)**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (KW)**
5	372	D5	I5	15.53	8.61	D5	5	0.000727	0.00056
4	374	D4	I4	29.50	8.61	D4	4	0.000727	0.00424
3	379	D3	I3	42.78	8.61	D3	3	0.000727	0.00938
2	383	D2	I2	55.39	8.61	D2	2	0.000727	0.04488
1	394	D1	I1	67.38	8.61	D1	1	0.000727	0.03736
	Total			**67.38**	**43.03**				**0.09642**

Table B.2: Assumed Numbers of Consumers on Distribution Boxes in 2022, Mukurimagu

(Under existing design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Feeder A		Feeder B		Feeder C		Feeder D	
DB	**2022**	**DB**	**2022**	**DB**	**2022**	**DB**	**2022**
A8	15	B8	15	C8	15	D5	15
A7	15	B7	15	C7	15	D4	15
A6	15	B6	15	C6	15	D3	15
A5	15	B5	15	C5	15	D2	15
A4	15	B4	15	C4	15	D1	15
A3	15	B3	15	C3	15		
A2	15	B2	15	C2	15		
A1	15	B1	15	C1	15		
Total	**120**		**120**		**120**		**75**

Appendix C:

Underground Cables Detail for Maaeboodhoo

(Under existing design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Table C.1: Power Cable Requirements for Maaeboodhoo with Criteria

(Under existing design criteria with a maximum allowable voltage drop of 10%,based on the forecasted load for year 2022)

Feeder A		PH-A1	A1-A2	A2-A3	A3-A4	A2-Ex1
Sections		**1**	**2**	**3**	**4**	**5**
Length (m)		***181***	***56***	***58***	***52***	***68***
Cable Size	16 mm2	**10.74**	**2.79**	**1.51**	**0.70**	**0.91**
Cable Size	25 mm2	6.61	1.72	0.93	0.43	0.56
Cable Size	35 mm2	4.96	1.29	0.70	0.32	0.42
Cable Size	50 mm2	3.59	0.93	0.51	0.23	0.31
Cable Size	70 mm2	2.52	0.65	0.35	0.16	0.21
Cable Size	95 mm2	1.86	0.48	0.26	0.12	0.16
Cable Size	120 mm2	1.49	0.39	0.21	0.10	0.13
Cable Size	150 mm2	1.24	0.32	0.17	0.08	0.11
Max.A.Vd	**40.00**					
PH-A4	15.74					
PH-A2/Ex1	14.44					

Feeder A	Terminal Voltage		Current (A) at		Load (KW)		Estimated Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Amps**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (kWhpa)**
5 (spur of 2)	406	A2-EX1	I5	5.19	3.13	A2-EX1	5	0.001150	3.5
4	404	A4	I4	5.19	3.13	A4	4	0.001150	2.6
3	405	A3	I3	9.97	3.13	A3	3	0.001150	11.0
2	406	**A2	I2	19.14	3.13	**A2	2	0.001150	39.0
1	409	*A1	I1	22.80	3.13	*A1	1	0.001150	178.8
	Total			**22.80**	**15.64**				**235**

Special Loads

* School

** Island Office

Feeder B		PH-B1	B1-B2	B2-B3	B3-B4	B4-B5	B5-B6	B3-B7	B2-Ex1
Sections		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length (m)		***80***	***104***	***101***	***99***	***101***	***96***	***128***	***99***
Cable Size	16 mm2	7.37	8.75	6.40	**5.41**	**4.51**	**3.26**	**2.83**	**1.73**
Cable Size	25 mm2	**4.54**	**5.39**	**3.94**	3.33	2.78	2.00	1.74	1.07
Cable Size	35 mm2	3.40	4.04	2.95	2.49	2.08	1.50	1.31	0.80
Cable Size	50 mm2	2.47	2.93	2.14	1.81	1.51	1.09	0.95	0.58
Cable Size	70 mm2	1.73	2.05	1.50	1.27	1.06	0.76	0.66	0.41
Cable Size	95 mm2	1.28	1.51	1.11	0.94	0.78	0.56	0.49	0.30
Cable Size	120 mm2	1.02	1.21	0.89	0.75	0.63	0.45	0.39	0.24
Cable Size	150 mm2	0.85	1.01	0.74	0.62	0.52	0.38	0.33	0.20
Max.A.Vd	**40**								
PH-B7	29.87								
PH-B2/Ex1	11.65								

Feeder B	Terminal Voltage		Current (A) at		Load (KW)		Estimated Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Amps**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (kWhpa)**
8 (spur of 2)	408	B2-EX1	I8	5.19	3.13	B2-EX1	8	0.001150	5.1
7	390	B7	I7	8.48	2.23	B7	7	0.001150	17.5
6	393	B6	I6	13.00	3.13	B6	6	0.001150	30.9
5	396	B5	I5	17.15	3.13	B5	5	0.001150	56.5
4	401	B4	I4	20.97	3.13	B4	4	0.001150	82.8
3	406	B3	I3	24.48	3.13	B3	3	0.000727	72.3
2	410	B2	I2	32.49	3.13	B2	2	0.000727	131.3
1	415	*B1	I1	35.35	3.13	B1	1	0.000727	120.4
	Total			**35.35**	**24.12**				**517**

Feeder C		PH-C1	C1-C2	C2-C3	C3-C4	C4-C5	C5-C6	C1-C7
Sections		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Length (m)		***229***	***100***	***50***	***46***	***96***	***99***	***79***
Cable Size	16 mm2	16.42	6.33	**2.67**	**2.04**	**3.57**	**2.55**	**1.07**
Cable Size	25 mm2	**10.10**	**3.89**	1.65	1.25	2.20	1.57	0.66
Cable Size	35 mm2	7.58	2.92	1.23	0.94	1.65	1.18	0.49
Cable Size	50 mm2	5.49	2.12	0.90	0.68	1.20	0.85	0.36
Cable Size	70 mm2	3.85	1.48	0.63	0.48	0.84	0.60	0.25
Cable Size	95 mm2	2.84	1.10	0.46	0.35	0.62	0.44	0.18
Cable Size	120 mm2	2.27	0.88	0.37	0.28	0.49	0.35	0.15
Cable Size	150 mm2	1.89	0.73	0.31	0.24	0.41	0.29	0.12
Max.A.Vd	**40.00**							
PH-C7	25.91							

Feeder C	Terminal Voltage		Current (A) at		Load (KW)		Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Amps**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (kWhpa)**
7	394	C7	I7	5.19	3.13	C7	7	0.001150	4.04
6	395	C6	I6	9.97	3.13	C6	6	0.001150	18.59
5	398	C5	I5	14.36	3.13	C5	5	0.001150	37.50
4	401	C4	I4	16.92	2.23	C4	4	0.001150	25.19
3	403	C3	I3	20.76	3.13	C3	3	0.001150	40.56
2	406	C2	I2	24.29	3.13	C2	2	0.000727	70.95
1	410	C1	I1	27.53	3.13	C1	1	0.000727	208.78
	Total			**27.53**	**21.00**				**406**

Table C.2: Assumed Numbers of Consumers on Distribution Boxes in 2022, Maaeboodhoo

(under existing design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Feeder A		Feeder B		Feeder C	
DB	2022	DB	2022	DB	2022
A2-Ex1	11	B2-Ex1	11	C7	11
A4	11	B7	8	C6	11
A3	11	B6	11	C5	11
A2	11	B5	11	C4	8
A1	11	B4	11	C3	11
		B3	11	C2	11
		B2	11	C1	11
		B1	11		
TOTAL	56		86		75

Appendix: D

Redesigning Underground Cables Detail for Mukurimagu

(Under a reviewed design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2017)

Table D.1: Power Cable Requirements for Mukurimagu Reduced Criteria

(Under a reviewed design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2017)

Feeder A		PH1-A1	A1-A2	A2-A3	A3-A4	A4-A5	A5-A6	A4-A4x1
Sections		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Length (m)		***198***	***179***	***82***	***179***	***82***	***124***	***96***
Cab. Size	16sq.mm	29.86	22.50	8.21	13.50	4.14	1.88	2.40
Cab. Size	25sq.mm	18.38	13.84	5.05	8.31	2.55	1.16	1.47
Cab. Size	35sq.mm	**13.78**	**10.38**	**3.79**	**6.23**	**1.91**	**0.87**	**1.11**
Cab. Size	50sq.mm	9.99	7.53	2.75	4.52	1.38	0.63	0.80
Cab. Size	70sq.mm	7.01	5.28	1.93	3.17	0.97	0.44	0.56
Cab. Size	95sq.mm	5.17	3.89	1.42	2.34	0.72	0.33	0.41
Cab. Size	120sq.mm	4.13	3.12	1.14	1.87	0.57	0.26	0.33
Cab. Size	150sq.mm	3.45	2.60	0.95	1.56	0.48	0.22	0.28
Max.A.Vd	**40V**	**38.07**						

Feeder A	Terminal Voltage		Current (A) at		Load (KW)		Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Current (A)**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (KW)**
7	365	A4x1	I7	9.65	5.81	A4x1	7	0.000529	0.00470
6	363	A6	I6	9.65	5.81	A6	6	0.000529	0.00612
5	364	A5	I5	19.29	5.81	A5	5	0.000529	0.01624
4	366	A4	I4	28.94	5.81	A4	4	0.000529	0.07952
3	372	A3	I3	38.59	5.81	A3	3	0.000529	0.06444
2	376	A2	I2	48.24	5.81	A2	2	0.000529	0.22080
1	386	A1	I1	57.88	5.81	A1	1	0.000529	0.35168
	Total			**57.88**	**40.68**				**0.74351**

Feeder B		FP1-B1	B1-B2	B2-B3	B3-B4	B4-B5	B5-B6	B2-B2x1
Sections		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Length (m)		***253***	***158***	***116***	***97***	***82***	***109***	***96***
Cab. Size	16sq.mm	35.07	19.50	12.40	8.63	5.69	5.25	2.41
Cab. Size	25sq.mm	21.58	12.00	7.63	5.31	3.50	3.23	1.48
Cab. Size	35sq.mm	16.19	**9.00**	**5.72**	**3.98**	**2.63**	**2.42**	**1.11**
Cab. Size	50sq.mm	**11.74**	6.53	4.15	2.89	1.90	1.76	0.81
Cab. Size	70sq.mm	8.23	4.58	2.91	2.02	1.33	1.23	0.56
Cab. Size	95sq.mm	6.07	3.38	2.15	1.49	0.98	0.91	0.42
Cab. Size	120sq.mm	4.86	2.70	1.72	1.19	0.79	0.73	0.33
Cab. Size	150sq.mm	4.05	2.25	1.43	1.00	0.66	0.61	0.28
Max.A.Vd	**40V**	**36.60**						

Feeder B	Terminal Voltage		Current (A) at		Load (KW)		Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Current (A)**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (KW)**
7	378	B2x1	I7	9.65	5.81	B2x1	7	0.000727	0.00650
6	365	*B6	I6	18.52	5.81	B6	6	0.000727	0.02719
5	367	**B5	I5	26.69	5.81	B5	5	0.000727	0.04246
4	370	B4	I4	34.20	5.81	B4	4	0.000727	0.08248
3	374	B3	I3	41.11	5.81	B3	3	0.000727	0.14254
2	379	B2	I2	47.47	5.81	B2	2	0.000727	0.25884
1	388	B1	I1	53.32	5.81	B1	1	0.000727	0.52292
	Total			**53.32**	**40.68**				**1.08293**

*Friday Mosque
** School/Lab

Feeder C		PH-C1
Sections		**1**
Length (m)		***210***
Cab. Size	16sq.mm	5.73
Cab. Size	25sq.mm	3.52
Cab. Size	35sq.mm	**2.64**
Cab. Size	50sq.mm	1.92
Cab. Size	70sq.mm	1.34
Cab. Size	95sq.mm	0.99
Cab. Size	120sq.mm	0.79
Cab. Size	150sq.mm	0.66
Max.A.Vd	**40V**	**2.64**

Feeder C	Terminal Voltage		Current (A) at		Load (KW)			Power Loss	
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Current (A)**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (KW)**
1	397	C1	I1	10.49	5.81	C1	1	0.000727	0.01679
	Total			**10.49**	**5.81**				**0.01679**

Table D.2: Assumed Numbers of Consumers on Distribution Boxes in 2017, Mukurimagu

(Under a reviewed design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2017)

Feeder A		Feeder B		Feeder C	
DB	2017	DB	2017	DB	2017
A4x1	12	B2x1	12	C1	12
A6	12	B6	12		
A5	12	B5	12		
A4	12	B4	12		
A3	12	B3	12		
A2	12	B2	12		
A1	12	B1	12		
Total:	84		84		12

Appendix E:

Redesigning Underground Cables Detail for Maaeboodhoo

(Under a reviewed design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Table E.1: Power Cable Requirements for Maaeboodhoo Reduced Criteria

(Under a reviewed design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Feeder A		PH-A1	A1-A2	A2-A3	A3-A4	A4-A5
Sections		**1**	**2**	**3**	**4**	**5**
Length (m)		***85***	***94***	***125***	***122***	***92***
Cable Size	16 mm2	**6.29**	**6.08**	**5.00**	**3.38**	**1.34**
Cable Size	25 mm2	3.87	3.74	3.08	2.08	0.82
Cable Size	35 mm2	2.90	2.81	2.31	1.56	0.62
Cable Size	50 mm2	2.11	2.03	1.67	1.13	0.45
Cable Size	70 mm2	1.48	1.43	1.17	0.79	0.31
Cable Size	95 mm2	1.09	1.05	0.87	0.59	0.23
Cable Size	120 mm2	0.87	0.84	0.69	0.47	0.18
Cable Size	150 mm2	0.73	0.70	0.58	0.39	0.15
Max.A.Vd	**40.00**					
PH-A5	**22.09**					

Feeder A	Terminal Voltage		Current (A) at		Load (KW)		Estimated Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Amps**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (kWhpa)**
5	406	A5	I5	5.56	3.35	A5	5	0.001150	5.4
4	399	A4	I4	10.68	3.35	A4	4	0.001150	26.4
3	403	A3	I3	15.39	3.35	A3	3	0.001150	56.2
2	408	**A2	I2	24.83	3.35	**A2	2	0.001150	110.3
1	414	*A1	I1	28.41	3.35	*A1	1	0.001150	130.6
	Total			**28.41**	**16.75**				**329**

Special Loads

* School

** Island Office

Feeder B		PH-B1	B1-B2	B2-B3	B3-B4	B4-B5
Sections		**1**	**2**	**3**	**4**	**5**
Length (m)		***251***	***85***	***82***	***93***	***140***
Cable Size	16 mm2	**15.49**	**4.35**	**3.28**	**2.59**	**2.03**
Cable Size	25 mm2	9.53	2.67	2.02	1.59	1.25
Cable Size	35 mm2	7.15	2.01	1.52	1.19	0.94
Cable Size	50 mm2	5.18	1.45	1.10	0.87	0.68
Cable Size	70 mm2	3.63	1.02	0.77	0.61	0.48
Cable Size	95 mm2	2.68	0.75	0.57	0.45	0.35
Cable Size	120 mm2	2.14	0.60	0.45	0.36	0.28
Cable Size	150 mm2	1.79	0.50	0.38	0.30	0.23
Max.A.Vd	**40**					
PH-B5	**28**					

Feeder B	Terminal Voltage		Current (A) at		Load (KW)		Estimated Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Amps**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (kWhpa)**
5	392	B5	I5	5.56	3.35	B5	5	0.001150	8.2
4	394	B4	I4	10.68	3.35	B4	4	0.001150	20.2
3	397	B3	I3	15.39	3.35	B3	3	0.001150	36.9
2	400	B2	I2	19.72	3.35	B2	2	0.001150	62.6
1	405	*B1	I1	23.70	3.35	B1	1	0.001150	268.1
	Total			**23.70**	**16.75**				**396**

Feeder C		PH-C1	C1-C2	C2-C3
Sections		**1**	**2**	**3**
Length (m)		***229***	***174***	***146***
Cable Size	16 mm2	**9.18**	**4.82**	**2.11**
Cable Size	25 mm2	5.65	2.97	1.30
Cable Size	35 mm2	4.23	2.23	0.97
Cable Size	50 mm2	3.07	1.61	0.71
Cable Size	70 mm2	2.15	1.13	0.49
Cable Size	95 mm2	1.59	0.83	0.37
Cable Size	120 mm2	1.27	0.67	0.29
Cable Size	150 mm2	1.06	0.56	0.24
Max.A.Vd	**40.00**			
PH-C3	**16.11**			

Feeder C	Terminal Voltage		Current (A) at		Load (KW)		Power Loss		
Section No.	**Voltage (V)**	**at DB No.**	**Node**	**Amps**	**Load (KW)**	**at DB No.**	**Section**	**Res. (Ω/m)**	**Loss (kWhpa)**
3	404	C3	I3	5.56	3.35	C3	3	0.001150	8.57
2	406	C2	I2	10.68	3.35	C2	2	0.001150	37.61
1	411	C1	I1	15.39	3.35	C1	1	0.001150	103.12
	Total			**15.39**	**10.05**				**149**

Table E.2: Assumed Numbers of Consumers on Distribution Boxes in 2022, Maaeboodhoo

(Under a reviewed design criteria with a maximum allowable voltage drop of 10%, based on the forecasted load for year 2022)

Feeder A		Feeder B		Feeder C	
DB	2022	DB	2022	DB	2022
A5	12	B5	12		
A4	12	B4	12		
A3	12	B3	12	C3	12
A2	12	B2	12	C2	12
A1	12	B1	12	C1	12
TOTAL	60		60		36

Appendix F:

Specification of PowerCommand Paralleling Generator Set Control

PowerCommand™ Paralleling Generator Set Control

Integrated Control System

The PowerCommand™ Control, is a microprocessor-based generator set monitoring, metering, and control system. It offers advanced levels of functions for reliability and optimum generator set performance.
An extensive array of integrated standard control and digital display features eliminates the need for discrete component devices such as the voltage regulator, governor control and protective relays.
It also eliminates the need for separate paralleling control devices such as synchronizers and load sharing controls, import/export controls, and var/power factor controls. The consolidation of controls allows the system to occupy much less physical space than conventional control arrangements.
The control system has sophisticated servicing capabilities that allow system parameters to be interrogated, monitored and adjusted with a laptop computer.

Comprehensive Standard Features

The control offers a wide range of standard control and digital display features, so custom control configurations are not needed to meet application specifications. System reliability is not compromised by the use of untested special components.

Reliability

The PowerCommand Control has been subjected to extensive hours of prototype and quality assurance testing at the factory and in the field. All control components are selected and integrated to withstand the vibration levels typical in a generator set installation. The control has been subjected to accelerated life tests to verify MTBF calculations in excess of 240,000 hours.

Single Source Solution

All the major components of our generating sets – the engine, alternator and control systems – are manufactured within the Cummins group, providing the assurance of a single source responsibility and servicing.

Major Control Features Include:

- **Digital governing, voltage regulation, synchronising and load sharing controls, including import/export controls for paralleling with an infinite (utility/mains) bus.**
- **AmpSentry™ Protection for true alternator overcurrent protection.**
- **Analog and Digital AC Output Metering.**
- **Battery Monitoring System to sense and warn against a weak battery condition.**
- **Digital Alarm and Status Message Display.**
- **GenSet Monitoring: Displays status of all critical engine and alternator generator set functions.**
- **Smart Starting Control System: Integrated fuel ramping to limit black smoke and frequency overshoot, in addition to optimized cold weather starting.**
- **Advanced Serviceability.**
- **PowerCommand Network Capability (optional).**
- **CE Compliant to Standard.**
- **Quality Assurance to ISO 9001.**
- **Dust, Water and Oil Resistant - Equivalent to IP54.**

Digital Governing, Voltage Regulation, Sychronizing, and Load Sharing Controls

The PowerCommand Control for Paralleling includes all governing, voltage regulation, synchronizing, and load sharing controls required for iolated bus paralleling applications. These functions were designed and prototype tested for optimum total system performance. Cummins Onan is the only **single source** manufacturer of engines, alternators, generator set controls, and paralleling electronics in the world. Single source experience and expertise results in a control system which meets the specifications of almost any situation, including demanding UPS and non-linear load applications. The controls are easy to adjust and transient performance is excellent.

Voltage Regulation Performance

- ***Voltage Regulation***
  ±0.5% from no load to full load.
- ***Voltage Drift***
  ±0.5% for 60°F (33°C) change in ambient over eight (8) hours with temperature stabilization at each point.
- ***Random Voltage Variation***
  For constant loads from no load to full load will not exceed ±0.5% of its mean value.

Governing Performance

- ***Frequency Regulation***
  Isochronous under varying loads from no load to full load.
- ***Frequency Drift***
  ±0.5% drift for a 60°F (33°C) change in ambient over 8 hours with temperature stabilization at both points.

Isochronous Real Load Sharing

- *Real load sharing controls allow generator sets to share load to within as low as 1% of equal. Load sharing controls operate directly on the engine governor actuator, to provide zero droop in frequency for loads from zero to 100% of rated generator set capacity.*
- *Kilowatt import and export control, to allow the generator set to share load with an infinite bus. The controls allow setting of ramping rate, and steady state operation level. Steady state kW load level can be based on a preset kW level, or on a signal from a remote control device which allows loading of the generator set as a function of the load provided by the utility (mains) service.*
- *Load demand ramping controls cause the generator set to ramp down to a low load condition prior to switching off on a load demand signal. On removing the load demand signal, the generator set will automatically start, synchronize to the system bus, and close at no load. The generator set then ramps up to its proportional share of the total load on the system.*

Isochronous Reactive Load Sharing

- *Reactive load sharing controls allow generator sets to share load to within as low as 1% of equal. Load sharing controls operate directly on the excitation system, to provide zero droop in voltage for loads from zero to 100% of rated generator set capacity.*
- *Reactive load sharing controls to allow the generator set to share reactive load with an infinite bus. The control system allows a technician to adjust the operating reactive load level on the generator set.*

Synchronizer

- ***Range:*** *The synchronizer can drive generator set frequency and voltage to a bus value which is –40% to +10% of selected voltage and frequency. Ramp speed for matchng is 4%/second.*
- ***Frequency Differential:*** *Controls generator set to match bus frequency.*
- ***Voltage Differential:*** *Electronically controls generator set voltage to within 1% of system bus voltage, and checks for correct phase rotation to bus.*
- ***Permissive Protection:*** *Adjustable for a phase difference of 5-20 degrees, with phase difference decreasing. Time delay is adjustable from 0.5 to 5 seconds.*
- ***Control System:*** *Automatically resets bus frequency and voltage to preset values after the paralleling breaker closes.*
- ***Includes "Dead Bus" Sensor:*** *Allows closure of the generator set to an inactive system bus.*

Control Panel Environmental Hardening

The front panel of the control is formed by a single membrane that covers the entire control surface. The control face is easy to clean and impervious to water spray, dust, and oil/exhaust residue. Electronic control switches for many functions are integral to the front panel. The control door is gasketed with a dual/moisture and RFI/EMI gasket to protect internal components from airborne contaminants. The control performs properly over a wide range of environmental conditions and is vibration, RFI/EMI, and surge tested.

- Operating Temperature: –40°C to +70°C.
- Storage Temperature: –40°C to +85°C.
- Humidity: Up to 95% relative, non-condensing.
- Altitude: Up to 3048 M (10,000 feet) without derating.

Controls and Adjustment Switches

An oil tight, three position switch starts and stops the generator set locally or enables start/stop control from a remote location. It provides the following functions:

- The *"OFF"* position de-energized all primary DC circuits. When the switch is in this position, the non-automatic indicator will flash continuously.
- The *"RUN"* position energized the control and initiates generator set starting operation.
- The breaker control switches are enabled only in the *"RUN"* position. The non-automatic indicator will flash when the switch is in the *"RUN"* position, indicating that the paralleling breaker will not automatically close.
- The *"AUTO"* position enables the control to receive a start signal from a remote location, such as an automatic transfer switch or master control panel.

Emergency Stop Switch

A two-position safety "mushroom" head switch provides an easy and obvious means to immediately shut down the generator set in the event of an emergency condition.

System Control

Control arrows on the screen lead the operator to information. The system control switches provide the operator with a positive indication that the switch is operated. The switches are totally sealed and designed to provide reliable service for the life of the generator set control.

Menu Selection Switches

These four switches allow the operator to select menu-driven control and monitoring information.

Menu "HOME" Switch
Returns the operator to the main menu selections screen, regardless of the position in the menu logic.

Panel Lights Switch
Turns the back-lit control illumination on and off, for easy reading of the entire control panel in dark lighting conditions. The panel lights automatically switch off after 5 minutes to save battery and lamp life.

Test Switch
Prompts the PowerCommand Control to perform a self-test and displays all fault messages.

Reset Switch
Clears the digital display and status panel and allows the generator set to start after a fault condition has been corrected.

Breaker Control Switches
Allows the operator to manually open or close the paralleling breaker when the control is in the *"RUN"* mode. The breaker close function is operated through a permissive function (with dead bus logic) to prevent accidental out-of-phase paralleling of the generator set with the system bus.

Adjustment Menu
Allow the operator to set basic generator set operating parameters. Adjustment ranges are limited to help prevent operator error and damage to connected equipment. Critical adjustments are possible only after entering an access code. Adjustments include:

- Voltage (±5%).
- Frequency (±5%).
- Time Delay Start (0-300 seconds).
- Time Delay Stop (0-600 seconds).

Critical service level adjustments are possible only after entering an access code. All operators and service level control system adjustments are made through digital raise/lower switches from the front of the control panel. The adjustment level is displayed on the control panel. There are no rotary switches or pots in the control system.

External Control Adjustments
All adjustments for automatic voltage regulation, engine speed governing, and other critical functions are performed directly on the control panel by using a security code and without entering the control enclosure.

Alarm and Status Message Display
Provides detailed information on all critical generator set parameters. Detailed messages provide a clear indication of problems with reference to the operator's service manual for further direction. Indicator lamps are high intensity, dual-element LED's for long life and easy reading in any lighting condition.

A two-line, 16 character-per-line, LED alphanumeric screen displays alarm and status messages and information regarding AC output, engine conditions, and adjustments via a menu-driven system. The operator can easily follow the logic path without the use of an operator's manual.

Status Indicators
Three dual-element LED indicating lamps provide basic generator set status information on the control face. Solid state indicators on internal circuit boards provide status and diagnostic information about the generator set.

Non-Automatic Indicator
When the Run/Off/Auto switch is in the OFF or RUN position, the red non-automatic indicator will flash on and off.

Warning Indicator
An amber light indicates the status screen is displaying a warning condition. The reset switch is used to clear the message after the warning condition is corrected.

Shutdown Indicator
A red light indicates the status screen is displaying a shutdown condition. The reset switch is used to clear the message after the shutdown condition is corrected.

Generator Set Monitoring
The digital display provides status of the following critical engine functions:

- Oil temperature (°F or °C).
- Coolant temperature (°F or °C). Left and right bank temperatures are provided for V-block engines.
- Oil pressure (PSI or kPA).
- Battery Voltage.
- Engine Operating Hours.
- Number of Engine Starts.
- RPM.
- Exhaust temperature (°F or °C). Left and right bank temperatures are provided for V-block engines (optional).

Engine Warning and Shutdown Messages
On sensing a warning or shutdown condition, the control displays the warning or shutdown message, lights the warning or shutdown indicator lamp on the front of the control, and provides a code number referenced to the generator set manuals. The manuals provide the operator with more information on the nature of the problem and how to get the generator set back into service. Functions provided include:

- Low oil pressure (warning).
- Low coolant temperature (warning).
- High coolant temperature (warning).
- Low coolant level (programmable warning or shutdown).
- Low Fuel – Daytank (warning, external input signal).
- Oil pressure sender (warning, indicates a sender or wiring failure in the oil pressure monitoring system).
- Engine temperature sender (warning, indicates a sender or wiring failure in the engine temperature monitoring equipment).
- Low oil pressure (shutdown).
- High coolant temperature (shutdown).
- Fail to crank (shutdown, indicates failure of engine to rotate on start command).
- Overcrank (shutdown, indicates cranking time exceeds 75 seconds or failed to start after all cycle cranking attempts).
- Magnetic pick-up failure (shutdown).
- Overspeed (shutdown, engine speed greater than 115% of nominal).
- Emergency Stop (shutdown).

The control has provisions for four programmable fault conditions. These may be either warning or shutdown conditions. Labels for customer faults can be programmed into the control.

The PowerCommand Control maintains an historical data log of the latest alarm and status conditions on the generator set. On an alarm or shutdown condition, the control logs the nature of the fault and the engine operating time that the fault occurred. This data log is useful for diagnosis of service problems on the generator set.

Control Options
☐ High alternator temperature alarm.
☐ Ground fault alarm.

Historical Data
The control displays the last 20 alarm and/or shutdown messages, along with the engine hour time that the condition occurred.

Duty Cycle Data
The control will display the number of engine operating hours at 0-10% load, 10-20% load, 20-30% load...., 100-110%, and 110-120% of rated kW capacity.

Generator Warning and Shutdown Messages

Overload - When total kW load exceeds 100% of the standby rating of the generator set (110% of prime rating) for 5 seconds, a load shed signal is issued and a warning alarm is activated.

Overcurrent - When the current on any phase exceeds 110% of the generator set rated current for more than 60 seconds, a warning alarm is activated.

Overcurrent - The generator set is shut down when the current on any phase is between 110-175% of rated and the time/current integral approaches alternator thermal limits.

Short Circuit - The generator set is shut down when the current on any phase exceeds 175% of rated and the time/current integral approaches alternator thermal limits.

Fail to Synchronize - The control system monitors the generator set as it is attempting to synchronize with a live bus, and initiates a fault signal if synchronizing is not achieved within an adjustable time delay period (10-120 seconds). The control system can be configured for warning, shutdown, or switching off this function.

Failure to Close - The control system monitors the paralleling breaker auxiliary contacts, and initiates a fault signal if the breaker fails to close within an adjustable time delay period after the control has signalled it to close (0.5-15 seconds). The control system can be configured for warning, shutdown, or switching off this function.

High AC Voltage - Generator set is shut down when AC voltage exceeds 110% for 10 seconds, or with no delay when voltage exceeds 130% of nominal.

Low AC Voltage - Generator set is shut down when AC voltage falls below 85% of rated voltage for more than 10 seconds.

Reverse Power - Generator set is shut down when kW flow into the generator set exceeds an adjustable set point (5-15% of generator set rating) for an adjustable time period (1-15 seconds).

Under Frequency - Generator set is shut down when AC frequency falls below 90% of rated frequency for more than 20 seconds.

Loss of Excitation - Generator set is shut down when kVAR is less than 0.16-0.41 per unit kVAR (adjustable) for more than 2-10 seconds (adjustable).

Phase Rotation - Prohibits paralleling when generator set phase rotation does not match system bus.

AC Output Metering

Combines digital and analog metering to provide accurate digital readout plus analog indication of trends and operating conditions.

Analog Meters

Analog metering on the control panel provides clear indication of generator set stability, including the magnitude of displacement and rate of change during load transients, which cannot be viewed as clearly with digital metering equipment. These meters are also ideal for "walk-by" status checks by the operator. All meters are 2.5 inch (63.5mm), 90 degree scale. Meter faces UV protected against discoloration from exposure to sunlight. The kilowatt meter and ammeter are scaled in percent of AC output for easy recognition of generator set status and load level (0-90% of rating: green; 90-100% of rating: amber; >100% of rating: red).

Kilowatt Meter: Indicates 3-phase AC power output as a percent of rated load. Provides a true indication of total kW load on the generator set, regardless of the load power factor. Scale is 0-125%. Accuracy is ±5%.

Frequency Meter: Indicates generator set output frequency in hertz. Calculated frequency is based on engine speed and alternator voltage zero-crossing and is not affected by voltage waveform distortion caused by non-linear loads. Scale is 45-65 Hz. Accuracy is ±0.5 Hz.

AC Voltmeter: Dual scale AC voltmeter indicates alternator output voltage. Accuracy: ±2%. Scales: 0-300 VAC, 0-400 VAC, 0-600 VAC; 0-750 VAC; 0-5260 VAC; or 0-15,000 VAC.

AC Ammeter: Indicates current output in percent of maximum rated standby current. Accuracy: ±2%. Scale: 0-125%.

Phase Select Switch: Allows the operator to select the phase monitored by the analog voltmeter and ammeter. LED indicators display which phase is being monitored and which voltage scale is applicable.

Digital Metering

The digital metering display provides access to alternator performance data and a more accurate readout of the AC output information displayed on the analog meters. The following outputs are included on the display:

- Generator set output voltage (3-phase, line-to-line, or line-to-neutral).
- Parallel bus voltage (3-phase, line-to-line).
- Generator set output current (3-phase).
- Power Factor (0 to 1, leading or lagging).
- AC Kilowatts.
- AC Kilowatt-hours.
- Alternator exciter duty and governor duty (%).
- Generator set output frequency (Hz).
- Parallel bus frequency (Hz).

The voltage and current data for all three phases is displayed simultaneously on a single screen so load and voltage balance is readily apparent.

Digital Synchroscope

The digital display includes a synchroscope function for monitoring the phase difference (in degrees, faster or slower than bus) between the generator set and the system bus. An indicator is provided to advise the operator when the generator set is within specified paralleling parameters.

AmpSentry Protection for Paralleling

AmpSentry Protection for paralleling is a comprehensive power monitoring and control system integral to the PowerCommand Control that guards the electrical integrity of the alternator and power system from the effects of overcurrent, short circuit, over/under voltage, under frequency and overload, reverse power, loss of excitation, alternator phase rotation, and parallel circuit breaker failure to close. Current is regulated to 300% for both single phase and 3-phase faults when a short circuit condition is sensed.

If the generator set is operating for an extended period at a potentially damaging current level, an overcurrent alarm will sound to warn the operator of an impending problem before it causes a system failure. If an overcurrent condition persists for the time pre-programmed in the time current characteristic for the alternator, the PMG excitation system is de-energized to avoid alternator damage. The overcurrent protection is time delayed in accordance with the alternator thermal capacity, allowing current to flow until secondary fuses or circuit breakers operate, isolating the fault and thus achieving selective co-ordination (discrimination). This enhances power service continuity by eliminating the need for a main line breaker mounted on the generator set, for generator set protection and the possibility of nuisance tripping of that breaker.

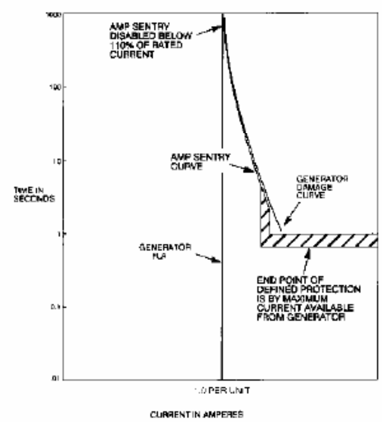
AmpSentry provides excellent, matched protection for the alternator, without the danger of nuisance tripping. The exact time current characteristics of AmpSentry are shown in the PowerCommand Control AmpSentry Time-Over-Current Characteristic Curve, Form Number R-1053.

After the fault is cleared, AmpSentry Protection softly loads the generator set by a controlled ramping of output voltage to rated level, allowing the generator set to resume normal operation without potentially damaging voltage overshoot.

Fixed over/under voltage and under frequency time delayed set points also provide a degree of protection for load equipment. Over/under voltage conditions trigger a shutdown message on the digital display screen. Under frequency condition prompt both a warning and shutdown message, depending on the length of time and magnitude of variance under rated frequency.

AmpSentry Protection includes an overload signal that can be use in conjunction with our transfer switches to automatically shed load, preventing a potential generator set shutdown. The overload signal is programmable for operation at a specific kW level, on the basis of an under frequency condition, or both.

AmpSentry Protection for Paralleling also includes protection for generator set reverse power, loss of excitation, alternator phase rotation, and circuit breaker failure to close. It includes permissive (synchronizing check) functions for automatic and manual breaker closure operations.



Digital Governing and Voltage Regulation

The PowerCommand Control includes all governing and voltage regulation. These functions were designed and prototype tested by the Company for optimum total system performance. The Company is the only single source manufacturer of engines, alternators, and generator set controls in the world. The experience and expertise of this true single source responsibility results in a control system which meets the specifications of almost any situation, including demanding UPS and non-linear load applications. The controls are easy to adjust and transient performance is excellent.

Digital Governing Performance

Frequency Regulation: Isochronous under varying loads from no load to full load.

Frequency Drift: ±0.5% drift for a 60°F (33°C) change in ambient over 8 hours with temperature stabilization at both points.

Voltage Regulation Performance

Voltage Regulation: ±0.5% from no load to full load.
Voltage Drift: ±0.5% for 60°F (33°C) change in ambient over eight (8) hours with temperature stabilization at each point.
Random Voltage Variation: For constant loads from no load to full load will not exceed ±0.5% of its mean value.

Smart Starting Control System

A multi-functional digital control system integrates fuel ramping and field excitation to minimize frequency and voltage overshoot and limit black smoke on starting.

Fuel Ramping

Upon receiving the start signal, the digital control system opens the engine fuel system only enough to allow the engine to fire. When the control system senses that the engine has reached start disconnect speed, it gradually increases fuel flow to ramp up the engine speed for a controlled acceleration to rated operating conditions. This process minimises black exhaust smoke, frequency overshoot, and improves cold starting capability.

Fail to Crank

As the start signal is initiated, the control checks the magnetic pick-up monitoring the engine speed to verify that the engine is rotating. If the engine is not rotating, the control switches off the starter and then makes another attempt. If the attempt fails, a shutdown message is signaled on the digital display screen and the generator set cannot be started until the fault is cleared. This process helps prevent starter or ring gear damage.

Temperature Dynamic Governing

A temperature dynamic adjustment capability enhances cold starting ability and improves stability when the engine is cold by automatically adjusting governing characteristics based on engine temperature. It also helps limit black smoke on starting.

Digital Excitation Control

The generator set voltage regulation system is 3-phase sensing and includes torque matching to provide single step, full load pick-up capability. During starting, the control ramps output voltage to rated value to minimise voltage overshoot.

Cycle Cranking

The PowerCommand Control includes a standard cycle cranking system that allows the operator to select continuous or cycle cranking mode. The operator can select 3, 4, 5, or 6 cranking cycles, and adjust the crank/rest times (7-20 seconds).

Idle Mode

Contacts are provided in the customer interface box to cause the control to start the generator set and operate it at idle speed. During idle mode, the excitation system is switched off. Idle mode can only be initiated from the *"RUN"* position on the generator set control. Idle speed is adjustable from 700-900 rpm.

Battery Monitoring System

The PowerCommand Control continually monitors the battery charging system for low and high DC voltage, and runs a battery load test every time the engine is started. Functions and messages include:

- Low DC voltage (battery voltage less that 25 VDC, except during engine cranking).
- High DC voltage (battery voltage greater than 32 VDC).
- Weak Battery (battery voltage less than 14.4 VDC for more than 2 seconds during engine cranking). This effectively load tests the starting battery every time the generator set is started.

First Start Sensor

The First Start Sensor System provides a positive interlock to prevent mulitple generator sets from simultaneously closing to a dead system bus. A back-up system is provided to allow normal system operation in the event that the primary first start sensor fails.

Customer Interface Box

All customer connections to the PowerCommand Control are made in an enclosure which is separate and isolated from the control equipment. Easy connection is possible with large, clearly labelled terminal blocks and terminals that do not require lugs for customer connections.

Output Contacts

The PowerCommand Control provides the following control, alarm, and status output contacts for customer use:

Common Alarm Relay - One form "C" contact, rated 2 amps at 30 VDC. Operates on all warning and shutdown conditions.

Common Shutdown Alarm Relay - One form "C" contact, rated 2 amps at 30 VDC. Operates on all shutdown conditions.

Load Shed Relay - One form "A" contact, rated 2 amps at 30 VDC. Operated when the "Overload" warning occurs.

Ready to Load - One form "A" contact, rated 2 amps 30 VDC. Operates when the generator set reaches 90% of rated voltage and frequency.

NFPA 110 Alarm Relays - One form "A" contact for each condition, rated 2 amps at 30 VDC. One contact set is provided for each required NFPA 110 warning or shutdown condition.

Auxiliary "Run" Relays (up to 3 optional) - Each relay provides three form "C" contacts, rated 2 amps at 30 VDC.

Breaker Operation Contacts - Provide breaker open and breaker close signals for a paralleling circuit breaker. Contacts are rated 5 amps at 30 VDC.

DC Power Supply

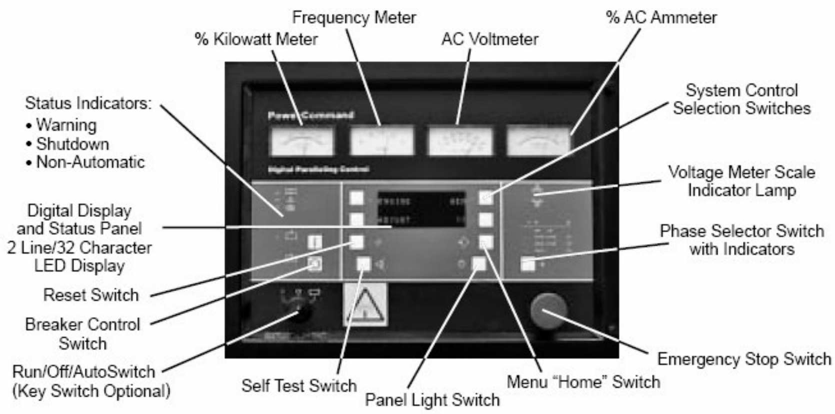
The PowerCommand Control is powered by the generator set starting batteries. The control functions over a voltage range from 8 VDC to 34 VDC. The control provides DC auxiliary power for customer use:

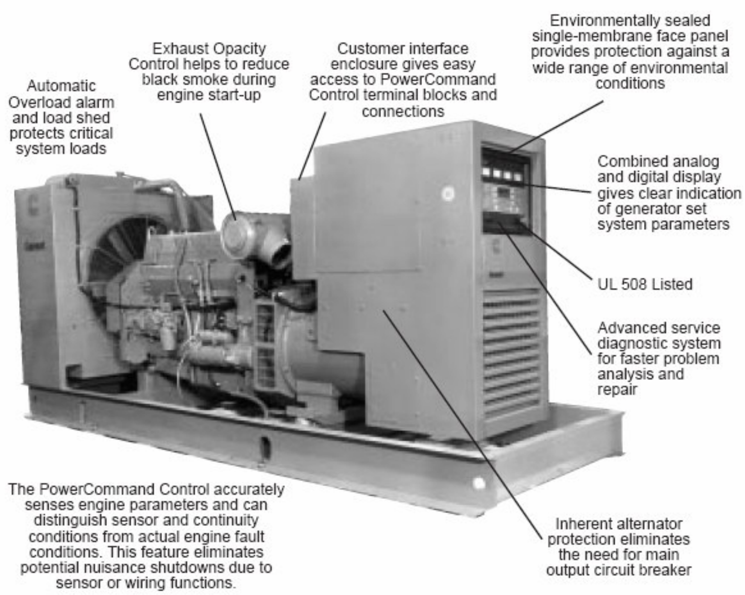
- 10 amp 24 VDC fused switched B+ supply.
- 20 amp 24 VDC fused B+ supply.

PowerCommand Communications Network

The PowerCommand Control includes provisions for optional communications over the PowerCommand Network. The network is suitable for local or remote control and monitoring functions using PowerCommand Software for Windows™ and network modules.

PowerCommand™ Paralleling Generator Set Control





Codes and Standards

The PowerCommand Control meets or exceeds the requirements of the following codes and standards:

- **UL508 -** Category NIWT7 for US and Canadian Usage.
- **UL489 -** Overcurrent performance verified by U.L.
- **ISO 8528-4 -** Control systems for reciprocating engine-driven generator sets.
- **Canadian Standards -** 282-M1.
- **CSA C22.2, No. 14 - M91** for Industrial Control Equipment.
- **NFPA 70 -** US National Electrical Code.
- **NFPA 110 -** Emergency Power Systems. Meets all requirements for Level 1 systems.
- **AS3000SAA Wiring Rules.**
- **AS3009 Emergency Power Supplies.**
- **AS3010.1 Electrical Supply by Generator Sets.**
- **Mil Std 461 Electromagnetic Emission and Susceptibility Requirements.**
- **IEC801.2 Electrostatic Discharge Test.**
- **IEC801.3 Radiated Susceptibility.**
- **IEC801.5 Radiated Emissions.**

These standards define the ability of the entire control system to withstand various electromagnetic interference levels and not interfere with the operation of other devices.

- **IEC801.4 Electrically Fast Transient.**
- **IEC801.5/IEEE587 Surge Immunity.**

These tests demonstrate that the control system is highly resistant to failure due to voltage surges.

Cummins Power Generation – Australia and South Pacific
2 Caribbean Drive
Scoresby, Victoria 3179
Australia
Phone: (61-3) 9765-3222
Fax: (61-3) 9764-0034
Email: cumminsa@ozemail.com.au

Cummins Power Generation – Southeast Asia
8 Tanjong Penjuru
Singapore 609019
Phone: (65) 265-0155
Fax: (65) 265-6909, 264-0664
Email: mktg@sing.cummins.com

Cummins Power Generation – Japan
Ark Mori Building 17F
12-32 Akasaka 1-Chome
Minato-Ku, Tokyo 107
Japan
Phone: (81-3) 5562-5531
Fax: (81-3) 5562-5485
Email: c.support@jp.cummins.com

Cummins Power Generation – East Asia
Suite 901, China World Tower
China World Trade Center
No. 1 Jian Guo Men Wai
Beijing 100004
People's Republic of China
Phone: (86-10) 6505-0055
Fax: (86-10) 6505-0657
Email: ceci@public.bta.net.cn

Cummins Power Generation – Korea
2nd Floor, Choyang Building
113 Samsung-Dong
Kangnam-Ku
Seoul, Korea 135-090
Phone: (82-2) 3452-4313
Fax: (82-2) 3452-4113
Email: ckabo@ckntl.ck.cummins.com

See your distributor for more information.

Standard and custom made generating sets from 30 kVA to 2000 kVA

Appendix G:

Calculation of Financial Rate of Return for Maaeboodhoo

Table G.1: Calculation of Financial Rate of Return, Maaeboodhoo: AUS'000
Single Busbar (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Sales excluding Street lighting	MWhpa	69	72	76	80	84	89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146	146
Increased Sales excluding Street lighting	MWhpa		4	7	11	16	20	25	30	34	39	43	49	54	59	65	71	78	78	78	78	78	78
Street lighting	MWhpa	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	9	9	9	9	9
Increase in Street lighting	MWhpa		0	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	4	4	4	4	4
Production	MWhpa	98	82	86	90	95	100	105	110	115	120	125	131	137	143	149	156	163	163	163	163	163	163
Savings from Reduced Losses	MWhpa		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Increased Production for Increased Sales	MWhpa		4	8	12	17	22	27	32	37	42	48	53	59	65	71	78	85	81	81	81	81	81
FIRR Calculation																							
Benefits																							
Increased Sales including Street lighting			4	9	14	19	24	30	35	41	46	52	58	65	71	78	85	93	93	93	93	93	93
Operational Savings on Existing (2006) Production																							
Savings in Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Savings in fuel costs (Engine Efficiency)			10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Savings in Lubricating Oil costs			0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Savings from Reduced Losses			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel Fuel			1.89	1.98	2.09	2.19	2.30	2.42	2.54	2.66	2.77	2.90	3.03	3.16	3.30	3.45	3.60	3.76	3.76	3.76	3.76	3.76	3.76
Lube Oil			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total Benefits			17	22	27	32	37	43	49	54	60	66	72	79	86	93	100	108	108	108	108	108	108
Capital Costs		512	0.67	0.67	0.67	0.71	0.81	0.88	93.42	0.79	0.82	0.90	0.89	0.93	1.01	111.15	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Increased Operating Costs																							
Diesel fuel			1.05	2.15	3.32	4.54	5.82	7.17	8.59	9.89	11.24	12.65	14.12	15.67	17.28	18.96	20.73	22.57	22.57	22.57	22.57	22.57	22.57
Lube Oil			0.04	0.09	0.13	0.18	0.24	0.29	0.35	0.40	0.45	0.51	0.57	0.63	0.70	0.77	0.84	0.91	0.91	0.91	0.91	0.91	0.91
Repairs & Maintenance			0.05	0.08	0.13	0.18	0.23	0.28	0.34	0.39	0.44	0.49	0.55	0.61	0.67	0.74	0.81	0.88	0.84	0.84	0.84	0.84	0.84
Labour Costs			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other			-0.11	-0.08	-0.05	-0.02	0.01	0.05	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.43	0.43	0.43	0.43	0.43	0.43
Total costs		512	1.8	3.0	4.3	5.7	7.2	8.8	102.9	11.7	13.2	14.9	16.5	18.2	20.1	132.1	24.0	26.0	26.0	26.0	26.0	26.0	26.0
Net Cash Flow		-512	15	19	23	26	30	34	-54	43	47	51	56	61	65	-39	76	82	82	82	82	82	82
FIRR		**4.7%**																					

Table G.2: Calculation of Financial Rate of Return, Maaeboodhoo: AUS'000
Split Busbar (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Sales excluding Street lighting	MWhpa	69	72	76	80	84	89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146	146
Increased Sales excluding Street lighting	MWhpa		4	7	11	16	20	25	30	34	39	43	49	54	59	65	71	78	78	78	78	78	78
Street lighting	MWhpa	5.16	5.32	5.48	5.64	5.81	5.99	6.16	6.35	6.54	6.74	6.94	7.15	7.36	7.58	7.81	8.04	8.29	8.87	8.87	8.87	8.87	8.87
Increase in Street lighting	MWhpa		0.15	0.31	0.48	0.65	0.82	1.00	1.19	1.38	1.57	1.78	1.98	2.20	2.42	2.65	2.88	3.12	3.70	3.70	3.70	3.70	3.70
Production	MWhpa	98	82	86	90	95	100	105	110	115	120	125	131	137	143	149	156	163	163	163	163	163	163
Savings from Reduced Losses	MWhpa		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Increased Production for Increased Sales	MWhpa		4	8	12	17	22	27	32	37	42	48	53	59	65	71	78	85	81	81	81	81	81
FIRR Calculation																							
Benefits																							
Increased Sales including Street lighting			4	9	13	18	23	28	34	39	45	50	56	62	69	75	82	90	90	90	90	90	90
Operational Savings on Existing (2006) Production																							
Savings in Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Savings in fuel costs (Engine Efficiency)			10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Savings in Lubricating Oil costs			0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Savings from Reduced Losses			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel Fuel			1.89	1.98	2.09	2.19	2.30	2.42	2.54	2.66	2.77	2.90	3.03	3.16	3.30	3.45	3.60	3.76	3.76	3.76	3.76	3.76	3.76
Lube Oil			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total Benefits			17	22	26	31	37	42	48	53	58	64	70	76	83	90	97	104	104	104	104	104	104
Capital Costs		502	0.67	0.67	0.67	0.71	0.81	0.88	90.24	0.79	0.82	0.90	0.89	0.93	1.01	92.03	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Increased Operating costs																							
Diesel fuel			1.05	2.15	3.32	4.54	5.82	7.17	8.59	9.89	11.24	12.65	14.12	15.67	17.28	18.96	20.73	22.57	22.57	22.57	22.57	22.57	22.57
Lube Oil			0.04	0.09	0.13	0.18	0.24	0.29	0.35	0.40	0.45	0.51	0.57	0.63	0.70	0.77	0.84	0.91	0.91	0.91	0.91	0.91	0.91
Repairs & Maintenance			0.05	0.08	0.13	0.18	0.23	0.28	0.34	0.39	0.44	0.49	0.55	0.61	0.67	0.74	0.81	0.88	0.84	0.84	0.84	0.84	0.84
Labour Costs			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other			-0.11	-0.08	-0.05	-0.02	0.01	0.05	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.43	0.43	0.43	0.43	0.43	0.43
Total costs		502	1.8	3.0	4.3	5.7	7.2	8.8	99.7	11.7	13.2	14.9	16.5	18.2	20.1	113.0	24.0	26.0	26.0	26.0	26.0	26.0	26.0
Net Cash Flow		-502	15	19	22	26	29	33	-52	41	45	49	54	58	63	-23	73	78	78	78	78	78	78
FIRR		**4.7%**																					

Table G.3: Calculation of Financial Rate of Return, Maaeboodhoo: AUS’000 Synchronising (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Sales excluding Street lighting	MWhpa	69	72	76	80	84	89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146	146
Increased Sales excluding Street lighting	MWhpa		4	7	11	16	20	25	30	34	39	43	49	54	59	65	71	78	78	78	78	78	78
Street lighting	MWhpa	5.16	5.32	5.48	5.64	5.81	5.99	6.16	6.35	6.54	6.74	6.94	7.15	7.36	7.58	7.81	8.04	8.29	8.87	8.87	8.87	8.87	8.87
Increase in Street lighting	MWhpa		0.15	0.31	0.48	0.65	0.82	1.00	1.19	1.38	1.57	1.78	1.98	2.20	2.42	2.65	2.88	3.12	3.70	3.70	3.70	3.70	3.70
Production	MWhpa	98	82	86	90	95	100	105	110	115	120	125	131	137	143	149	156	163	163	163	163	163	163
Savings from Reduced Losses	MWhpa		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Increased Production for Increased Sales	MWhpa		4	8	12	17	22	27	32	37	42	48	53	59	65	71	78	85	81	81	81	81	81
FIRR Calculation																							
Benefits																							
Increased Sales including Street lighting			4	9	13	18	23	29	34	40	45	51	57	63	69	76	83	90	90	90	90	90	90
Operational Savings on Existing (2006) Production																							
Savings in Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Savings in fuel costs (Engine Efficiency)			10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Savings in Lubricating Oil costs			0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Savings from Reduced Losses			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel Fuel			1.89	1.98	2.09	2.19	2.30	2.42	2.54	2.66	2.77	2.90	3.03	3.16	3.30	3.45	3.60	3.76	3.76	3.76	3.76	3.76	3.76
Lube Oil			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total Benefits			17	22	26	31	37	42	48	53	59	65	71	77	84	91	98	105	105	105	105	105	105
Capital Costs		524	0.67	0.67	0.67	0.71	0.81	0.88	71.85	0.79	0.82	0.90	0.89	0.93	1.01	84.04	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Increased Operating costs																							
Diesel fuel			1.05	2.15	3.32	4.54	5.82	7.17	8.59	9.89	11.24	12.65	14.12	15.67	17.28	18.96	20.73	22.57	22.57	22.57	22.57	22.57	22.57
Lube Oil			0.04	0.09	0.13	0.18	0.24	0.29	0.35	0.40	0.45	0.51	0.57	0.63	0.70	0.77	0.84	0.91	0.91	0.91	0.91	0.91	0.91
Repairs & Maintenance			0.05	0.08	0.13	0.18	0.23	0.28	0.34	0.39	0.44	0.49	0.55	0.61	0.67	0.74	0.81	0.88	0.84	0.84	0.84	0.84	0.84
Labour Costs			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other			-0.11	-0.08	-0.05	-0.02	0.01	0.05	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.43	0.43	0.43	0.43	0.43	0.43
Total costs		524	1.8	3.0	4.3	5.7	7.2	8.8	81.3	11.7	13.2	14.9	16.5	18.2	20.1	105.0	24.0	26.0	26.0	26.0	26.0	26.0	26.0
Net Cash Flow		-524	15	19	22	26	29	33	-33	42	46	50	54	59	64	-14	74	79	79	79	79	79	79
FIRR		**4.7%**																					

Table G.4: Calculation of Financial Rate of Return, Maaeboodhoo: AUS’000 Synchronising (Digital)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Sales excluding Street lighting	MWhpa	69	72	76	80	84	89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146	146
Increased Sales excluding Street lighting	MWhpa		4	7	11	16	20	25	30	34	39	43	49	54	59	65	71	78	78	78	78	78	78
Street lighting	MWhpa	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	9	9	9	9	9
Increase in Street lighting	MWhpa		0	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	4	4	4	4	4
Production	MWhpa	98	82	86	90	95	100	105	110	115	120	125	131	137	143	149	156	163	163	163	163	163	163
Savings from Reduced Losses	MWhpa		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Increased Production for Increased Sales	MWhpa		4	8	12	17	22	27	32	37	42	48	53	59	65	71	78	85	81	81	81	81	81
FIRR Calculation																							
Benefits																							
Increased Sales including Street lighting			3	7	11	14	19	23	27	32	36	40	45	50	55	61	66	72	72	72	72	72	72
Operational Savings on Existing (2006) Production																							
Savings in Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Savings in fuel costs (Engine Efficiency)			10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Savings in Lubricating Oil costs			0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Savings from Reduced Losses			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel Fuel			1.89	1.98	2.09	2.19	2.30	2.42	2.54	2.66	2.77	2.90	3.03	3.16	3.30	3.45	3.60	3.76	3.76	3.76	3.76	3.76	3.76
Lube Oil			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total Benefits			16	20	24	28	32	36	41	45	50	54	59	64	70	75	81	87	87	87	87	87	87
Capital Costs		398	0.67	0.67	0.67	0.71	0.81	0.88	71.85	0.79	0.82	0.90	0.89	0.93	1.01	84.04	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Increased Operating costs																							
Diesel fuel			1.05	2.15	3.32	4.54	5.82	7.17	8.59	9.89	11.24	12.65	14.12	15.67	17.28	18.96	20.73	22.57	22.57	22.57	22.57	22.57	22.57
Lube Oil			0.04	0.09	0.13	0.18	0.24	0.29	0.35	0.40	0.45	0.51	0.57	0.63	0.70	0.77	0.84	0.91	0.91	0.91	0.91	0.91	0.91
Repairs & Maintenance			0.05	0.08	0.13	0.18	0.23	0.28	0.34	0.39	0.44	0.49	0.55	0.61	0.67	0.74	0.81	0.88	0.84	0.84	0.84	0.84	0.84
Labour Costs			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other			-0.11	-0.08	-0.05	-0.02	0.01	0.05	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.43	0.43	0.43	0.43	0.43	0.43
Total costs		398	1.8	3.0	4.3	5.7	7.2	8.8	81.3	11.7	13.2	14.9	16.5	18.2	20.1	105.0	24.0	26.0	26.0	26.0	26.0	26.0	26.0
Net Cash Flow		-398	15	17	19	22	25	28	-40	34	37	39	43	46	49	-30	57	61	61	61	61	61	61
FIRR		**4.7%**																					

Table G.5: Calculation of Financial Rate of Return, Maaeboodhoo: AUS'000 Reviewed Distribution Design

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Sales excluding Street lighting	MWhpa	69	72	76	80	84	89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146	146
Increased Sales excluding Street lighting	MWhpa		4	7	11	16	20	25	30	34	39	43	49	54	59	65	71	78	78	78	78	78	78
Street lighting	MWhpa	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	9	9	9	9	9
Increase in Street lighting	MWhpa		0	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	4	4	4	4	4
Production	MWhpa	98	83	88	92	97	102	107	112	117	123	128	134	140	146	152	159	166	166	166	166	166	166
Savings from Reduced Losses	MWhpa		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Increased Production for Increased Sales	MWhpa		4	8	13	17	22	28	33	38	43	49	54	60	66	73	80	87	81	81	81	81	81
FIRR Calculation																							
Benefits																							
Increased Sales including Street lighting			4	9	13	18	23	29	34	40	45	51	57	63	69	76	83	90	90	90	90	90	90
Operational Savings on Existing (2006) Production																							
Savings in Maintenance			0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Savings in fuel costs (Engine Efficiency)			10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Savings in Lubricating Oil costs			0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Savings from Reduced Losses			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel Fuel			1.64	1.72	1.81	1.90	1.99	2.10	2.20	2.30	2.40	2.51	2.62	2.74	2.86	2.98	3.12	3.26	3.26	3.26	3.26	3.26	3.26
Lube Oil			0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Maintenance			0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Total Benefits			17	21	26	31	36	42	48	53	58	64	70	77	83	90	97	105	105	105	105	105	105
Capital Costs		512	0.67	1.25	0.67	0.71	0.58	0.90	71.86	0.81	0.84	0.92	0.91	0.95	1.03	84.07	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Increased Operating costs																							
Diesel fuel			1.07	2.20	3.39	4.63	5.95	7.33	8.78	10.10	11.48	12.92	14.43	16.00	17.65	19.37	21.17	23.05	23.05	23.05	23.05	23.05	23.05
Lube Oil			0.04	0.09	0.14	0.19	0.24	0.30	0.35	0.41	0.46	0.52	0.58	0.65	0.71	0.78	0.86	0.93	0.93	0.93	0.93	0.93	0.93
Repairs & Maintenance			0.05	0.09	0.13	0.18	0.23	0.29	0.34	0.39	0.45	0.50	0.56	0.63	0.69	0.76	0.83	0.90	0.84	0.84	0.84	0.84	0.84
Labour Costs			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other			-0.10	-0.07	-0.04	-0.01	0.03	0.06	0.10	0.13	0.17	0.20	0.24	0.28	0.32	0.36	0.41	0.46	0.46	0.46	0.46	0.46	0.46
Total Costs		512	1.9	3.7	4.4	5.8	7.2	9.0	81.6	12.0	13.5	15.2	16.9	18.6	20.5	105.5	24.5	26.6	26.5	26.5	26.5	26.5	26.5
Net Cash Flow		-512	15	18	22	25	29	33	-34	41	45	49	53	58	63	-15	73	78	78	78	78	78	78
FIRR		**4.7%**																					

Table G.6: Calculation of Financial Rate of Return, Maaeboodhoo: AUS'000 Synchronising (Digital) and Reviewed Distribution Design

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Sales excluding Street lighting	MWhpa	69	72	76	80	84	89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146	146
Increased Sales excluding Street lighting	MWhpa		4	7	11	16	20	25	30	34	39	43	49	54	59	65	71	78	78	78	78	78	78
Street lighting	MWhpa	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8	9	9	9	9	9
Increase in Street lighting	MWhpa		0	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	4	4	4	4	4
Production	MWhpa	98	82	86	90	95	100	105	110	115	120	125	131	137	143	149	156	163	163	163	163	163	163
Savings from Reduced Losses	MWhpa		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Increased Production for Increased Sales	MWhpa		4	8	12	17	22	27	32	37	42	48	53	59	65	71	78	85	81	81	81	81	81
FIRR Calculation																							
Benefits																							
Increased Sales including Street lighting			3	7	10	14	18	22	27	31	35	39	44	49	54	59	65	70	70	70	70	70	70
Operational Savings on Existing (2006) Production																							
Savings in Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Savings in fuel costs (Engine Efficiency)			10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Savings in Lubricating Oil costs			0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Savings from Reduced Losses			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel Fuel			1.89	1.98	2.09	2.19	2.30	2.42	2.54	2.66	2.77	2.90	3.03	3.16	3.30	3.45	3.60	3.76	3.76	3.76	3.76	3.76	3.76
Lube Oil			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Maintenance			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total Benefits			16	20	24	27	32	36	40	45	49	53	58	63	68	74	79	85	85	85	85	85	85
Capital Costs		386	0.67	0.67	0.67	0.71	0.81	0.88	74.74	0.79	0.82	0.90	0.89	0.93	1.01	79.78	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Increased Operating costs																							
Diesel fuel			1.05	2.15	3.32	4.54	5.82	7.17	8.59	9.89	11.24	12.65	14.12	15.67	17.28	18.96	20.73	22.57	22.57	22.57	22.57	22.57	22.57
Lube Oil			0.04	0.09	0.13	0.18	0.24	0.29	0.35	0.40	0.45	0.51	0.57	0.63	0.70	0.77	0.84	0.91	0.91	0.91	0.91	0.91	0.91
Repairs & Maintenance			0.05	0.08	0.13	0.18	0.23	0.28	0.34	0.39	0.44	0.49	0.55	0.61	0.67	0.74	0.81	0.88	0.84	0.84	0.84	0.84	0.84
Labour Costs			0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other			-0.11	-0.08	-0.05	-0.02	0.01	0.05	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.34	0.39	0.43	0.43	0.43	0.43	0.43	0.43
Total costs		386	1.8	3.0	4.3	5.7	7.2	8.8	84.2	11.7	13.2	14.9	16.5	18.2	20.1	100.7	24.0	26.0	26.0	26.0	26.0	26.0	26.0
Net Cash Flow		-386	14	17	19	22	24	27	-44	33	36	39	42	45	48	-27	55	59	59	59	59	59	59
FIRR		**4.7%**																					

Appendix H:

Calculation of Financial Rate of Return for Mukurimagu

Table H.1: Calculation of Financial Rate of Return, Mukurimagu: AUS'000
Single Busbar (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Sales Excluding Street lighting	MWhpa	142	150	159	169	179	189	200	212	225	238	252	267	267	267	267	267	267	267
Increased Sales Excluding Street lighting	MWhpa		8	17	27	37	47	59	71	83	96	111	126	126	126	126	126	126	126
Street Lighting Sales	MWhpa	12	12	13	13	13	14	14	15	15	15	16	16	17	17	17	17	17	17
Increase in Street Lighting Sales	MWhpa		0	1	1	1	2	2	3	3	4	4	5	5	5				
Production	MWhpa	194	171	181	191	202	214	226	239	253	267	282	299	299	299	299	299	299	299
Savings from Reduced Losses	MWhpa		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Increased Production	MWhpa		11	19	29	40	52	64	77	91	105	121	137	138	138	132	132	132	132
FIRR Calculation																			
Benefits																			
Increased Sales			5.98	12.32	19.02	26.12	33.63	41.57	49.99	58.89	68.32	78.30	88.86	89.17	89.17	89.17	89.17	89.17	89.17
Existing Operation																			
Savings in Maintenance			0.40	0.42	0.45	0.47	0.50	0.53	0.56	0.59	0.62	0.66	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Savings in Diesel Fuel Costs			8.51	9.00	9.51	10.06	10.64	11.25	11.89	12.58	13.30	14.07	14.88	14.88	14.88	14.88	14.88	14.88	14.88
Savings in Lubricating Oil Costs			0.38	0.41	0.43	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Savings from Reduced Losses																			
Diesel Fuel			10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92
Lubricating Oil			0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Total Benefits			27	33	41	48	57	65	74	84	94	105	116	117	117	117	117	117	117
Capital Costs		467	0.00	2.61	2.75	2.90	33.13	3.22	3.39	64.52	3.76	3.96	4.17	35.26	4.63	4.95	72.72	5.41	5.70
Increased Operating costs																			
Diesel fuel			2.95	5.05	7.80	10.70	13.78	17.03	20.48	24.13	27.99	32.08	36.40	36.54	36.54	36.54	36.54	36.54	36.54
Lube Oil			0.12	0.20	0.32	0.43	0.56	0.69	0.83	0.98	1.13	1.30	1.47	1.48	1.48	1.48	1.48	1.48	1.48
Repairs & Maintenance			0.15	0.25	0.39	0.54	0.69	0.86	1.03	1.21	1.40	1.61	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Labour Costs			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		467	3.22	8.12	11.26	14.57	48.16	21.80	25.73	90.83	34.29	38.94	43.87	75.12	44.48	44.80	112.58	45.26	45.55
Net Cash Flow		-467	23.35	25.31	29.45	33.82	8.37	43.35	48.54	-6.92	59.85	66.01	72.53	41.59	72.23	71.91	4.14	71.45	71.16
FIRR		**4.7%**																	

Table H.2: Calculation of Financial Rate of Return, Mukurimagu: AUS'000
Split Busbar (Analogue)

Year		**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Sales Excluding Street lighting	MWhpa	142	150	159	169	179	189	200	212	225	238	252	267	267	267	267	267	267	267
Increased Sales Excluding Street lighting	MWhpa		8	17	27	37	47	59	71	83	96	111	126	126	126	126	126	126	126
Street Lighting Sales	MWhpa	12	12	13	13	13	14	14	15	15	15	16	16	17	17	17	17	17	17
Increase in Street Lighting Sales	MWhpa		0	1	1	1	2	2	3	3	4	4	5	5	5				
Production	MWhpa	194	171	181	191	202	214	226	239	253	267	282	299	299	299	299	299	299	299
Savings from Reduced Losses	MWhpa		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Increased Production	MWhpa		11	19	29	40	52	64	77	91	105	121	137	138	138	132	132	132	132
FIRR Calculation																			
Benefits																			
Increased Sales			5.89	12.12	18.71	25.69	33.07	40.89	49.17	57.93	67.20	77.02	87.41	87.71	87.71	84.57	84.57	84.57	84.57
Existing Operation																			
Savings in Maintenance			0.40	0.42	0.45	0.47	0.50	0.53	0.56	0.59	0.62	0.66	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Savings in Diesel Fuel Costs			8.51	9.00	9.51	10.06	10.64	11.25	11.89	12.58	13.30	14.07	14.88	14.88	14.88	14.88	14.88	14.88	14.88
Savings in Lubricating Oil Costs			0.38	0.41	0.43	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Savings from Reduced Losses																			
Diesel Fuel			10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92
Lubricating Oil			0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Total Benefits			26	33	40	48	56	64	73	83	93	104	115	115	115	112	112	112	112
Capital Costs		439	0.00	2.61	2.75	2.90	33.93	3.22	3.39	65.31	3.76	3.96	4.17	41.11	4.63	4.95	78.57	5.41	5.70
Increased Operating costs																			
Diesel fuel			2.95	5.05	7.80	10.70	13.78	17.03	20.48	24.13	27.99	32.08	36.40	36.54	36.54	36.54	36.54	36.54	36.54
Lube Oil			0.12	0.20	0.32	0.43	0.56	0.69	0.83	0.98	1.13	1.30	1.47	1.48	1.48	1.48	1.48	1.48	1.48
Repairs & Maintenance			0.15	0.25	0.39	0.54	0.69	0.86	1.03	1.21	1.40	1.61	1.83	1.83	1.83	1.76	1.76	1.76	1.76
Labour Costs			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.21	0.31	0.42
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		439	3.22	8.12	11.26	14.57	48.95	21.80	25.73	91.63	34.29	38.94	43.87	80.96	44.48	44.83	118.55	45.50	45.90
Net Cash Flow		-439	23.26	25.11	29.13	33.39	7.03	42.67	47.72	-8.68	58.73	64.72	71.07	34.29	70.77	67.28	-6.44	66.61	66.21
FIRR		**4.7%**																	

Table H.3: Calculation of Financial Rate of Return, Mukurimagu: AUS'000 Synchronising (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Sales Excluding Street lighting	MWhpa	142	150	159	169	179	189	200	212	225	238	252	267	267	267	267	267	267	267
Increased Sales Excluding Street lighting	MWhpa		8	17	27	37	47	59	71	83	96	111	126	126	126	126	126	126	126
Street Lighting Sales	MWhpa	12	12	13	13	13	14	14	15	15	15	16	16	17	17	17	17	17	17
Increase in Street Lighting Sales	MWhpa		0	1	1	1	2	2	3	3	4	4	5	5	5	5	5	5	5
Production	MWhpa	194	171	181	191	202	214	226	239	253	267	282	299	299	299	299	299	299	299
Savings from Reduced Losses	MWhpa		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Increased Production	MWhpa		11	19	29	40	52	64	77	91	105	121	137	138	138	138	138	138	138
FIRR Calculation																			
Benefits																			
Increased Sales			5.98	12.32	19.02	26.12	33.63	41.57	49.99	58.89	68.32	78.30	88.86	89.17	89.17	89.17	89.17	89.17	89.17
Existing Operation																			
Savings in Maintenance			0.40	0.42	0.45	0.47	0.50	0.53	0.56	0.59	0.62	0.66	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Savings in Diesel Fuel Costs			8.51	9.00	9.51	10.06	10.64	11.25	11.89	12.58	13.30	14.07	14.88	14.88	14.88	14.88	14.88	14.88	14.88
Savings in Lubricating Oil Costs			0.38	0.41	0.43	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Savings from Reduced Losses																			
Diesel Fuel			10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92
Lubricating Oil			0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Total Benefits			27	33	41	48	57	65	74	84	94	105	116	117	117	117	117	117	117
Capital Costs		467	0.00	2.61	2.75	2.90	33.13	3.22	3.39	64.52	3.76	3.96	4.17	35.26	4.63	4.95	72.72	5.41	5.70
Increased Operating costs																			
Diesel fuel			2.95	5.05	7.80	10.70	13.78	17.03	20.48	24.13	27.99	32.08	36.40	36.54	36.54	36.54	36.54	36.54	36.54
Lube Oil			0.12	0.20	0.32	0.43	0.56	0.69	0.83	0.98	1.13	1.30	1.47	1.48	1.48	1.48	1.48	1.48	1.48
Repairs & Maintenance			0.15	0.25	0.39	0.54	0.69	0.86	1.03	1.21	1.40	1.61	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Labour Costs			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		467	3.22	8.12	11.26	14.57	48.16	21.80	25.73	90.83	34.29	38.94	43.87	75.12	44.48	44.80	112.58	45.26	45.55
Net Cash Flow		-467	23.35	25.31	29.45	33.82	8.37	43.35	48.54	-6.92	59.85	66.01	72.53	41.59	72.23	71.91	4.14	71.45	71.16
FIRR		**4.7%**																	

Table H.4: Calculation of Financial Rate of Return, Mukurimagu: AUS'000 Synchronising (Digital)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Sales Excluding Street lighting	MWhpa	142	150	159	169	179	189	200	212	225	238	252	267	267	267	267	267	267	267
Increased Sales Excluding Street lighting	MWhpa		8	17	27	37	47	59	71	83	96	111	126	126	126	126	126	126	126
Street Lighting Sales	MWhpa	12	12	13	13	13	14	14	15	15	15	16	16	17	17	17	17	17	17
Increase in Street Lighting Sales	MWhpa		0	1	1	1	2	2	3	3	4	4	5	5	5				
Production	MWhpa	194	171	181	191	202	214	226	239	253	267	282	299	299	299	299	299	299	299
Savings from Reduced Losses	MWhpa		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Increased Production	MWhpa		11	19	29	40	52	64	77	91	105	121	137	138	138	132	132	132	132
FIRR Calculation																			
Benefits																			
Increased Sales			5.40	11.11	17.15	23.55	30.32	37.49	45.07	53.10	61.60	70.60	80.12	80.40	80.40	77.53	77.53	77.53	77.53
Existing Operation																			
Savings in Maintenance			0.40	0.42	0.45	0.47	0.50	0.53	0.56	0.59	0.62	0.66	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Savings in Diesel Fuel Costs			8.51	9.00	9.51	10.06	10.64	11.25	11.89	12.58	13.30	14.07	14.88	14.88	14.88	14.88	14.88	14.88	14.88
Savings in Lubricating Oil Costs			0.38	0.41	0.43	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Savings from Reduced Losses																			
Diesel Fuel			10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92
Lubricating Oil			0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Total Benefits			26	32	39	46	53	61	69	78	87	97	108	108	108	105	105	105	105
Capital Costs		394	0.00	2.61	2.75	2.90	33.13	3.22	3.39	65.31	3.76	3.96	4.17	35.26	4.63	4.95	78.57	5.41	5.70
Increased Operating costs																			
Diesel fuel			2.95	5.05	7.80	10.70	13.78	17.03	20.48	24.13	27.99	32.08	36.40	36.54	36.54	36.54	36.54	36.54	36.54
Lube Oil			0.12	0.20	0.32	0.43	0.56	0.69	0.83	0.98	1.13	1.30	1.47	1.48	1.48	1.48	1.48	1.48	1.48
Repairs & Maintenance			0.15	0.25	0.39	0.54	0.69	0.86	1.03	1.21	1.40	1.61	1.83	1.83	1.83	1.76	1.76	1.76	1.76
Labour Costs			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Cost		394	3	8	11	15	48	22	26	92	34	39	44	75	44	45	118	45	45
Net Cash Flow		-394	22.76	24.10	27.57	31.25	5.06	39.26	43.62	-13.50	53.13	58.30	63.79	32.82	63.46	60.34	-13.28	59.87	59.58
FIRR		**4.7%**																	

Table H.5: Calculation of Financial Rate of Return, Mukurimagu: AUS'000
Reviewed Distribution Design

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Sales Excluding Street lighting	MWhpa	142	150	159	169	179	189	200	212	225	238	252	267	267	267	267	267	267	267
Increased Sales Excluding Street lighting	MWhpa		8	17	27	37	47	59	71	83	96	111	126	126	126	126	126	126	126
Street Lighting Sales	MWhpa	12	12	13	13	13	14	14	15	15	15	16	16	17	17	17	17	17	17
Increase in Street Lighting Sales	MWhpa		0	1	1	1	2	2	3	3	4	4	5	5	5	5	5	5	5
Production	MWhpa	194	171	181	191	202	214	226	239	253	267	282	299	299	299	299	299	299	299
Savings from Reduced Losses	MWhpa		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Increased Production	MWhpa		11	19	29	40	52	64	77	91	105	121	137	138	138	138	138	138	138
FIRR Calculation																			
Benefits																			
Increased Sales			5.35	11.01	16.99	23.33	30.04	37.14	44.66	52.62	61.04	69.96	79.39	79.67	79.67	79.67	79.67	79.67	79.67
Existing Operation																			
Savings in Maintenance			0.40	0.42	0.45	0.47	0.50	0.53	0.56	0.59	0.62	0.66	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Savings in Diesel Fuel Costs			8.51	9.00	9.51	10.06	10.64	11.25	11.89	12.58	13.30	14.07	14.88	14.88	14.88	14.88	14.88	14.88	14.88
Savings in Lubricating Oil Costs			0.38	0.41	0.43	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Savings from Reduced Losses																			
Diesel Fuel			10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92	10.92
Lubricating Oil			0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Total Benefits			26	32	39	46	53	61	69	78	87	97	107	107	107	107	107	107	107
Capital Costs		398	0.00	2.61	2.75	2.90	33.13	3.22	3.39	64.52	3.76	3.96	4.17	35.26	4.63	4.95	72.72	5.41	5.70
Increased Operating costs																			
Diesel fuel			2.95	5.05	7.80	10.70	13.78	17.03	20.48	24.13	27.99	32.08	36.40	36.54	36.54	36.54	36.54	36.54	36.54
Lube Oil			0.12	0.20	0.32	0.43	0.56	0.69	0.83	0.98	1.13	1.30	1.47	1.48	1.48	1.48	1.48	1.48	1.48
Repairs & Maintenance			0.15	0.25	0.39	0.54	0.69	0.86	1.03	1.21	1.40	1.61	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Labour Costs			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Cost		398	3.22	8.12	11.26	14.57	48.16	21.80	25.73	90.83	34.29	38.94	43.87	75.12	44.48	44.80	112.58	45.26	45.55
Net Cash Flow		-398	22.72	24.00	27.42	31.04	4.79	38.92	43.21	-13.19	52.57	57.66	63.06	32.09	62.73	62.41	-5.37	61.95	61.66
FIRR		**4.7%**																	

Table H.6: Calculation of Financial Rate of Return, Mukurimagu: AUS'000
Synchronising (Digital) and Reviewed Distribution Design

Year		**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Sales Excluding Street lighting	MWhpa	142	150	159	169	179	189	200	212	225	238	252	267	267	267	267	267	267	267
Increased Sales Excluding Street lighting	MWhpa		8	17	27	37	47	59	71	83	96	111	126	126	126	126	126	126	126
Street Lighting Sales	MWhpa	12	12	13	13	13	14	14	15	15	15	16	16	17	17	17	17	17	17
Increase in Street Lighting Sales	MWhpa		0	1	1	1	2	2	3	3	4	4	5	5	5				
Production	MWhpa	194	171	181	191	202	214	226	239	253	267	282	299	299	299	299	299	299	299
Savings from Reduced Losses	MWhpa		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Increased Production	MWhpa		11	19	29	40	52	64	77	91	105	121	137	138	138	132	132	132	132
FIRR Calculation																			
Benefits																			
Increased Sales			4.9	10.0	15.4	21.2	27.3	33.7	40.6	47.8	55.4	63.5	72.1	72.4	72.4	69.8	69.8	69.8	69.8
Existing Operation																			
Savings in Maintenance			0.40	0.42	0.45	0.47	0.50	0.53	0.56	0.59	0.62	0.66	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Savings in Diesel Fuel Costs			8.51	9.00	9.51	10.06	10.64	11.25	11.89	12.58	13.30	14.07	14.88	14.88	14.88	14.88	14.88	14.88	14.88
Savings in Lubricating Oil Costs			0.38	0.41	0.43	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Savings from Reduced Losses																			
Diesel Fuel			11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Lubricating Oil			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Benefits			25	31	37	43	50	57	65	73	81	90	100	100	100	97	97	97	97
Capital Costs		343	0	3	3	3	33	3	3	65	4	4	4	35	5	5	73	5	6
Increased Operating costs																			
Diesel fuel			2.95	5.05	7.80	10.70	13.78	17.03	20.48	24.13	27.99	32.08	36.40	36.54	36.54	36.54	36.54	36.54	36.54
Lube Oil			0.12	0.20	0.32	0.43	0.56	0.69	0.83	0.98	1.13	1.30	1.47	1.48	1.48	1.48	1.48	1.48	1.48
Repairs & Maintenance			0.15	0.25	0.39	0.54	0.69	0.86	1.03	1.21	1.40	1.61	1.83	1.83	1.83	1.76	1.76	1.76	1.76
Labour Costs			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Cost		343	3	8	11	15	48	22	26	91	34	39	44	75	44	45	113	45	45
Net Cash Flow		-343	22	23	26	29	2	36	39	-18	47	51	56	25	55	53	-15	52	52
FIRR		**4.7%**																	

Appendix I:

Cash Flow Calculation for Maaeboodhoo

Table I.1: Cash Flow Calculation, Maaeboodhoo: AUS'000
Single Busbar (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		512																
GOM Loan Cost		488																
Interest During Grace Period		10																
Community Labour		14																
Ongoing Capital Costs		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	93.42	0.79	0.82	0.90	0.89	0.93	1.01	111.15	1.09
Electricity Sales																		
Sales Less Streetlights	MWhpa		89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146
Streetlight Sales	MWhpa		6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8
Revenues																		
Required Tariff	$/kWh		1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Sales			83	88	92	97	102	108	113	118	124	129	135	141	148	154	161	169
Less Bad Debts			-0.42	-0.44	-0.46	-0.49	-0.51	-0.54	-0.57	-0.59	-0.62	-0.65	-0.68	-0.71	-0.74	-0.77	-0.81	-0.84
Street Lights			6.12	6.31	6.50	6.69	6.89	7.10	7.31	7.53	7.76	7.99	8.23	8.48	8.73	8.99	9.26	9.54
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Revenue			89	94	98	103	109	114	120	125	131	137	143	149	156	162	170	177
Operating Expenses																		
Diesel fuel and oil			23	24	25	26	28	29	30	32	33	35	36	38	39	41	43	45
Wages, Allowances plus Management			0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Maintenance			1.09	1.15	1.20	1.26	1.33	1.40	1.47	1.53	1.60	1.67	1.75	1.82	1.90	1.99	2.08	2.17
Other			0.54	0.57	0.60	0.63	0.66	0.70	0.73	0.77	0.80	0.84	0.87	0.91	0.95	0.99	1.04	1.08
Total			25	26	27	29	30	32	33	35	36	38	39	41	43	45	47	49
Cash available from Operations		9	64	68	71	75	79	83	87	91	95	99	103	108	113	118	123	128
Project Debt Servicing																		
Interest			39	39	39	39	34	29	24	20	15	10	5	0				
Principal repayment							61	61	61	61	61	61	61	61				
Total			39	39	39	39	95	90	85	80	76	71	66	61				
Other Loans																		
Interest											0	0	0	0	0			
Principal repayment											0	0	0	0	0			
Total					0	0	0	0	0	0	0	0	0	0	0			
Total Debt Service			39	39	39	39	95	90	85	80	76	71	66	61	0	0	0	0
Summary of Cash Flow																		
Cash Flow after Debt Service		9	25.2	28.5	32.0	35.6	-16.6	-7.7	1.4	10.1	19.1	28.1	37.4	46.9	112.7	117.7	123.0	128.5
Initial Project Investment		488	0.0															
Capital replacement/expansion		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	93.42	0.79	0.82	0.90	0.89	0.93	1.01	111.15	1.09
Project Financing																		
External Funding																		
Loan funds		488	0															
Total Funds		488	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Cash Flow		0	25	29	32	36	-17	-8	1	10	19	28	37	47	113	118	123	128
Cumulative Cash Flow		0	25	54	86	121	105	97	99	109	128	156	193	240	353	471	594	722

Table I.2: Cash Flow Calculation, Maaeboodhoo: AUS’000
Split Busbar (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		502																
GOM Loan Cost		478																
Interest During Grace Period		10																
Community Labour		14																
Ongoing Capital Costs		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	90.24	0.79	0.82	0.90	0.89	0.93	1.01	92.03	1.09
Electricity Sales																		
Sales Less Streetlights	MWhpa		89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146
Streetlight Sales	MWhpa		6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8
Revenues																		
Required Tariff	$/kWh		1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Sales			80	85	89	94	99	104	109	114	119	125	130	136	142	149	155	162
Less Bad Debts			-0.40	-0.42	-0.44	-0.47	-0.49	-0.52	-0.55	-0.57	-0.60	-0.62	-0.65	-0.68	-0.71	-0.74	-0.78	-0.81
Street Lights			5.90	6.08	6.26	6.45	6.65	6.84	7.05	7.26	7.48	7.70	7.93	8.17	8.42	8.67	8.93	9.20
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Revenue			86	90	95	100	105	110	116	121	126	132	137	144	150	157	164	171
Operating Expenses																		
Diesel fuel and oil			23	24	25	26	28	29	30	32	33	35	36	38	39	41	43	45
Wages, Allowances plus Management			0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Maintenance			1.09	1.15	1.20	1.26	1.33	1.40	1.47	1.53	1.60	1.67	1.75	1.82	1.90	1.99	2.08	2.17
Other			0.54	0.57	0.60	0.63	0.66	0.70	0.73	0.77	0.80	0.84	0.87	0.91	0.95	0.99	1.04	1.08
Total			25	26	27	29	30	32	33	35	36	38	39	41	43	45	47	49
Cash available from Operations		9	61	64	67	71	75	78	82	86	90	94	98	103	107	112	117	122
Project Debt Servicing																		
Interest			38	38	38	38	33	29	24	19	14	10	5	0				
Principal repayment							60	60	60	60	60	60	60	60				
Total			38	38	38	38	93	89	84	79	74	69	65	60				
Other Loans																		
Interest																		
Principal repayment																		
Total					0	0	0	0	0	0	0	0	0	0	0			
Total Debt Service			38	38	38	38	93	89	84	79	74	69	65	60	0	0	0	0
Summary of Cash Flow																		
Cash Flow after Debt Service		9	22.8	25.9	29.2	32.7	-18.7	-10.1	-1.3	7.2	15.8	24.6	33.6	42.7	107.1	111.9	116.9	122.1
Initial Project Investment		478	0.0															
Capital replacement/expansion		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	90.24	0.79	0.82	0.90	0.89	0.93	1.01	92.03	1.09
Project Financing																		
External Funding																		
Loan funds		478	0															
Total Funds		478	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Cash Flow		0	23	26	29	33	-19	-10	-1	7	16	25	34	43	107	112	117	122
Cumulative Cash Flow		0	23	49	78	111	92	82	81	88	104	128	162	204	311	423	540	662

Table I.3: Cash Flow Calculation, Maaeboodhoo: AUS'000 Synchronising (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		524																
GOM Loan Cost		500																
Interest During Grace Period		10																
Community Labour		14																
Ongoing Capital Costs		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	71.85	0.79	0.82	0.90	0.89	0.93	1.01	84.04	1.09
Electricity Sales																		
Sales Less Streetlights	MWhpa		89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146
Streetlight Sales	MWhpa		6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8
Revenues																		
Required Tariff	$/kWh		1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Sales			81	85	90	94	99	105	110	115	120	126	131	137	144	150	157	164
Less Bad Debts			-0.41	-0.43	-0.45	-0.47	-0.50	-0.52	-0.55	-0.58	-0.60	-0.63	-0.66	-0.69	-0.72	-0.75	-0.78	-0.82
Street Lights			5.96	6.14	6.32	6.51	6.71	6.91	7.12	7.33	7.55	7.78	8.01	8.25	8.50	8.75	9.01	9.28
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Revenue			87	91	96	101	106	111	117	122	127	133	139	145	151	158	165	172
Operating Expenses																		
Diesel fuel and oil			23	24	25	26	28	29	30	32	33	35	36	38	39	41	43	45
Wages, Allowances plus Management			0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Maintenance			1.09	1.15	1.20	1.26	1.33	1.40	1.47	1.53	1.60	1.67	1.75	1.82	1.90	1.99	2.08	2.17
Other			0.54	0.57	0.60	0.63	0.66	0.70	0.73	0.77	0.80	0.84	0.87	0.91	0.95	0.99	1.04	1.08
Total			25	26	27	29	30	32	33	35	36	38	39	41	43	45	47	49
Cash available from Operations		9	62	65	68	72	76	79	84	87	91	95	99	104	108	113	118	124
Project Debt Servicing																		
Interest			40	40	40	40	35	30	25	20	15	10	5	0				
Principal repayment							62	62	62	62	62	62	62	62				
Total			40	40	40	40	97	92	87	82	77	72	67	62				
Other Loans																		
Interest																		
Principal repayment																		
Total					0	0	0	0	0	0	0	0	0	0	0			
Total Debt Service			40	40	40	40	97	92	87	82	77	72	67	62	0	0	0	0
Summary of Cash Flow																		
Cash Flow after Debt Service		9	21.9	25.1	28.4	31.9	-21.9	-13.0	-3.9	4.8	13.7	22.7	32.0	41.4	108.5	113.3	118.4	123.7
Initial Project Investment		500	0.0															
Capital replacement/expansion		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	71.85	0.79	0.82	0.90	0.89	0.93	1.01	84.04	1.09
Project Financing																		
External Funding																		
Loan funds		500	0															
Total Funds		500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Cash Flow		0	22	25	28	32	-22	-13	-4	5	14	23	32	41	108	113	118	124
Cumulative Cash Flow		0	22	47	75	107	85	72	68	73	87	110	142	183	291	405	523	647

Table I.4: Cash Flow Calculation, Maaeboodhoo: AUS'000 Synchronising (Digital)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		398																
GOM Loan Cost		376																
Interest During Grace Period		8																
Community Labour		14																
Ongoing Capital Costs		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	71.85	0.79	0.82	0.90	0.89	0.93	1.01	84.04	1.09
Electricity Sales																		
Sales Less Streetlights	MWhpa		89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146
Streetlight Sales	MWhpa		6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8
Revenues																		
Required Tariff	$/kWh		0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Sales			65	68	71	75	79	83	88	92	96	100	105	109	114	119	125	131
Less Bad Debts			-0.32	-0.34	-0.36	-0.38	-0.40	-0.42	-0.44	-0.46	-0.48	-0.50	-0.52	-0.55	-0.57	-0.60	-0.62	-0.65
Street Lights			4.75	4.89	5.03	5.19	5.34	5.50	5.67	5.84	6.01	6.19	6.38	6.57	6.77	6.97	7.18	7.39
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Revenue			69	72	76	80	84	88	93	97	101	106	110	115	121	126	131	137
Operating Expenses																		
Diesel fuel and oil			23	24	25	26	28	29	30	32	33	35	36	38	39	41	43	45
Wages, Allowances plus Management			0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Maintenance			1.09	1.15	1.20	1.26	1.33	1.40	1.47	1.53	1.60	1.67	1.75	1.82	1.90	1.99	2.08	2.17
Other			0.54	0.57	0.60	0.63	0.66	0.70	0.73	0.77	0.80	0.84	0.87	0.91	0.95	0.99	1.04	1.08
Total			25	26	27	29	30	32	33	35	36	38	39	41	43	45	47	49
Cash available from Operations		9	44	46	49	51	54	57	60	62	65	68	71	74	78	81	85	89
Project Debt Servicing																		
Interest			30	30	30	30	26	23	19	15	11	8	4	0				
Principal repayment							47	47	47	47	47	47	47	47				
Total			30	30	30	30	73	70	66	62	58	55	51	47				
Other Loans																		
Interest																		
Principal repayment																		
Total					0	0	0	0	0	0	0	0	0	0	0			
Total Debt Service			30	30	30	30	73	70	66	62	58	55	51	47	0	0	0	0
Summary of Cash Flow																		
Cash Flow after Debt Service		9	14.1	16.4	18.8	21.3	-19.4	-12.8	-6.1	0.3	6.9	13.5	20.3	27.3	77.7	81.1	84.8	88.6
Initial Project Investment		376	0.0															
Capital replacement/expansion		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	71.85	0.79	0.82	0.90	0.89	0.93	1.01	84.04	1.09
Project Financing																		
External Funding																		
Loan funds		376	0															
Total Funds		376	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Cash Flow		0	14	16	19	21	-19	-13	-6	0	7	14	20	27	78	81	85	89
Cumulative Cash Flow		0	14	30	49	71	51	38	32	33	39	53	73	101	178	259	344	433

Table I.5: Cash Flow Calculation, Maaeboodhoo: AUS’000
Reviewed Distribution Design

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		512																
GOM Loan Cost		487																
Interest During Grace Period		10																
Community Labour		14																
Ongoing Capital Costs		9	0.00	0.67	1.25	0.67	0.71	0.58	0.90	71.86	0.81	0.84	0.92	0.91	0.95	1.03	84.07	1.11
Electricity Sales																		
Sales Less Streetlights	MWhpa		89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146
Streetlight Sales	MWhpa		6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8
Revenues																		
Required Tariff	$/kWh		1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Sales			81	85	90	94	99	105	110	115	120	126	131	137	144	150	157	164
Less Bad Debts			0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Street Lights			6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9
Other			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Revenue			87	91	96	101	106	111	117	122	127	133	139	145	151	158	165	172
Operating Expenses																		
Diesel fuel and oil			23	24	25	27	28	30	31	32	34	35	37	39	40	42	44	46
Wages, Allowances plus Management			0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Maintenance			1.11	1.17	1.23	1.29	1.36	1.43	1.50	1.57	1.64	1.71	1.78	1.86	1.95	2.03	2.12	2.22
Other			0.56	0.58	0.61	0.65	0.68	0.71	0.75	0.78	0.82	0.85	0.89	0.93	0.97	1.02	1.06	1.11
Total			25	27	28	29	31	32	34	35	37	38	40	42	44	46	48	50
Cash available from Operations		9	61	64	68	71	75	79	83	87	90	94	99	103	108	112	117	123
Project Debt Servicing																		
Interest			39	39	39	39	34	29	24	19	15	10	5	0				
Principal repayment							61	61	61	61	61	61	61	61				
Total			39	39	39	39	95	90	85	80	76	71	66	61				
Other Loans																		
Interest																		
Principal repayment																		
Total					0	0	0	0	0	0	0	0	0	0	0			
Total Debt Service			39	39	39	39	95	90	85	80	76	71	66	61	0	0	0	0
Summary of Cash Flow																		
Cash Flow after Debt Service		9	22	25	29	32	-20	-11	-2	6	15	24	33	42	108	112	117	123
Initial Project Investment		487	0															
Capital replacement/expansion		9	0	1	1	1	1	1	1	72	1	1	1	1	1	1	84	1
Project Financing																		
External Funding																		
Loan funds		487	0															
Total Funds		487	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Cash Flow		0	22	25	29	32	-20	-11	-2	6	15	24	33	42	108	112	117	123
Cumulative Cash Flow		0	22	48	77	109	89	77	75	81	96	120	152	194	302	414	532	654

Table I.6: Cash Flow Calculation, Maaeboodhoo: AUS'000
Synchronising (Digital) and Reviewed Distribution Design

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		386																
GOM Loan Cost		364																
Interest During Grace Period		7																
Community Labour		14																
Ongoing Capital Costs		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	74.74	0.79	0.82	0.90	0.89	0.93	1.01	79.78	1.09
Electricity Sales																		
Sales Less Streetlights	MWhpa		89	93	98	103	107	112	117	123	128	134	140	146	146	146	146	146
Streetlight Sales	MWhpa		6	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8
Revenues																		
Required Tariff	$/kWh		0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Sales			63	66	70	73	77	81	86	90	94	98	102	107	112	117	122	128
Less Bad Debts			-0.32	-0.33	-0.35	-0.37	-0.39	-0.41	-0.43	-0.45	-0.47	-0.49	-0.51	-0.53	-0.56	-0.58	-0.61	-0.64
Street Lights			4.64	4.77	4.92	5.06	5.22	5.37	5.53	5.70	5.87	6.05	6.23	6.42	6.61	6.81	7.01	7.22
Other			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Revenue			67	71	74	78	82	86	91	95	99	103	108	113	118	123	128	134
Operating Expenses																		
Diesel fuel and oil			23	24	25	26	28	29	30	32	33	35	36	38	39	41	43	45
Wages, Allowances plus Management			0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Maintenance			1.09	1.15	1.20	1.26	1.33	1.40	1.47	1.53	1.60	1.67	1.75	1.82	1.90	1.99	2.08	2.17
Other			0.54	0.57	0.60	0.63	0.66	0.70	0.73	0.77	0.80	0.84	0.87	0.91	0.95	0.99	1.04	1.08
Total			25	26	27	29	30	32	33	35	36	38	39	41	43	45	47	49
Cash available from Operations		9	43	45	47	50	52	55	58	60	63	66	69	72	75	78	82	85
Project Debt Servicing																		
Interest			29	29	29	29	25	22	18	15	11	7	4	0				
Principal repayment							45	45	45	45	45	45	45	45				
Total			29	29	29	29	71	67	64	60	56	53	49	45				
Other Loans																		
Interest																		
Principal repayment																		
Total					0	0	0	0	0	0	0	0	0	0	0			
Total Debt Service			29	29	29	29	71	67	64	60	56	53	49	45	0	0	0	0
Summary of Cash Flow																		
Cash Flow after Debt Service		9	13.5	15.7	18.0	20.4	-18.9	-12.6	-6.1	0.1	6.4	12.9	19.5	26.2	74.9	78.2	81.7	85.4
Initial Project Investment		364	0.0															
Capital replacement/expansion		9	0.00	0.67	0.67	0.67	0.71	0.81	0.88	74.74	0.79	0.82	0.90	0.89	0.93	1.01	79.78	1.09
Project Financing																		
External Funding																		
Loan funds		364	0															
Total Funds		364	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Cash Flow		0	14	16	18	20	-19	-13	-6	0	6	13	19	26	75	78	82	85
Cumulative Cash Flow		0	14	29	47	68	49	36	30	30	37	50	69	95	170	248	330	415

Appendix J:

Cash Flow Calculation for Mukurimagu

Table J.1: Cash Flow Calculation, Mukurimagu: AUS'000
Single Busbar (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		457																
GOM Loan		435																
Interest During Grace Period		9																
Community		8																
Ongoing Capital Costs		5	0	3	3	3	49	3	3	79	4	4	4	55	5	5	86	5
Electricity Sales																		
Sales (MWh)			150	159	169	179	189	200	212	225	238	252	267	283	300	318	337	357
Revenues																		
Required Tariff	$/kWh		0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Sales			106	112	118	125	132	140	148	156	165	175	185	195	207	219	231	245
Less Bad Debts			-0.05	-0.06	-0.06	-0.06	-0.07	-0.07	-0.07	-0.08	-0.08	-0.09	-0.09	-0.10	-0.10	-0.11	-0.12	-0.12
Street Lights			8	8	8	9	9	9	9	10	10	10	11	11	11	12	12	12
Other			11	11	12	12	13	14	15	16	17	17	18	20	21	22	23	24
Net Revenue			124	131	138	146	154	163	172	181	192	202	214	226	238	252	266	281
Operating Expenses																		
Diesel fuel and oil			47	50	53	56	59	62	66	70	74	78	83	87	92	98	103	109
Wages, Allces plus Mngt			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Maintenance			2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5
Other			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total			56	59	62	65	69	72	76	80	84	89	93	98	104	109	116	122
Cash available from Operations			68	72	76	81	85	90	96	101	107	114	120	127	135	142	151	159
Project Debt Servicing																		
Interest			36	36	36	36	33	29	24	20	15	10	6	1				
Principal repayment			0	0	0	0	57	57	57	57	57	57	57	57				
Total			36	36	36	36	90	86	81	77	72	68	63	58				
Future Loans																		
Interest								0	0	0	4	4	1	4				
Principal repayment								0	0	0	17	17	17	17				
Total								0	0	0	22	22	19	22				
Total Debt Service		0	36	36	36	36	90	86	81	77	22	22	19	22				
Summary of Cash Flow																		
Cash Flow after Debt Service		0	32	36	41	45	-5	5	14	25	86	92	101	106	135	142	151	159
Initial project investment		8	0															
Capital replacement/expansion		8.5	0.0	2.6	2.8	2.9	49.0	3.2	3.4	79.2	3.8	4.0	4.2	55.1	4.6	4.9	86.0	5.4
Project Financing																		
External Funding																		
Loan funds							0	0	0	70								
Total Funds							0			70				0				
Annual Cash Flow			32	34	38	42	-54	1	11	15	82	88	97	51	130	137	65	154
Cumulative Cash Flow		0	32	66	104	146	92	93	104	119	201	289	387	437	567	705	769	923

Table J.2: Cash Flow Calculation, Mukurimagu: AUS'000
Split Busbar (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		461																
GOM Loan		439																
Interest During Grace Period		9																
Community		8																
Ongoing Capital Costs		5	0	3	3	3	34	3	3	65	4	4	4	41	5	5	79	5
Electricity Sales																		
Sales (MWh)			150	159	169	179	189	200	212	225	238	252	267	283	300	318	337	357
Revenues																		
Required Tariff	$/kWh		0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Sales			101	107	113	119	126	134	141	149	158	167	177	187	198	209	221	234
Less Bad Debts			-0.05	-0.05	-0.06	-0.06	-0.06	-0.07	-0.07	-0.07	-0.08	-0.08	-0.09	-0.09	-0.10	-0.10	-0.11	-0.12
Street Lights			8	8	8	8	9	9	9	9	10	10	10	11	11	11	11	12
Other			10	11	11	12	13	13	14	15	16	17	18	19	20	21	22	23
Net Revenue			119	125	132	140	147	156	164	174	183	194	204	216	228	241	255	269
Operating Expenses																		
Diesel fuel and oil			47	50	53	56	59	62	66	70	74	78	83	87	92	98	103	109
Wages, Allces plus Mngt			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Maintenance			2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5
Other			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total			56	59	62	65	69	72	76	80	84	89	93	98	104	109	116	122
Cash available from Operations			62	66	70	74	79	83	88	94	99	105	111	118	124	132	139	147
Project Debt Servicing																		
Interest			36	36	36	36	34	29	24	20	15	10	6	1				
Principal repayment			0	0	0	0	58	58	58	58	58	58	58	58				
Total			36	36	36	36	91	87	82	77	73	68	64	59				
Future Loans																		
Interest								0	0	0	4	4	1	4				
Principal repayment								0	0	0	15	15	15	15				
Total								0	0	0	19	19	17	19				
Total Debt Service		0	36	36	36	36	91	87	82	77	19	19	17	19				
Summary of Cash Flow																		
Cash Flow after Debt Service		0	27	30	34	38	-13	-3	6	16	80	86	94	98	124	132	139	147
Initial project investment		8	0															
Capital replacement/expansion		8.5	0.0	2.6	2.8	2.9	33.9	3.2	3.4	65.3	3.8	4.0	4.2	41.1	4.6	4.9	78.6	5.4
Project Financing																		
External Funding																		
Loan funds										62								
Total Funds										62								
Annual Cash Flow			27	28	31	36	-46	-6	3	13	76	82	90	57	120	127	61	142
Cumulative Cash Flow		0	27	54	86	121	75	68	71	84	160	242	332	389	509	636	696	838

Table J.3: Cash Flow Calculation, Mukurimagu: AUS'000
Synchronising (Analogue)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		489																
GOM Loan		467																
Interest During Grace Period		9																
Community		8																
Ongoing Capital Costs		5	0	3	3	3	33	3	3	65	4	4	4	35	5	5	73	5
Electricity Sales																		
Sales (MWh)			150	159	169	179	189	200	212	225	238	252	267	283	300	318	337	357
Revenues																		
Required Tariff	$/kWh		0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Sales			103	109	115	121	128	136	144	152	161	170	180	190	201	213	225	238
Less Bad Debts	%		-0.05	-0.05	-0.06	-0.06	-0.06	-0.07	-0.07	-0.08	-0.08	-0.08	-0.09	-0.09	-0.10	-0.11	-0.11	-0.12
Street Lights			8	8	8	8	9	9	9	9	10	10	10	11	11	11	12	12
Other			10	11	11	12	13	14	14	15	16	17	18	19	20	21	22	24
Net Revenue			121	127	134	142	150	158	167	176	186	197	208	220	232	245	259	274
Operating Expenses																		
Diesel fuel and oil			47	50	53	56	59	62	66	70	74	78	83	87	92	98	103	109
Wages, Allces plus Mngt			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Maintenance			2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5
Other			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total			56	59	62	65	69	72	76	80	84	89	93	98	104	109	115	121
Cash available from Operations			64	68	72	77	81	86	91	96	102	108	114	121	128	136	144	152
Project Debt Servicing																		
Interest			38	38	38	38	36	31	26	21	16	11	6	1				
Principal repayment			0	0	0	0	61	61	61	61	61	61	61	61				
Total			38	38	38	38	97	92	87	82	77	72	67	63				
Future Loans																		
Interest								2	2	2	4	4	1	4				
Principal repayment								8	8	8	23	16	16	16				
Total								9	9	9	28	20	16	20				
Total Debt Service		0	38	38	38	38	97	101	96	91	28	20	16	20				
Summary of Cash Flow																		
Cash Flow after Debt Service		0	26	30	34	39	-16	-15	-5	5	74	88	98	102	128	136	144	152
Initial project investment		8	0															
Capital replacement/expansion		8.5	0.0	2.6	2.8	2.9	33.1	3.2	3.4	64.5	3.8	4.0	4.2	35.3	4.6	4.9	72.7	5.4
Project Financing																		
External Funding																		
Loan funds							30			63								
Total Funds							30			63								
Annual Cash Flow			26	28	31	36	-19	-18	-9	4	71	85	94	66	124	131	71	147
Cumulative Cash Flow		0	26	54	85	121	102	84	75	79	149	234	328	394	518	649	720	866

Table J.4: Cash Flow Calculation, Mukurimagu: AUS'000
Synchronising (Digital)

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		416																
GOM Loan		394																
Interest During Grace Period		8																
Community		8																
Ongoing Capital Costs		5	0	3	3	3	33	3	3	65	4	4	4	35	5	5	79	5
Electricity Sales																		
Sales (MWh)			150	159	169	179	189	200	212	225	238	252	267	283	300	318	337	357
Revenues																		
Required Tariff	$/kWh		0.62	0.62	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.60	0.60	0.60	0.60	0.60
Sales			93	98	104	109	116	122	129	137	145	153	162	171	181	192	203	215
Less Bad Debts			-0.05	-0.05	-0.05	-0.05	-0.06	-0.06	-0.06	-0.07	-0.07	-0.08	-0.08	-0.09	-0.09	-0.10	-0.10	-0.11
Street Lights			7	7	7	8	8	8	8	9	9	9	9	10	10	10	11	11
Other			9	10	10	11	12	12	13	14	14	15	16	17	18	19	20	21
Net Revenue			109	115	121	128	135	143	151	159	168	177	187	198	209	221	233	247
Operating Expenses																		
Diesel fuel and oil			47	50	53	56	59	62	66	70	74	78	83	87	92	98	103	109
Wages, Allces plus Mngt			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Maintenance			2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5
Other			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total			56	59	62	65	69	72	76	80	84	89	93	98	104	109	115	121
Cash available from Operations			52	56	59	63	66	70	75	79	84	89	94	100	105	112	118	125
Project Debt Servicing																		
Interest			32	32	32	32	30	26	22	18	13	9	5	1				
Principal repayment			0	0	0	0	52	52	52	52	52	52	52	52				
Total			32	32	32	32	82	78	74	70	65	61	57	53				
Future Loans																		
Interest								2	2	2	4	4	1	4				
Principal repayment								8	8	8	23	15	15	15				
Total								9	9	9	27	19	16	19				
Total Debt Service		0	32	32	32	32	82	87	83	79	27	19	16	19				
Summary of Cash Flow																		
Cash Flow after Debt Service		0	20	24	27	30	-16	-17	-8	0	57	70	78	80	105	112	118	125
Initial project investment		8	0															
Capital replacement/expansion		8.5	0.0	2.6	2.8	2.9	33.1	3.2	3.4	65.3	3.8	4.0	4.2	35.3	4.6	4.9	78.6	5.4
Project Financing																		
External Funding																		
Loan funds							30			62								
Total Funds							30			62								
Annual Cash Flow			20	21	24	28	-19	-20	-12	-3	53	66	74	45	101	107	40	120
Cumulative Cash Flow		0	20	41	65	93	74	54	42	39	92	157	231	276	377	484	524	643

Table J.5: Cash Flow Calculation, Mukurimagu: AUS'000
Reviewed Distribution Design

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		419																
GOM Loan		398																
Interest During Grace Period		8																
Community		8																
Ongoing Capital Costs		5	0	3	3	3	33	3	3	65	4	4	4	35	5	5	73	5
Electricity Sales																		
Sales (MWh)			150	159	169	179	189	200	212	225	238	252	267	283	300	318	337	357
Revenues																		
Required Tariff	$/kWh		0.61	0.61	0.61	0.61	0.61	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Sales			92	97	103	109	115	121	128	136	143	152	160	170	180	190	201	213
Less Bad Debts	%		-0.05	-0.05	-0.05	-0.05	-0.06	-0.06	-0.06	-0.07	-0.07	-0.08	-0.08	-0.08	-0.09	-0.09	-0.10	-0.11
Street Lights			7	7	7	8	8	8	8	8	9	9	9	10	10	10	10	11
Other			9	10	10	11	11	12	13	14	14	15	16	17	18	19	20	21
Net Revenue			108	114	120	127	134	141	149	158	166	176	186	196	207	219	231	244
Operating Expenses																		
Diesel fuel and oil			47	50	53	56	59	62	66	70	74	78	83	87	92	98	103	109
Wages, Allces plus Mngt			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Maintenance			2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5
Other			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total			56	59	62	65	69	72	76	80	84	89	93	98	104	109	115	121
Cash available from Operations			51	55	58	61	65	69	73	78	82	87	92	98	104	110	116	123
Project Debt Servicing																		
Interest			32	32	32	32	30	26	22	18	14	9	5	1				
Principal repayment			0	0	0	0	52	52	52	52	52	52	52	52				
Total			32	32	32	32	83	79	74	70	66	62	58	53				
Future Loans																		
Interest								2	2	2	5	4	1	4				
Principal repayment								8	8	8	24	17	17	17				
Total								9	9	9	29	21	17	21				
Total Debt Service		0	32	32	32	32	83	88	84	79	29	21	17	21				
Summary of Cash Flow																		
Cash Flow after Debt Service		0	19	22	26	29	-18	-19	-10	-2	54	67	75	77	104	110	116	123
Initial project investment		8	0															
Capital replacement/expansion		8.5	0.0	2.6	2.8	2.9	33.1	3.2	3.4	64.5	3.8	4.0	4.2	35.3	4.6	4.9	72.7	5.4
Project Financing																		
External Funding																		
Loan funds							30	0	0	66								
Total Funds							30			66				0				
Annual Cash Flow			19	20	23	26	-21	-22	-14	0	50	63	71	42	99	105	43	118
Cumulative Cash Flow		0	19	39	61	88	67	45	31	31	81	144	214	256	355	460	503	621

Table J.6: Cash Flow Calculation, Mukurimagu: AUS'000
Synchronising (Digital) and Reviewed Distribution Design

Year		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Project Capital Costs - Total		363																
GOM Loan		343																
Interest During Grace Period		7																
Community		8																
Ongoing Capital Costs		5	0	3	3	3	33	3	3	65	4	4	4	35	5	5	73	5
Electricity Sales																		
Sales (MWh)			150	159	169	179	189	200	212	225	238	252	267	283	300	318	337	357
Revenues																		
Required Tariff	$/kWh		0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.54	0.54	0.54	0.54	0.54
Sales			83	88	93	99	104	110	117	123	130	138	146	154	163	173	182	193
Less Bad Debts			-0.04	-0.04	-0.05	-0.05	-0.05	-0.06	-0.06	-0.06	-0.07	-0.07	-0.07	-0.08	-0.08	-0.09	-0.09	-0.10
Street Lights			6	6	7	7	7	7	7	8	8	8	8	9	9	9	9	10
Other			8	9	9	10	10	11	12	12	13	14	15	15	16	17	18	19
Net Revenue			98	103	109	115	122	128	136	143	151	160	169	178	188	199	210	222
Operating Expenses																		
Diesel fuel and oil			47	50	53	56	59	62	66	70	74	78	83	87	92	98	103	109
Wages, Allces plus Mngt			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Maintenance			2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5
Other			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Total			56	59	62	65	69	72	76	80	84	89	93	98	104	109	115	121
Cash available from Operations			42	44	47	50	53	56	60	63	67	71	75	80	85	90	95	101
Project Debt Servicing																		
Interest			28	28	28	28	26	23	19	15	12	8	4	1				
Principal repayment			0	0	0	0	45	45	45	45	45	45	45	45				
Total			28	28	28	28	72	68	64	61	57	53	50	46				
Future Loans																		
Interest								2	2	2	5	4	1	4				
Principal repayment								8	8	8	26	18	18	18				
Total								10	10	10	31	22	19	22				
Total Debt Service		0	28	28	28	28	72	78	75	71	31	22	19	22				
Summary of Cash Flow																		
Cash Flow after Debt Service		0	14	16	19	22	-19	-22	-15	-8	36	49	56	57	85	90	95	101
Initial project investment		8	0															
Capital replacement/expansion		8	0	3	3	3	33	3	3	65	4	4	4	35	5	5	73	5
Project Financing																		
External Funding																		
Loan funds							33	0	0	72								
Total Funds							33			72				0				
Annual Cash Flow			14	14	16	19	-19	-25	-18	0	32	45	52	22	80	85	22	95
Cumulative Cash Flow		0	14	27	43	62	44	19	0	0	32	77	129	151	231	316	338	433

Appendix K:

Estimated Base Capital Cost For Maaeboodhoo

Table K.1: Estimated Cost AUS$, Tools, Maaeboodhoo

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
TOOLS		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,340**	**-**	**-**	**-**	**47.27**	**7,340**	**47.27**	**7,388**
Mechanical																
Vernier calliper, digital (metric)	1	-	440	-	-	-	3	-	440	-	-	-	3	440	3	443
Feeler gauge (metric)	1	-	10	-	-	-	0	-	10	-	-	-	0	10	0	10
Oil filter wrench for engine offered: Set	1	-	61	-	-	-	0	-	61	-	-	-	0	61	0	62
Battery Charger: Set	1	-	176	-	-	-	1	-	176	-	-	-	1	176	1	177
Portable welding plant: Set	1	-	440	-	-	-	3	-	440	-	-	-	3	440	3	443
Bench Vice, No. 5	1	-	182	-	-	-	1	-	182	-	-	-	1	182	1	183
Hand Grinder	1	-	390	-	-	-	3	-	390	-	-	-	3	390	3	393
Hand drill (battery): Set	1	-	349	-	-	-	2	-	349	-	-	-	2	349	2	351
Heavy duty hand drill (electrical), HILTI: Set	1	-	547	-	-	-	4	-	547	-	-	-	4	547	4	550
Set drill bits for steel (1 - 13 mm): Set	1	-	208	-	-	-	1	-	208	-	-	-	1	208	1	209
Set drill bits for concrete (1 - 13 mm): Set	1	-	26	-	-	-	0		26	-	-	-	0	26	0	26
Set drill bits wood (1 - 13 mm): Set	1	-	38	-	-	-	0	-	38	-	-	-	0	38	0	38
Hacksaw frame	1	-	16	-	-	-	0	-	16	-	-	-	0	16	0	16
Hacksaw blade	1	-	2	-	-	-	0.01	-	1.58	-	-	-	0.01	1.58	0.01	1.59
Compressor, with hose, gun and can: Set	1	-	770	-	-	-	5	-	770	-	-	-	5	770	5	775
Wrench set, open ring (metric): Set	1	-	42	-	-	-	0	-	42	-	-	-	0	42	0	42
Box Socket set, includes metal box, 8 mm - 32 mm sockets 1/2", 1/2" ratchet, 1/2" T-bar, 1/2" universal socket: Set	1	-	713	-	-	-	5	-	713	-	-	-	5	713	5	718
Adjustable spanner, 8"	1	-	10	-	-	-	0	-	10	-	-	-	0	10	0	10
Adjustable spanner, 21"	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Allen key set, mm: Set	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Screw driver set	1	-	59	-	-	-	0	-	59	-	-	-	0	59	0	60
Hole punch set	1	-	40	-	-	-	0	-	40	-	-	-	0	40	0	40
Plastic hammer	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Ball peen hammer	1	-	21	-	-	-	0	-	21	-	-	-	0	21	0	21
Hand cold chisel	1	-	4	-	-	-	0	-	4	-	-	-	0	4	0	4
Hand shear	1	-	4	-	-	-	0	-	4	-	-	-	0	4	0	4
Grease gun set, includes grease nipples: Set	1	-	27	-	-	-	0	-	27	-	-	-	0	27	0	27
Oil can	1	-	9	-	-	-	0	-	9	-	-	-	0	9	0	9

Table K.1: Estimated Cost AUS$, Tools, Maaeboodhoo

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
Electrical																
Tool Box -Big Volume Box with four tray cantilever	1	-	99	-	-	-	1	-	99	-	-	-	1	99	1	100
Digital Multi-Meter Similar to: Model: Hioki 3200-50	1	-	341	-	-	-	2	-	341	-	-	-	2	341	2	343
Power outlet tester	1	-	38	-	-	-	0	-	38	-	-	-	0	38	0	38
Rubber Hand Glove - 600V/1000V	1	-	89	-	-	-	1	-	89	-	-	-	1	89	1	90
Pen Tester (neon tester - 6")	1	-	3	-	-	-	0	-	3	-	-	-	0	3	0	3
Pen Tester (neon tester - 8")	1	-	4	-	-	-	0	-	4	-	-	-	0	4	0	4
Crimping Tool (16mm^2 to 120mm^2)	1	-	446	-	-	-	3	-	446	-	-	-	3	446	3	448
Adjustable Wrench - Plastic-Dipped Handles (150mm)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Adjustable Wrench - Plastic-Dipped Handles (255mm)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Combination Wrench Set (12Pcs Set)	1	-	297	-	-	-	2	-	297	-	-	-	2	297	2	299
Socket Wrench Set (12Pcs Set)	1	-	297	-	-	-	2	-	297	-	-	-	2	297	2	299
L-Style Hex-Key Set (Caddy Set)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Hammer (1Lb)	1	-	21	-	-	-	0	-	21	-	-	-	0	21	0	21
Hammer (2Lb)	1	-	32	-	-	-	0	-	32	-	-	-	0	32	0	32
Cable Cutter (16mm^2 to 120mm^2)	1	-	257	-	-	-	2	-	257	-	-	-	2	257	2	259
Standard-Nose Diagonal Cutter	1	-	30	-	-	-	0	-	30	-	-	-	0	30	0	30
Pliers (12")	1	-	30	-	-	-	0	-	30	-	-	-	0	30	0	30
Pliers (8")	1	-	24	-	-	-	0	-	24	-	-	-	0	24	0	24
NT-Cutter - Big	1	-	9	-	-	-	0	-	9	-	-	-	0	9	0	9
Blade set (for NT-Cutter)	1	-	10	-	-	-	0	-	10	-	-	-	0	10	0	11
Steel Tape - 20' (Measuring Tape)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Screw Driver 12" (-)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Combination Screwdriver Set	1	-	99	-	-	-	1	-	99	-	-	-	1	99	1	100
ECPI wire cutter for sealing purpose	1	-	129	-	-	-	1	-	129	-	-	-	1	129	1	130
Meter Sealing Equipment	1	-	347	-	-	-	2	-	347	-	-	-	2	347	2	349

Table K.2: Estimated Cost, Aus$ for Civil Works and Distribution Works, Maaeboodhoo

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
CIVIL WORKS								**267**	**1,333**	**15,309**	**-**	**264,690**	**1,749**	**1,600**	**281,748**	**283,348**
Site preparation including road, parking area, drainage	0.2	-	-	-	-	11,984	-	-	-	-	-	2,397	-	-	2,397	2,397
Power station modification	1	-	-	-	-	103,502	-	-	-	-	-	103,502	-	-	103,502	103,502
Power station structure, cladding, roofing, lining.	0.75	-	-	-	-	146,203	-	-	-	-	-	109,652	-	-	109,652	109,652
Power station slab and foundations	0.75	-	-	-	-	17,648	-	-	-	-	-	13,236	-	-	13,236	13,236
Generating set foundations	3	-	-	-	-	7,925	-	-	-	-	-	23,776	-	-	23,776	23,776
Foundations, bund and oil interceptor for bulk fuel	0.75	-	-	-	-	3,040	-	-	-	-	-	2,280	-	-	2,280	2,280
Bulk fuel tank	1	-	-	15,175	-	2,251	1,412	-	-	15,175	-	2,251	1,412	-	18,838	18,838
Toilet, washbasin, shower, septic tank, plumbing.	0	-	-	-	-	4,257	-	-	-	-	-	-	-	-	-	-
Rain water collection, water tank, water pump	0	-	-	-	-	7,558	94	-	-	-	-	-	-	-	-	-
Power station light and power	0.75	-	-	-	-	4,864	253	-	-	-	-	3,648	190	-	3,838	3,838
Lightning Protection	1	-	-	-	-	3,282	107	-	-	-	-	3,282	107	-	3,389	3,389
Fire extinguishers	1	267	1,333	133	-	667	40	267	1,333	133	-	667	40	1,600	840	2,440
DISTRIBUTION WORKS		**-**	**-**	**-**	**-**	**-**	**-**	**406**	**41,980**	**-**	**-**	**14,098**	**812**	**42,386**	**14,910**	**57,295**
4Cx25sq.mm Cu/PVC/SWA/PVC Underground Cable	675	0	10	-	-	1	0.20	69	6,702	-	-	420	138	6,771	559	7,329
4Cx16sq.mm Cu/PVC/SWA/PVC Underground Cable	1,439	0	9	-	-	0	0.19	137	13,258	-	-	597	273	13,395	871	14,266
4Cx16sq.mm Cu/PVC/PVC Underground Cable	50	0	7	-	-	0	0.15	4	364	-	-	21	8	368	28	396
2Cx6sq.mm Cu/PVC/PVC Underground Cable	6,450	0	1	-	-	0	0.01	33	3,228	-	-	2,677	67	3,261	2,744	6,005
2Cx2.5sq.mm Cu/PVC/PVC Underground Cable	0	0	2	-	-	0	0.03	-	-	-	-	-	-	-	-	-
4Cx25sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	16	0	39	-	-	12	0.06	0	621	-	-	199	1	621	200	822
4Cx16sq.mm Cu Cable 600/1000VTerminationsand Joints per Conductor	80	0	6	-	-	2	0.01	0	517	-	-	166	1	518	167	685
4Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	3	0	6	-	-	2	0.01	0	19	-	-	6	0	19	6	26
2Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	258	0	6	-	-	2	0.01	1	1,668	-	-	535	3	1,670	538	2,208
2Cx2.5sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	0	0	6	-	-	2	0.01	-	-	-	-	-	-	-	-	-
GRP Distribution Box (650x500x250mm), complete	20	8	780	-	-	149	16.08	161	15,602	-	-	2,988	322	15,763	3,310	19,073
Cable Trenches	2,273	-	-	-	-	3	-	-	-	-	-	6,487	-	-	6,487	6,487

Table K.2: Estimated Cost, Aus$ of Spares, Maaeboodhoo

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
SPARES								**-**	**1,658**	**-**	**-**	**-**	**11**	**1,658**	**11**	**1,670**
Diesel engine																
Cartridge, Fuel filter	2	-	7	-	-	-	0.05	-	13.47	-	-	-	0.09	13.47	0.09	14
Cartridge, Lube oil filter	6	-	7	-	-	-	0.05	-	40.41	-	-	-	0.28	40.41	0.28	41
Cartridge, Air filter	2	-	39	-	-	-	0.27	-	78.75	-	-	-	0.54	78.75	0.54	79
Gasket set, Overhaul	1	-	263	-	-	-	1.81	-	262.66	-	-	-	1.81	262.66	1.81	264
Repair kit, Turbocharger	1	-	33	-	-	-	0.23	-	33.16	-	-	-	0.23	33.16	0.23	33
Repair kit, Cooling water pump	1	-	105	-	-	-	0.72	-	105.17	-	-	-	0.72	105.17	0.72	106
Repair kit, Lube oil pump	1	-	50	-	-	-	0.35	-	50.25	-	-	-	0.35	50.25	0.35	51
Alternator																
Diode set	1	-	52	-	-	-	0.36	-	51.81	-	-	-	0.36	51.81	0.36	52
Surge suppressor	1	-	52	-	-	-	0.36	-	51.81	-	-	-	0.36	51.81	0.36	52
AVR	1	-	104	-	-	-	0.71	-	103.61	-	-	-	0.71	103.61	0.71	104
Bearing, drive end	1	-	52	-	-	-	0.36	-	51.81	-	-	-	0.36	51.81	0.36	52
Bearing, non - drive end	1	-	45	-	-	-	0.31	-	45.07	-	-	-	0.31	45.07	0.31	45.38
Distribution		-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Straight through jointing kit for 4 core 25 sq.mm cable	2	-	23	-	-	-	0.16	-	46.63	-	-	-	0.32	46.63	0.32	46.95
Straight through jointing kit for 4 core 16 sq.mm cable	1	-	21	-	-	-	0.14	-	20.72	-	-	-	0.14	20.72	0.14	20.87
Ferrule (Butt Connectors) -600/1000V for 25 sq.mm Cables	8	-	0	-	-	-	0.00	-	3.32	-	-	-	0.02	3.32	0.02	3.34
Ferrule (Butt Connectors) -600/1000V for 16 sq.mm Cables	4	-	0	-	-	-	0.00	-	1.55	-	-	-	0.01	1.55	0.01	1.56
Ferrule (Butt Connectors) -600/1000V for 6 sq.mm Cables	16	-	0	-	-	-	0.00	-	5.80	-	-	-	0.04	5.80	0.04	5.84
Cu Lugs for 25 sq.mm Cable	2	-	0	-	-	-	0.00	-	0.47	-	-	-	0.00	0.47	0.00	0.47
Cu Lugs for 16 sq.mm Cable	1	-	0	-	-	-	0.00	-	0.16	-	-	-	0.00	0.16	0.00	0.16
Cu Lugs for 6 sq.mm Cable	8	-	0	-	-	-	0.00	-	0.21	-	-	-	0.00	0.21	0.00	0.21
Lug Sleeves for 25 sq.mm Cable(Red colour)	2	-	0	-	-	-	0.00	-	0.10	-	-	-	0.00	0.10	0.00	0.10
Lug Sleeves for 25 sq.mm Cable(Yellow colour)	2	-	0	-	-	-	0.00	-	0.10	-	-	-	0.00	0.10	0.00	0.10
Lug Sleeves for 25 sq.mm Cable(Blue colour)	2	-	0	-	-	-	0.00	-	0.10	-	-	-	0.00	0.10	0.00	0.10
Lug Sleeves for 25 sq.mm Cable(Black colour)	2	-	0	-	-	-	0.00	-	0.10	-	-	-	0.00	0.10	0.00	0.10
Lug Sleeves for 16 sq.mm Cable(Red colour)	2	-	0	-	-	-	0.00	-	0.08	-	-	-	0.00	0.08	0.00	0.08
Lug Sleeves for 16 sq.mm Cable(Yellow colour)	1	-	0	-	-	-	0.00	-	0.04	-	-	-	0.00	0.04	0.00	0.04
Lug Sleeves for 16 sq.mm Cable(Blue colour)	1	-	0	-	-	-	0.00	-	0.04	-	-	-	0.00	0.04	0.00	0.04
Lug Sleeves for 16 sq.mm Cable(Black colour)	1	-	0	-	-	-	0.00	-	0.04	-	-	-	0.00	0.04	0.00	0.04
Insulation Tape (Red colour)	10	-	0	-	-	-	0.00	-	1.55	-	-	-	0.01	1.55	0.01	1.56
Insulation Tape (Yellow colour)	10	-	0	-	-	-	0.00	-	1.55	-	-	-	0.01	1.55	0.01	1.56
Insulation Tape (Blue Colour)	10	-	0	-	-	-	0.00	-	1.55	-	-	-	0.01	1.55	0.01	1.56
Insulation Tape (Black Colour)	10	-	0	-	-	-	0.00	-	1.55	-	-	-	0.01	1.55	0.01	1.56
Scotch Tape (Scotch 23)	3	-	4	-	-	-	0.02	-	10.72	-	-	-	0.07	10.72	0.07	10.80
Distribution box (spare)	1	-	285	-	-	-	1.96	-	284.69	-	-	-	1.96	284.69	1.96	287
63A (16KA) 3P MCCB	2	-	142	-	-	-	0.98	-	283.20	-	-	-	1.95	283.20	1.95	285
40A/32A (4.5KA) Single Pole MCB	10	-	5	-	-	-	0.03	-	49.56	-	-	-	0.34	49.56	0.34	50
4 Way Terminal Block (for DB Boxes)	1	-	2	-	-	-	0.02	-	2.36	-	-	-	0.02	2.36	0.02	2.38
Meter Seals	300	-	0	-	-	-	0.00	-	28.32	-	-	-	0.20	28.32	0.20	28.52
Sealing Wire Roll	1	-	26	-	-	-	0.18	-	25.96	-	-	-	0.18	25.96	0.18	26.14

Table K.3: Capital Cost, Aus$, for Maaeboodhoo
Single Busbar (Analogue)

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
MECHANICAL AND ELECTRICAL GENERATION WORKS								**1,131**	**109,680**	**-**	**-**	**12,718**	**2,672**	**110,811**	**15,390**	**126,201**
48 kW diesel generator set	3	269	26,134	-	-	3,020	653	808	78,402	-	-	9,060	1,960	79,211	11,020	90,231
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Generator panel with synchronising	3	34	3,276	-	-	625	68	34	3,276	-	-	625	68	3,310	692	4,002
Feeder Panel, 5feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Exhaust systems	3	22	2,156	-	-	378	54	67	6,468	-	-	1,133	162	6,535	1,294	7,829
Remote Governor & AVR	3	27	2,574	-	-	-	53	80	7,722	-	-	-	159	7,801	159	7,961
CIVIL WORKS								**267**	**1,333**	**15,309**	**-**	**264,690**	**1,749**	**1,600**	**281,748**	**283,348**
DISTRIBUTION WORKS								**406**	**41,980**	**-**	**-**	**14,098**	**812**	**42,386**	**14,910**	**57,295**
SPARES								**-**	**1,658**	**-**	**-**	**-**	**11**	**1,658**	**11**	**1,670**
TOOLS		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,340**	**-**	**-**	**-**	**47.27**	**7,340**	**47.27**	**7,388**
TOTAL 2004 PRICES								1,803	161,992	15,309	-	291,506	5,291	163,796	312,106	475,902
INFLATION 1 YEAR @ 2.5% PA								45	4,050	383	-	7,288	132	4,095	7,803	11,898
TOTAL 2005 PRICES								1,848	166,042	15,691	-	298,794	5,424	167,890	319,909	**487,799**

Table K.4: Capital Cost, Aus$, for Maaeboodhoo
Split Busbar (Analogue)

Description	Qty	Estimated Unit Price						Estimated Total Price								
			Material		Labour		F & I		Material		Labour		F & I			
		Design		Local	Intern'l		Local	Design			Intern'l		Local	Intern'l	Local	Total
		Intern'l	CIF			Local		Intern'l	CIF	Local		Local				
MECHANICAL AND ELECTRICAL GENERATION WORKS								**1,033**	**100,241**	**-**	**-**	**13,347**	**2,422**	**101,275**	**15,769**	**117,044**
31 kW diesel generator set	2	206	19,956	-	-	3,020	499	411	39,913	-	-	6,040	998	40,324	7,038	47,362
40 kW diesel generator set	1	265	25,750	-	-	3,020	644	265	25,750	-	-	3,020	644	26,016	3,664	29,680
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Generator panel with synchronising	3	68	6,576	-	-	1,254	136	68	6,576	-	-	1,254	136	6,644	1,389	8,033
Feeder Panel, 5feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Exhaust systems	3	22	2,156	-	-	378	54	67	6,468	-	-	1,133	162	6,535	1,294	7,829
Remote Governor & AVR	3	27	2,574	-	-	-	53	80	7,722	-	-	-	159	7,801	159	7,961
CIVIL WORKS								**267**	**1,333**	**15,309**	**-**	**264,690**	**1,749**	**1,600**	**281,748**	**283,348**
DISTRIBUTION WORKS								**406**	**41,980**	**-**	**-**	**14,098**	**812**	**42,386**	**14,910**	**57,295**
SPARES								**-**	**1,658**	**-**	**-**	**-**	**11**	**1,658**	**11**	**1,670**
TOOLS		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,340**	**-**	**-**	**-**	**47.27**	**7,340**	**47.27**	**7,388**
TOTAL 2004 PRICES								1,706	152,553	15,309	-	292,135	5,041	154,259	312,485	466,744
INFLATION 1 YEAR @ 2.5% PA								43	3,814	383	-	7,303	126	3,856	7,812	11,669
TOTAL 2005 PRICES								1,749	156,367	15,691	-	299,439	5,167	158,116	320,297	**478,413**

Table K.5: Capital Cost, Aus$, Maaeboodhoo Synchronising (Analogue)

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
MECHANICAL AND ELECTRICAL GENERATION WORKS								**1,187**	**115,115**	**-**	**-**	**18,882**	**2,666**	**116,301**	**21,548**	**137,850**
18 kW diesel generator set	1	119	11,588	-	-	3,020	290	119	11,588	-	-	3,020	290	11,707	3,310	15,017
31 kW diesel generator set	2	206	19,956	-	-	3,020	499	411	39,913	-	-	6,040	998	40,324	7,038	47,362
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Control equipment with synchronising (Analogue)	3	122	11,871	-	-	2,263	245	367	35,612	-	-	6,788	734	35,980	7,522	43,502
Feeder Panel, 5feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Exhaust systems	3	22	2,156	-	-	378	54	67	6,468	-	-	1,133	162	6,535	1,294	7,829
Remote Governor & AVR	3	27	2,574	-	-	-	53	80	7,722	-	-	-	159	7,801	159	7,961
CIVIL WORKS								**267**	**1,333**	**15,309**	**-**	**264,690**	**1,749**	**1,600**	**281,748**	**283,348**
DISTRIBUTION WORKS								**406**	**41,980**	**-**	**-**	**14,098**	**812**	**42,386**	**14,910**	**57,295**
SPARES								**-**	**1,658**	**-**	**-**	**-**	**11**	**1,658**	**11**	**1,670**
TOOLS		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,340**	**-**	**-**	**-**	**47.27**	**7,340**	**47.27**	**7,388**
TOTAL 2004 PRICES								1,859	167,427	15,309	-	297,670	5,286	169,286	318,264	487,550
INFLATION 1 YEAR @ 2.5% PA								56	5,023	459	-	8,930	159	5,079	9,548	12,189
TOTAL 2005 PRICES								**1,915**	**172,449**	**15,768**	**-**	**306,600**	**5,444**	**174,364**	**327,812**	**499,739**

Table K.6: Capital Cost, Aus$, Maaeboodhoo Synchronising (Digital)

Description	Qty	Estimated Unit Price: Design	Material		Labour		F & I	Estimated Total Price: Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
CIVIL WORKS								**267**	**1,333**	**15,309**	**-**	**153,053**	**1,749**	**1,600**	**170,110**	**171,710**
Site preparation including road, parking area, drainage	0.2	-	-	-	-	11,984	-	-	-	-	-	2,397	-	-	2,397	2,397
Power station modification	1	-	-	-	-	103,502	-	-	-	-	-	103,502	-	-	103,502	103,502
Power station structure, cladding, roofing, lining. (without control room)	0.75	-	-	-	-	15,001	-	-	-	-	-	11,250	-	-	11,250	11,250
Power station slab and foundations(without control room)	0.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Generating set foundations	3	-	-	-	-	7,925	-	-	-	-	-	23,776	-	-	23,776	23,776
Foundations, bund and oil interceptor for bulk fuel	0.75	-	-	-	-	3,040	-	-	-	-	-	2,280	-	-	2,280	2,280
Bulk fuel tank	1	-	-	15,175	-	2,251	1,412	-	-	15,175	-	2,251	1,412	-	18,838	18,838
Toilet, washbasin, shower, septic tank, plumbing.	0	-	-	-	-	4,257	-	-	-	-	-	-	-	-	-	-
Rain water collection, water tank, water pump	0	-	-	-	-	7,558	94	-	-	-	-	-	-	-	-	-
Power station light and power	0.75	-	-	-	-	4,864	253	-	-	-	-	3,648	190	-	3,838	3,838
Lightning Protection	1	-	-	-	-	3,282	107	-	-	-	-	3,282	107	-	3,389	3,389
Fire extinguishers	1	267	1,333	133	-	667	40	267	1,333	133	-	667	40	1,600	840	2,440
MECHANICAL AND ELECTRICAL GENERATION WORKS								**1,111**	**107,768**	**-**	**-**	**17,544**	**2,660**	**108,879**	**20,205**	**129,084**
18 kW diesel generator set	1	119	11,588	-	-	3,020	290	119	11,588	-	-	3,020	290	11,707	3,310	15,017
31 kW diesel generator set	2	206	19,956	-	-	3,020	499	411	39,913	-	-	6,040	998	40,324	7,038	47,362
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Generator panel with digital synchronising	3	103	9,971	-	-	1,901	249	308	29,914	-	-	5,702	748	30,223	6,450	36,673
Feeder Panel, 5feeders, 100Amps MCB	1	34	3,297	-	-	503	82	34	3,297	-	-	503	82	3,331	585	3,917
Exhaust systems	3	22	2,156	-	-	378	54	67	6,468	-	-	1,133	162	6,535	1,294	7,829
Remote Governor & AVR	3	27	2,574	-	-	-	53	80	7,722	-	-	-	159	7,801	159	7,961
DISTRIBUTION WORKS								**406**	**41,980**	**-**	**-**	**14,098**	**812**	**42,386**	**14,910**	**57,295**
SPARES								**-**	**1,658**	**-**	**-**	**-**	**11**	**1,658**	**11**	**1,670**
TOOLS		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,340**	**-**	**-**	**-**	**47.27**	**7,340**	**47.27**	**7,388**
TOTAL 2004 PRICES								1,784	160,237	15,309	-	184,695	5,281	162,020	205,284	367,304
INFLATION 1 YEAR @ 2.5% PA								54	4,807	459	-	5,541	158	4,861	6,159	9,183
TOTAL 2005 PRICES								1,837	165,044	15,768	-	190,236	5,439	166,881	211,443	**376,487**

Table K.7: Estimated Cost, Aus$, for Maaeboodhoo

(Spares for Reviewed Distribution Design)

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
SPARES								**-**	**1,658**	**-**	**-**	**-**	**11**	**1,658**	**11**	**1,670**
Diesel engine																
Cartridge, Fuel filter	2	-	7	-	-	-	0	-	13	-	-	-	0	13	0	14
Cartridge, Lube oil filter	6	-	7	-	-	-	0	-	40	-	-	-	0	40	0	41
Cartridge, Air filter	2	-	39	-	-	-	0	-	79	-	-	-	1	79	1	79
Gasket set, Overhaul	1	-	263	-	-	-	2	-	263	-	-	-	2	263	2	264
Repair kit, Turbocharger	1	-	33	-	-	-	0	-	33	-	-	-	0	33	0	33
Repair kit, Cooling water pump	1	-	105	-	-	-	1	-	105	-	-	-	1	105	1	106
Repair kit, Lube oil pump	1	-	50	-	-	-	0	-	50	-	-	-	0	50	0	51
Alternator																
Diode set	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
Surge suppressor	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
AVR	1	-	104	-	-	-	1	-	104	-	-	-	1	104	1	104
Bearing, drive end	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
Bearing, non - drive end	1	-	45	-	-	-	0	-	45	-	-	-	0	45	0	45
Distribution		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Straight through jointing kit for 4 core 25 sq.mm cable	2	-	23	-	-	-	0	-	47	-	-	-	0	47	0	47
Straight through jointing kit for 4 core 16 sq.mm cable	1	-	21	-	-	-	0	-	21	-	-	-	0	21	0	21
Ferrule (Butt Connectors) -600/1000V for 25 sq.mm Cables	8	-	0	-	-	-	0	-	3	-	-	-	0	3	0	3
Ferrule (Butt Connectors) -600/1000V for 16 sq.mm Cables	4	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Ferrule (Butt Connectors) -600/1000V for 6 sq.mm Cables	16	-	0	-	-	-	0	-	6	-	-	-	0	6	0	6
Cu Lugs for 25 sq.mm Cable	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Cu Lugs for 16 sq.mm Cable	1	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Cu Lugs for 6 sq.mm Cable	8	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 25 sq.mm Cable(Red colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 25 sq.mm Cable(Yellow colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 25 sq.mm Cable(Blue colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 25 sq.mm Cable(Black colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 16 sq.mm Cable(Red colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 16 sq.mm Cable(Yellow colour)	1	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 16 sq.mm Cable(Blue colour)	1	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 16 sq.mm Cable(Black colour)	1	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Insulation Tape (Red colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape (Yellow colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape (Blue Colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape (Black Colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Scotch Tape (Scotch 23)	3	-	4	-	-	-	0	-	11	-	-	-	0	11	0	11
Distribution box (spare)	1	-	285	-	-	-	2	-	285	-	-	-	2	285	2	287
63A (16KA) 3P MCCB	2	-	142	-	-	-	1	-	283	-	-	-	2	283	2	285
40A/32A (4.5KA) Single Pole MCB	10	-	5	-	-	-	0	-	50	-	-	-	0	50	0	50
4 Way Terminal Block (for DB Boxes)	1	-	2	-	-	-	0	-	2	-	-	-	0	2	0	2
Meter Seals	300	-	0	-	-	-	0	-	28	-	-	-	0	28	0	29
Sealing Wire Roll	1	-	26	-	-	-	0	-	26	-	-	-	0	26	0	26

Table K.8: Capital Cost Aus$, Maaeboodhoo
Reviewed Distribution Design

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
MECHANICAL AND ELECTRICAL GENERATION WORKS								**1,187**	**115,115**	**-**	**-**	**18,882**	**2,666**	**116,301**	**21,548**	**137,850**
18 kW diesel generator set	1	119	11,588	-	-	3,020	290	119	11,588	-	-	3,020	290	11,707	3,310	15,017
31 kW diesel generator set	2	206	19,956	-	-	3,020	499	411	39,913	-	-	6,040	998	40,324	7,038	47,362
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Generator panel with synchronising	3	122	11,871	-	-	2,263	245	367	35,612	-	-	6,788	734	35,980	7,522	43,502
Feeder Panel, 5feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Exhaust systems	3	22	2,156	-	-	378	54	67	6,468	-	-	1,133	162	6,535	1,294	7,829
Remote Governor & AVR	3	27	2,574	-	-	-	53	80	7,722	-	-	-	159	7,801	159	7,961
CIVIL WORKS								**267**	**1,333**	**15,309**	**-**	**264,690**	**1,749**	**1,600**	**281,748**	**283,348**
DISTRIBUTION WORKS		**-**	**-**	**-**	**-**	**-**	**-**	**323**	**33,174**	**-**	**-**	**11,084**	**646**	**33,496**	**11,730**	**45,226**
4Cx25sq.mm Cu/PVC/SWA/PVC Underground Cable	0	0	10	-	-	1	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu/PVC/SWA/PVC Underground Cable	1,891	0	9	-	-	0	0	180	17,417	-	-	785	359	17,596	1,144	18,740
4Cx16sq.mm Cu/PVC/PVC Underground Cable	50	0	7	-	-	0	0	4	364	-	-	21	8	368	28	396
2Cx6sq.mm Cu/PVC/PVC Underground Cable	6,450	0	1	-	-	0	0	33	3,228	-	-	2,677	67	3,261	2,744	6,005
2Cx2.5sq.mm Cu/PVC/PVC Underground Cable	0	0	2	-	-	0	0	-	-	-	-	-	-	-	-	-
4Cx25sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	0	0	39	-	-	12	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu Cable 600/1000VTerminations and Joints per Conductor	52	0	6	-	-	2	0	0	336	-	-	108	1	337	108	445
4Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	3	0	6	-	-	2	0	0	19	-	-	6	0	19	6	26
2Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	258	0	6	-	-	2	0	1	1,668	-	-	535	3	1,670	538	2,208
2Cx2.5sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	0	0	6	-	-	2	0	-	-	-	-	-	-	-	-	-
GRP Distribution Box (650x500x250mm), complete	13	8	780	-	-	149	16	105	10,141	-	-	1,942	209	10,246	2,152	12,397
Cable Trenches	1,756	-	-	-	-	3	-	-	-	-	-	5,010	-	-	5,010	5,010
SPARES								**-**	**1,658**	**-**	**-**	**-**	**11**	**1,658**	**11**	**1,670**
TOOLS								**-**	**7,497**	**-**	**-**	**-**	**48**	**7,497**	**48**	**7,546**
TOTAL 2004 PRICES								1,776	158,621	15,309	-	294,656	5,119	160,397	315,084	475,481
INFLATION 1 YEAR @ 2.5% PA								53	4,759	459	-	8,840	154	4,812	9,453	11,887
TOTAL 2005 PRICES								1,829	163,379	15,768	-	303,496	5,273	165,209	324,537	**487,368**

Table K.9: Capital Cost Aus$, Maaeboodhoo Synchronising (Digital) and Reviewed Distribution Design

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
CIVIL WORKS								**267**	**1,333**	**15,309**	**-**	**153,053**	**1,749**	**1,600**	**170,110**	**171,710**
Site preparation including road, parking area, drainage	0.2	-	-	-	-	11,984	-	-	-	-	-	2,397	-	-	2,397	2,397
Power station modification	1	-	-	-	-	103,502	-	-	-	-	-	103,502	-	-	103,502	103,502
Power station structure, cladding, roofing, lining.	0.75	-	-	-	-	15,001	-	-	-	-	-	11,250	-	-	11,250	11,250
Power station slab and foundations	0.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Generating set foundations	3	-	-	-	-	7,925	-	-	-	-	-	23,776	-	-	23,776	23,776
Foundations, bund and oil interceptor for bulk fuel	0.75	-	-	-	-	3,040	-	-	-	-	-	2,280	-	-	2,280	2,280
Bulk fuel tank	1	-	-	15,175	-	2,251	1,412	-	-	15,175	-	2,251	1,412	-	18,838	18,838
Toilet, washbasin, shower, septic tank, plumbing.	0	-	-	-	-	4,257	-	-	-	-	-	-	-	-	-	-
Rain water collection, water tank, water pump	0	-	-	-	-	7,558	94	-	-	-	-	-	-	-	-	-
Power station light and power	0.75	-	-	-	-	4,864	253	-	-	-	-	3,648	190	-	3,838	3,838
Lightning Protection	1	-	-	-	-	3,282	107	-	-	-	-	3,282	107	-	3,389	3,389
Fire extinguishers	1	267	1,333	133	-	667	40	267	1,333	133	-	667	40	1,600	840	2,440
MECHANICAL AND ELECTRICAL GENERATION WORKS								**1,111**	**107,768**	**-**	**-**	**17,544**	**2,660**	**108,879**	**20,205**	**129,084**
18 kW diesel generator set	1	119	11,588	-	-	3,020	290	119	11,588	-	-	3,020	290	11,707	3,310	15,017
31 kW diesel generator set	2	206	19,956	-	-	3,020	499	411	39,913	-	-	6,040	998	40,324	7,038	47,362
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Generator panel with synchronising	3	103	9,971	-	-	1,901	249	308	29,914	-	-	5,702	748	30,223	6,450	36,673
Feeder Panel, 5feeders, 100Amps MCB	1	34	3,297	-	-	503	82	34	3,297	-	-	503	82	3,331	585	3,917
Exhaust systems	3	22	2,156	-	-	378	54	67	6,468	-	-	1,133	162	6,535	1,294	7,829
Remote Governor & AVR	3	27	2,574	-	-	-	53	80	7,722	-	-	-	159	7,801	159	7,961
DISTRIBUTION WORKS		**-**	**-**	**-**	**-**	**-**	**-**	**323**	**33,174**	**-**	**-**	**11,084**	**646**	**33,496**	**11,730**	**45,226**
4Cx25sq.mm Cu/PVC/SWA/PVC Underground Cable	0	0	10	-	-	1	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu/PVC/SWA/PVC Underground Cable	1,891	0	9	-	-	0	0	180	17,417	-	-	785	359	17,596	1,144	18,740
4Cx16sq.mm Cu/PVC/PVC Underground Cable	50	0	7	-	-	0	0	4	364	-	-	21	8	368	28	396
2Cx6sq.mm Cu/PVC/PVC Underground Cable	6,450	0	1	-	-	0	0	33	3,228	-	-	2,677	67	3,261	2,744	6,005
2Cx2.5sq.mm Cu/PVC/PVC Underground Cable	0	0	2	-	-	0	0	-	-	-	-	-	-	-	-	-
4Cx25sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	0	0	39	-	-	12	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu Cable 600/1000VTerminations and Joints per Conductor	52	0	6	-	-	2	0	0	336	-	-	108	1	337	108	445
4Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	3	0	6	-	-	2	0	0	19	-	-	6	0	19	6	26
2Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	258	0	6	-	-	2	0	1	1,668	-	-	535	3	1,670	538	2,208
2Cx2.5sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	0	0	6	-	-	2	0	-	-	-	-	-	-	-	-	-
GRP Distribution Box (650x500x250mm), complete	13	8	780	-	-	149	16	105	10,141	-	-	1,942	209	10,246	2,152	12,397
Cable Trenches	1,756	-	-	-	-	3	-	-	-	-	-	5,010	-	-	5,010	5,010
SPARES								-	**1,658**	-	-	**-**	**11**	**1,658**	**11**	**1,670**
TOOLS								**-**	**7,497**	**-**	**-**	**-**	**48**	**7,497**	**48**	**7,546**
TOTAL 2004 PRICES								1,700	151,274	15,309	-	181,681	5,113	152,974	202,103	355,077
INFLATION 1 YEAR @ 2.5% PA								51	4,538	459	-	5,450	153	4,589	6,063	8,877
TOTAL 2005 PRICES								1,751	155,812	15,768	-	187,131	5,267	157,564	208,166	**363,954**

Appendix L:

Estimated Base Capital Cost for Mukurimagu

Table L.1: Estimated Cost AUS$, Tools, Mukurimagu
(Mechanical Tools)

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
TOOLS								**-**	**7,497**	**-**	**-**	**-**	**48**	**7,497**	**48**	**7,546**
Mechanical																
Vernier calliper, digital (metric)	1	-	440	-	-	-	3	-	440	-	-	-	3	440	3	443
Feeler gauge (metric)	1	-	10	-	-	-	0	-	10	-	-	-	0	10	0	10
Oil filter wrench for engine offered: Set	1	-	61	-	-	-	0	-	61	-	-	-	0	61	0	62
Battery Charger: Set	1	-	176	-	-	-	1	-	176	-	-	-	1	176	1	177
Portable welding plant: Set	1	-	440	-	-	-	3	-	440	-	-	-	3	440	3	443
Bench Vice, No. 5	1	-	182	-	-	-	1	-	182	-	-	-	1	182	1	183
Hand Grinder	1	-	390	-	-	-	3	-	390	-	-	-	3	390	3	393
Hand drill (battery): Set	1	-	349	-	-	-	2	-	349	-	-	-	2	349	2	351
Heavy duty hand drill (electrical), HILTI: Set	1	-	547	-	-	-	4	-	547	-	-	-	4	547	4	550
Set drill bits for steel (1 - 13 mm): Set	1	-	208	-	-	-	1	-	208	-	-	-	1	208	1	209
Set drill bits for concrete (1 - 13 mm): Set	1	-	26	-	-	-	0	-	26	-	-	-	0	26	0	26
Set drill bits wood (1 - 13 mm): Set	1	-	38	-	-	-	0	-	38	-	-	-	0	38	0	38
Hacksaw frame	1	-	16	-	-	-	0	-	16	-	-	-	0	16	0	16
Hacksaw blade	100	-	2	-	-	-	0	-	158	-	-	-	1	158	1	159
Compressor, with hose, gun and can: Set	1	-	770	-	-	-	5	-	770	-	-	-	5	770	5	775
Wrench set, open ring (metric): Set	1	-	42	-	-	-	0	-	42	-	-	-	0	42	0	42
Box Socket set, includes metal box, 8 mm - 32 mm sockets 1/2", 1/2" ratchet, 1/2" T-bar, 1/2" universal socket: Set	1	-	713	-	-	-	5	-	713	-	-	-	5	713	5	718
Adjustable spanner, 8"	1	-	10	-	-	-	0	-	10	-	-	-	0	10	0	10
Adjustable spanner, 21"	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Allen key set, mm: Set	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Screw driver set	1	-	59	-	-	-	0	-	59	-	-	-	0	59	0	60
Hole punch set	1	-	40	-	-	-	0	-	40	-	-	-	0	40	0	40
Plastic hammer	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Ball peen hammer	1	-	21	-	-	-	0	-	21	-	-	-	0	21	0	21
Hand cold chisel	1	-	4	-	-	-	0	-	4	-	-	-	0	4	0	4
Hand shear	1	-	4	-	-	-	0	-	4	-	-	-	0	4	0	4
Grease gun set, includes grease nipples: Set	1	-	27	-	-	-	0	-	27	-	-	-	0	27	0	27
Oil can	1	-	9	-	-	-	0	-	9	-	-	-	0	9	0	9

Table L.1: Estimated Cost AUS$, Tools, Mukurimagu
(Electrical Tools)

Description		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
Electrical																
Tool Box -Big Volume Box with four tray cantilever	1	-	99	-	-	-	1	-	99	-	-	-	1	99	1	100
Digital Multi-Meter Similar to: Model: Hioki 3200-50	1	-	341	-	-	-	2	-	341	-	-	-	2	341	2	343
Power outlet tester	1	-	38	-	-	-	0	-	38	-	-	-	0	38	0	38
Rubber Hand Glove - 600V/1000V	1	-	89	-	-	-	1	-	89	-	-	-	1	89	1	90
Pen Tester (neon tester - 6")	1	-	3	-	-	-	0	-	3	-	-	-	0	3	0	3
Pen Tester (neon tester - 8")	1	-	4	-	-	-	0	-	4	-	-	-	0	4	0	4
Crimping Tool (16mm^2 to 120mm^2)	1	-	446	-	-	-	3	-	446	-	-	-	3	446	3	448
Adjustable Wrench - Plastic-Dipped Handles (150mm)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Adjustable Wrench - Plastic-Dipped Handles (255mm)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Combination Wrench Set (12Pcs Set)	1	-	297	-	-	-	2	-	297	-	-	-	2	297	2	299
Socket Wrench Set (12Pcs Set)	1	-	297	-	-	-	2	-	297	-	-	-	2	297	2	299
L-Style Hex-Key Set (Caddy Set)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Hammer (1Lb)	1	-	21	-	-	-	0	-	21	-	-	-	0	21	0	21
Hammer (2Lb)	1	-	32	-	-	-	0	-	32	-	-	-	0	32	0	32
Cable Cutter (16mm^2 to 120mm^2)	1	-	257	-	-	-	2	-	257	-	-	-	2	257	2	259
Standard-Nose Diagonal Cutter	1	-	30	-	-	-	0	-	30	-	-	-	0	30	0	30
Pliers (12")	1	-	30	-	-	-	0	-	30	-	-	-	0	30	0	30
Pliers (8")	1	-	24	-	-	-	0	-	24	-	-	-	0	24	0	24
NT-Cutter - Big	1	-	9	-	-	-	0	-	9	-	-	-	0	9	0	9
Blade set (for NT-Cutter)	1	-	10	-	-	-	0	-	10	-	-	-	0	10	0	11
Steel Tape - 20' (Measuring Tape)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Screw Driver 12" (-)	1	-	20	-	-	-	0	-	20	-	-	-	0	20	0	20
Combination Screwdriver Set	1	-	99	-	-	-	1	-	99	-	-	-	1	99	1	100
ECPI wire cutter for sealing purpose	1	-	129	-	-	-	1	-	129	-	-	-	1	129	1	130
Meter Sealing Equipment	1	-	347	-	-	-	2	-	347	-	-	-	2	347	2	349

Table L.2: Estimated Cost, Aus$ for Civil Works, Distribution Works, Spares: Mukurimagu

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design Intern'l	Material		Labour		T'sport	Design Intern'l	Material		Labour		T'sport Local	Intern'l	Local	**Total**
	Qty		CIF	Local	Intern'l	Local	Local		CIF	Local	Intern'l	Local				
CIVIL WORKS								**-**	**-**	**15,175**	**-**	**168,293**	**1,772**	**-**	**185,241**	**187,681**
Power station structure, cladding, roofing required interior lining.	1	-	-	-	-	146,203	-	-	-	-	-	116,962	-	-	116,962	116,962
Power station slab and foundations	1	-	-	-	-	17,648	-	-	-	-	-	14,118	-	-	14,118	14,118
Generating set foundations	3	-	-	-	-	7,925	-	-	-	-	-	23,776	-	-	23,776	23,776
Concrete Foundations only for bulk fuel storage	1	-	-	-	-	3,040	-	-	-	-	-	3,040	-	-	3,040	3,040
Bulk Fuel Tanks	1	-	-	15,175	-	2,251	1,412	-	-	15,175	-	2,251	1,412	-	18,838	18,838
Toilet, washbasin, shower, septic tank, soakage, drainage, plumbing.	-	-	-	-	-	4,257	-	-	-	-	-	-	-	-	-	-
Rain water collection, water tank, water pump, and reticulation.	-	-	-	-	-	7,558	94	-	-	-	-	-	-	-	-	-
Power station light and power, distribution box and cabling.	1	-	-	-	-	4,864	253	-	-	-	-	4,864	253	-	5,117	5,117
Fire extinguishers	1	-	-	-	-	3,282	107	-	-	-	-	3,282	107	-	3,389	3,389
Lightning Protection	1	267	1,333	133	-	667	40	267	1,333	133	-	667	40	1,600	840	2,440
DISTRIBUTION WORKS								**1,084**	**110,276**	**-**	**-**	**12,414**	**2,169**	**111,360**	**14,583**	**125,944**
4Cx95sq.mm Cu/PVC/SWA/PVC Underground Cable	827	0	30	-	-	2	1	259	25,107	-	-	1,287	518	25,366	1,805	27,171
4Cx70sq.mm Cu/PVC/SWA/PVC Underground Cable	1,738	0	22	-	-	1	0	402	39,031	-	-	1,082	805	39,433	1,887	41,320
4Cx50sq.mm Cu/PVC/SWA/PVC Underground Cable	761	0	16	-	-	1	0	124	11,983	-	-	474	247	12,107	721	12,828
4Cx16sq.mm Cu/PVC/PVC Underground Cable	100	0	7	-	-	0	0	8	728	-	-	42	15	735	57	792
2Cx6sq.mm Cu/PVC/PVC Underground Cable	7,250	0	1	-	-	0	0	37	3,628	-	-	3,009	75	3,666	3,084	6,750
2Cx2.5sq.mm Cu/PVC/PVC Cable 600/1000V c/w lugs, sleeves joints.	1,000	0	2	-	-	0	0	17	1,653	-	-	415	34	1,670	449	2,120
4Cx95sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	6	0	259	-	-	83	0	1	1,552	-	-	498	2	1,553	501	2,054
4Cx70sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	30	0	39	-	-	12	0	1	1,164	-	-	374	2	1,165	375	1,540
4Cx50sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	22	0	39	-	-	12	0	1	854	-	-	274	1	854	275	1,130
4Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	6	0	6	-	-	2	0	0	39	-	-	12	0	39	13	51
2Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	290	0	6	-	-	2	0	2	1,875	-	-	602	3	1,877	605	2,482
2Cx2.5sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	6	0	6	-	-	2	0	0	39	-	-	12	0	39	13	51
GRP Distribution Box complete	29	8	780	-	-	149	16	233	22,622	-	-	4,333	466	22,856	4,800	27,655
SPARES								-	**1,582**	-	-	-	**9**	**1,582**	**9**	**2,471**
Diesel engine																
Cartridge, Fuel filter	2	-	7	-	-	-	0	-	13	-	-	-	0	13	0	14
Cartridge, Lub oil filter	4	-	7	-	-	-	0	-	27	-	-	-	0	27	0	27
Cartridge, Air filter	2	-	39	-	-	-	0	-	79	-	-	-	1	79	1	79
Gasket set, Overhaul	1	-	263	-	-	-	2	-	263	-	-	-	2	263	2	264
Repair kit, Turbocharger	1	-	33	-	-	-	0	-	33	-	-	-	0	33	0	33
Repair kit, Cooling water pump	1	-	105	-	-	-	1	-	105	-	-	-	1	105	1	106
Repair kit, Lub oil pump	1	-	50	-	-	-	0	-	50	-	-	-	0	50	0	51
Alternator		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diode set	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
Surge suppressor	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
AVR	1	-	104	-	-	-	1	-	104	-	-	-	1	104	1	104
Bearing, drive end	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
Bearing, non - drive end	1	-	45	-	-	-	0	-	45	-	-	-	0	45	0	45

Table L.2: Estimated Cost, Aus$ for Civil Works, Distribution Works, Spares: Mukurimagu

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design Intern'l	Material		Labour		T'sport	Design Intern'l	Material		Labour		T'sport Local	Intern'l	Local	Total
			CIF	Local	Intern'l	Local	Local		CIF	Local	Intern'l	Local				
Distribution	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2C X 6mm^2 Cu/PVC/PVC Cable	-	-	0	-	-	-	0	-	-	-	-	-	-	-	-	-
4C X 16mm^2 Cu/PVC/PVC Cable	-	-	2	-	-	-	0	-	-	-	-	-	-	-	-	-
Resin Packs (100g) -	5	-	40	-	-	-	0	-	199	-	-	-	1	199	1	201
Straight through jointing kit for 4 core 150sq.mm Cu/PVC/SWA/PVC cable		-	34	-	-	-	0	-	-	-	-	-	-	-	-	-
Straight through jointing kit for 4 core 120sq.mm Cu/PVC/SWA/PVC cable		-	34	-	-	-	0	-	-	-	-	-	-	-	-	-
Straight through jointing kit for 4 core 95sq.mm Cu/PVC/SWA/PVC cable	2	-	44	-	-	-	0	-	89	-	-	-	1	89	1	89
Straight through jointing kit for 4 core 70sq.mm Cu/PVC/SWA/PVC cable	4	-	40	-	-	-	0	-	160	-	-	-	1	160	1	161
Straight through jointing kit for 4 core 50sq.mm Cu/PVC/SWA/PVC cable	2	-	34	-	-	-	0	-	67	-	-	-	0	67	0	68
Cu Ferrule (Butt Connectors) -600/1000V for 95sq.mm Cu Cables	6	-	1	-	-	-	0	-	5	-	-	-	0	5	0	5
Cu Ferrule (Butt Connectors) -600/1000V for 70sq.mm Cu Cables	12	-	1	-	-	-	0	-	7	-	-	-	0	7	0	8
Cu Ferrule (Butt Connectors) -600/1000V for 50sq.mm Cu Cables	6	-	1	-	-	-	0	-	3	-	-	-	0	3	0	3
CuLugsfor95sq.mmCable	8	-	1	-	-	-	0	-	5	-	-	-	0	5	0	5
CuLugsfor70sq.mmCable	16	-	0	-	-	-	0	-	7	-	-	-	0	7	0	8
CuLugsfor50sq.mmCable	8	-	0	-	-	-	0	-	3	-	-	-	0	3	0	3
CuLugsfor16sq.mmCable	4	-	0	-	-	-	0	-	1	-	-	-	0	1	0	1
CuLugsfor6sq.mmCable	30	-	0	-	-	-	0	-	1	-	-	-	0	1	0	1
LugSleevesfor95sq.mmCable (Red colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor95sq.mmCable (Yellow colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor95sq.mmCable (Blue colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor95sq.mmCable (Black colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor70sq.mmCable (Red colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor70sq.mmCable (Yellow colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor70sq.mmCable (Blue colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor70sq.mmCable (Black colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor50sq.mmCable (Red colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor50sq.mmCable (Yellow colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor50sq.mmCable (Blue colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
LugSleevesfor50sq.mmCable (Black colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Insulation Tape(Red colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape(Yellow colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape(Blue Colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape(Black Colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Scotch Tape(Scotch23)	3	-	4	-	-	-	0	-	11	-	-	-	0	11	0	11
Distribution box(spare)	1	-	285	-	-	-	2	-	285	-	-	-	2	285	2	287
63A(16KA)3PMCCB	2	-	142	-	-	-	1	-	283	-	-	-	2	283	2	285
40A/32A(4.5KA)Single Pole MCB	10	-	5	-	-	-	0	-	50	-	-	-	0	50	0	50
KWh meter(10-40A)-Single Phase (MEB Approved Types Only)	5	-	44	-	-	-	-	-	220	-	-	-	-	220	-	220
KWh meter(10-60Aor20-80A)-Three Phase (MEB Approved)	1	-	120	-	-	-	-	-	120	-	-	-	-	120	-	120
4WayTerminalBlock(for DB Boxes)	1	-	2	-	-	-	0	-	2	-	-	-	0	2	0	2
Meter Seals	300	-	0	-	-	-	0	-	28	-	-	-	0	28	0	29
Sealing Wire roll	1	-	26	-	-	-	0	-	26	-	-	-	0	26	0	26

Table L.3: Capital Cost, AUS$, for Mukurimagu
Single busbar (Analogue)

		Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		T'sport	Design	Material		Labour					
Description	Qty	Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	T'sport Local	Intern'l	Local	Total
MECHANICAL AND ELECTRICAL GENERATION WORKS								788	76,416	-	-	11,529	1,841	77,204	13,369	**90,573**
Supply and Install 84 kW diesel generator set with cabling and wiring.	1	326	31,649	-	-	3,948	791	326	31,649	-	-	3,948	791	31,975	4,740	36,715
Supply and Install 30 kW diesel generator set with cabling and wiring.	1	206	19,956	-	-	3,020	499	206	19,956	-	-	3,020	499	20,162	3,519	23,681
Relocate and install 84 kW diesel generator from exiting Power Station, associated power cabling and control wiring.	1	-	-	-	-	2,035	-	-	-	-	-	2,035	-	-	2,035	2,035
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Control equipment without split busbar (Analogue)	1	34	3,276	-	-	625	68	34	3,276	-	-	625	68	3,310	692	4,002
Feeder Panel, 8 feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Remote Electronic Governors & AVRs	2	27	2,574	-	-	-	53	53	5,148	-	-	-	106	5,201	106	5,307
Remote Governor & AVR for existing machines	1	27	2,574	-	-	-	53	27	2,574	-	-	-	53	2,600	53	2,654
CIVIL WORKS								-	-	15,175	-	168,293	1,772	-	185,241	**187,681**
DISTRIBUTION WORKS								1,084	110,276	-	-	12,414	2,169	111,360	14,583	**125,944**
SPARES								-	1,582	-	-	-	9	1,582	9	**2,471**
TOOLS								-	7,497	-	-	-	48	7,497	48	**7,546**
TOTAL 2004 PRICES								1,872	195,771	15,175	-	192,236	5,838	197,643	213,250	414,213
INFLATION 1 YEAR @ 2.5% PA								95	9,911	768	-	9,732	296	10,006	10,796	20,970
TOTAL								1,967	205,682	15,944	-	201,968	6,134	207,649	224,045	**435,183**

Table L.4: Capital Cost, AUS$, for Mukurimagu Split busbar (analogue)

Description	Qty	Estimated Unit Price: Design Intern'l	Unit Price: Material CIF	Unit Price: Material Local	Unit Price: Labour Intern'l	Unit Price: Labour Local	Unit Price: T'sport Local	Estimated Total Price: Design Intern'l	Total Price: Material CIF	Total Price: Material Local	Total Price: Labour Intern'l	Total Price: Labour Local	Total Price: T'sport Local	Intern'l	Local	Total
MECHANICAL AND ELECTRICAL GENERATION WORKS								829	80,378	-	-	11,229	1,925	81,207	13,155	**94,362**
Supply and Install 50 kW diesel generator set with cabling and wiring.	2	269	26,134	-	-	3,020	653	539	52,268	-	-	6,040	1,307	52,807	7,347	60,154
Relocate and install 84 kW diesel generator room exiting Power station, associated power cabling and control wiring.	1	-	-	-	-	2,035	-	-	-	-	-	2,035	-	-	2,035	2,035
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	8,866	-	-	1,146	222	8,957	1,368	10,325
Control equipment with split bus bar (Analogue)	1	68	6,576	-	-	1,254	136	68	6,576	-	-	1,254	136	6,644	1,389	8,033
Feeder Panel, 8 feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Remote Electronic Governors & AVRs	2	27	2,574	-	-	-	53	53	5,148	-	-	-	106	5,201	106	5,307
Remote Governor & AVR for existing machines	1	27	2,574	-	-	-	53	27	2,574	-	-	-	53	2,600	53	2,654
CIVIL WORKS								-	-	15,175	-	168,293	1,772	-	185,241	**187,681**
DISTRIBUTION WORKS								1,084	110,276	-	-	12,414	2,169	111,360	14,583	**125,944**
SPARES								-	1,582	-	-	-	9	1,582	9	**2,471**
TOOLS								-	7,497	-	-	-	48	7,497	48	**7,546**
TOTAL 2004 PRICES								1,913	199,734	15,175	-	191,937	5,923	201,647	213,035	418,002
INFLATION 1 YEAR @ 2.5% PA								97	10,112	768	-	9,717	300	10,208	10,785	21,161
TOTAL								2,010	209,845	15,944	-	201,654	6,222	211,855	223,820	**439,163**

Table L.5: Capital Cost, AUS$, for Mukurimagu Synchronising (Analogue)

Description	Qty	Estimated Unit Price: Design Intern'l	Unit Price: Material CIF	Unit Price: Material Local	Unit Price: Labour Intern'l	Unit Price: Labour Local	Unit Price: T'sport Local	Estimated Total Price: Design Intern'l	Total Price: Material CIF	Total Price: Material Local	Total Price: Labour Intern'l	Total Price: Labour Local	Total Price: T'sport Local	Intern'l	Local	Total
MECHANICAL AND ELECTRICAL GENERATION WORKS								1,119	99,787	-	-	16,764	2,503	100,907	19,267	**120,173**
Supply and Install 40 kW diesel generator set with cabling and wiring.	2	265	25,750	-	-	3,020	644	531	51,501	-	-	6,040	1,288	52,031	7,328	59,359
Relocate and install 84 kW diesel generator from exiting Power station, associated power cabling and control wiring.	1	-	-	-	-	2,035	-	-	-	-	-	2,035	-	-	2,035	2,035
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	91	-	-	1,146	222	183	1,368	1,551
Control equipment with synchronising (Analogue)	3	122	11,871	-	-	2,263	245	367	35,612	-	-	6,788	734	35,980	7,522	43,502
Feeder Panel, 8 feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Remote Electronic Governors & AVRs	2	27	2,574	-	-	-	53	53	5,148			-	106	5,201	106	5,307
Remote Governor & AVR for existing machines	1	26	2,489	-	-	-	51	26	2,489			-	51	2,515	51	2,566
CIVIL WORKS								-	-	15,175	-	168,293	1,772	-	185,241	**187,681**
DISTRIBUTION WORKS								1,084	110,276	-	-	12,414	2,169	111,360	14,583	**125,944**
SPARES								-	1,582	-	-	-	9	1,582	9	**2,471**
TOOLS								-	7,497	-	-	-	48	7,497	48	**7,546**
TOTAL 2004 PRICES								2,204	219,501	15,175	-	197,472	6,503	221,705	219,150	444,033
INFLATION 1 YEAR @ 2.5% PA								112	11,112	768	-	9,997	329	11,224	11,094	22,479
TOTAL								2,315	230,614	15,944	-	207,469	6,832	232,929	230,244	**466,512**

Table L.6: Capital Cost, AUS$, for Mukurimagu Synchronising (Digital)

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I			
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	Local	Total
CIVIL WORKS								**-**	**-**	**15,175**	-	**136,631**	**1,772**	**-**	**153,578**	**156,018**
Site preparation including road, parking area, drainage	-	-	-	-	-	11,984	-	-	-	-	-	-	-	-	-	-
Power station modification	-	-	-	-	-	103,502	-	-	-	-	-	-	-	-	-	-
Power station structure, cladding, roofing required interior lining. (without control room)	0.8	-	-	-	-	124,272	-	-	-	-	-	99,418	-	-	99,418	99,418
Power station slab and foundations (without control room)	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Generating set foundations	3	-	-	-	-	7,925	-	-	-	-	-	23,776	-	-	23,776	23,776
Concrete Foundations only for bulk fuel storage	1	-	-	-	-	3,040	-	-	-	-	-	3,040	-	-	3,040	3,040
Bulk Fuel Tanks	1	-	-	15,175	-	2,251	1,412	-	-	15,175	-	2,251	1,412	-	18,838	18,838
Toilet, washbasin, shower, septic tank, soakage, drainage, plumbing.	-	-	-	-	-	4,257	-	-	-	-	-	-	-	-	-	-
Rain water collection, water tank, water pump, and reticulation.	-	-	-	-	-	7,558	94	-	-	-	-	-	-	-	-	-
Power station light and power, distribution box and cabling.	1	-	-	-	-	4,864	253	-	-	-	-	4,864	253	-	5,117	5,117
Fire extinguishers	1	-	-	-	-	3,282	107	-	-	-	-	3,282	107	-	3,389	3,389
Lightning Protection	1	267	1,333	133	-	667	40	267	1,333	133	-	667	40	1,600	840	2,440
MECHANICAL AND ELECTRICAL GENERATION WORKS										906	67,505	-	-	12,631	1,874	**68,411**
Supply and Install 40 kW diesel generator set with cabling and wiring.	2	265	19,956	-	-	3,020	499	531	39,913	-	-	6,040	998	40,444	7,038	47,482
Relocate and install 84 kW diesel generator from exiting Power station, associated power cabling and control wiring.	1	-	-	-	-	2,035	-	-	-	-	-	2,035	-	-	2,035	2,035
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	91	-	-	1,146	222	183	1,368	1,551
Control Equipment with synchronising (Digital)	3	34	3,297	-	-	503	82	102	9,892	-	-	1,508	247	9,994	1,756	11,750
Feeder Panel, 5 feeders, 100Amps MCB	1	103	9,971	-	-	1,901	249	103	9,971	-	-	1,901	249	10,074	2,150	12,224
Remote Electronic Governors & AVRs	2	27	2,574	-	-	-	53	53	5,148			-	106	5,201	106	5,307
Remote Governor & AVR for existing machines	1	26	2,489	-	-	-	51	26	2,489			-	51	2,515	51	2,566
DISTRIBUTION WORKS								1,084	110,276	-	-	12,414	2,169	111,360	14,583	**125,944**
SPARES								-	1,582	-	-	-	9	1,582	9	**2,471**
TOOLS								-	7,497	-	-	-	48	7,497	48	**7,546**
TOTAL 2004 PRICES								**1,990**	**187,219**	**15,175**	**-**	**161,676**	**5,873**	**189,209**	**182,725**	**375,202**
INFLATION 1 YEAR @ 2.5% PA								**101**	**9,478**	**768**	**-**	**8,185**	**297**	**9,579**	**9,250**	**18,995**
TOTAL 2005 PRICES								**2,091**	**196,697**	**15,944**	**-**	**169,861**	**6,171**	**198,788**	**191,975**	**394,197**

Table L.7: Estimated Cost, Aus$, Spares for reviewed distribution design, Mukurimagu

Description	Qty	Estimated Unit Price						Estimated Total Price								
			Material		Labour		F & I		Material		Labour					
		Design Intern'l	CIF	Local	Intern'l	Local	Local	Design Intern'l	CIF	Local	Intern'l	Local	F & I Local	Intern'l	Local	Total
SPARES								-	**1,446**	-	-	-	**8**	**1,446**	**8**	**2,334**
Diesel engine																
Cartridge, Fuel filter	2	-	7	-	-	-	0	-	13	-	-	-	0	13	0	14
Cartridge, Lub oil filter	4	-	7	-	-	-	0	-	27	-	-	-	0	27	0	27
Cartridge, Air filter	2	-	39	-	-	-	0	-	79	-	-	-	1	79	1	79
Gasket set, Overhaul	1	-	263	-	-	-	2	-	263	-	-	-	2	263	2	264
Repair kit, Turbocharger	1	-	33	-	-	-	0	-	33	-	-	-	0	33	0	33
Repair kit, Cooling water pump	1	-	105	-	-	-	1	-	105	-	-	-	1	105	1	106
Repair kit, Lub oil pump	1	-	50	-	-	-	0	-	50	-	-	-	0	50	0	51
Alternator		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diode set	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
Surge suppressor	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
AVR	1	-	104	-	-	-	1	-	104	-	-	-	1	104	1	104
Bearing, drive end	1	-	52	-	-	-	0	-	52	-	-	-	0	52	0	52
Bearing, non - drive end	1	-	45	-	-	-	0	-	45	-	-	-	0	45	0	45
Distribution																
Resin Packs (100g) -	5	-	40	-	-	-	0	-	199	-	-	-	1	199	1	201
Straight through jointing kit for 4 core 50sq.mm Cu/PVC/SWA/PVC cable	2	-	34	-	-	-	0	-	67	-	-	-	0	67	0	68
Straight through jointing kit for 4 core 35sq.mm Cu/PVC/SWA/PVC cable	4	-	30	-	-	-	0	-	118	-	-	-	1	118	1	119
Cu Ferrule (Butt Connectors) -600/1000V for 50sq.mm Cu Cables	6	-	1	-	-	-	0	-	3	-	-	-	0	3	0	3
Cu Ferrule (Butt Connectors) -600/1000V for 35sq.mm Cu Cables	28	-	1	-	-	-	0	-	15	-	-	-	0	15	0	15
Cu Lugs for 50sq.mm Cable	16	-	0	-	-	-	0	-	7	-	-	-	0	7	0	7
Cu Lugs for 35sq.mm Cable	8	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Cu Lugs for 16sq.mm Cable	4	-	0	-	-	-	0	-	1	-	-	-	0	1	0	1
Cu Lugs for 6sq.mm Cable	30	-	0	-	-	-	0	-	1	-	-	-	0	1	0	1
Lug Sleeves for 50sq.mm Cable(Red colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 50sq.mm Cable(Yellow colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 50sq.mm Cable(Blue colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 50sq.mm Cable(Black colour)	2	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 35sq.mm Cable(Red colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 35sq.mm Cable(Yellow colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 35sq.mm Cable(Blue colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Lug Sleeves for 35sq.mm Cable(Black colour)	4	-	0	-	-	-	0	-	0	-	-	-	0	0	0	0
Insulation Tape (Red colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape (Yellow colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape (Blue Colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Insulation Tape (Black Colour)	10	-	0	-	-	-	0	-	2	-	-	-	0	2	0	2
Scotch Tape (Scotch 23)	3	-	4	-	-	-	0	-	11	-	-	-	0	11	0	11
Distribution box (spare)	1	-	285	-	-	-	2	-	285	-	-	-	2	285	2	287
63A (16KA) 3P MCCB	2	-	142	-	-	-	1	-	283	-	-	-	2	283	2	285
40A/32A (4.5KA) Single Pole MCB	10	-	5	-	-	-	0	-	50	-	-	-	0	50	0	50
KWh meter (10-40A) - Single Phase (MEB Approved Types Only)	5	-	44	-	-	-	-	-	220	-	-	-	-	220	-	220
KWh meter (10-60A or 20-80A) - Three Phase (MEB Approved)	1	-	120	-	-	-	-	-	120	-	-	-	-	120	-	120
4 Way Terminal Block (for DB Boxes)	1	-	2	-	-	-	0	-	2	-	-	-	0	2	0	2
Meter Seals	300	-	0	-	-	-	0	-	28	-	-	-	0	28	0	29
Sealing Wire roll	1	-	26	-	-	-	0	-	26	-	-	-	0	26	0	26

Table L.8: Capital Cost, AUS$, for Mukurimagu Reviewed Distribution Design

Description	Qty	Estimated Unit Price Design Intern'l	Material CIF	Material Local	Labour Intern'l	Labour Local	F & I Local	Estimated Total Price Design Intern'l	Material CIF	Material Local	Labour Intern'l	Labour Local	F & I Local	Intern'l	Local	Total
MECHANICAL AND ELECTRICAL GENERATION WORKS								1,119	99,787	-	-	16,764	2,503	100,907	19,267	**120,173**
Supply and Install 40 kW diesel generator set with cabling and wiring.	2	265	25,750	-	-	3,020	644	531	51,501	-	-	6,040	1,288	52,031	7,328	59,359
Relocate and install 84 kW diesel generator from exiting Power station, associated power cabling and control wiring.	1	-	-	-	-	2,035	-	-	-	-	-	2,035	-	-	2,035	2,035
Daily fuel tank and fuel lines per machine	3	30	2,955	-	-	382	74	91	91	-	-	1,146	222	183	1,368	1,551
Control equipment with synchronising (Analogue)	3	122	11,871	-	-	2,263	245	367	35,612	-	-	6,788	734	35,980	7,522	43,502
Feeder Panel, 8 feeders, 100Amps MCB	1	51	4,946	-	-	754	102	51	4,946	-	-	754	102	4,997	856	5,853
Remote Electronic Governors & AVRs	2	27	2,574	-	-	-	53	53	5,148			-	106	5,201	106	5,307
Remote Governor & AVR for existing machines	1	26	2,489	-	-	-	51	26	2,489			-	51	2,515	51	2,566
DISTRIBUTION WORKS								497	51,050	-	-	8,120	993	51,546	9,113	**60,659**
4Cx150sq.mm Cu/PVC/SWA/PVC Underground Cable	-	1	49	-	-	2	1	-	-	-	-	-	-	-	-	-
4Cx120sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	38	-	-	2	1	-	-	-	-	-	-	-	-	-
4Cx95sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	30	-	-	2	1	-	-	-	-	-	-	-	-	-
4Cx70sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	22	-	-	1	0	-	-	-	-	-	-	-	-	-
4Cx50sq.mm Cu/PVC/SWA/PVC Underground Cable	278	0	16	-	-	1	0	45	4,381	-	-	173	90	4,426	264	4,690
4Cx35sq.mm Cu/PVC/SWA/PVC Underground Cable	1,990	0	13	-	-	1	0	266	25,841	-	-	1,239	533	26,107	1,772	27,879
4Cx25sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	10	-	-	1	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	9	-	-	0	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu/PVC/PVC Underground Cable	100	0	7	-	-	0	0	8	728	-	-	42	15	735	57	792
2Cx6sq.mm Cu/PVC/PVC Underground Cable	7,250	0	1	-	-	0	0	37	3,628	-	-	3,009	75	3,666	3,084	6,750
2Cx2.5sq.mm Cu/PVC/PVC Cable 600/1000V c/w lugs, sleeves joints.	1,000	0	2	-	-	0	0	17	1,653	-	-	415	34	1,670	449	2,120
4Cx150sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	259	-	-	83	0	-	-	-	-	-	-	-	-	-
4Cx120sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	259	-	-	83	0	-	-	-	-	-	-	-	-	-
4Cx95sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	259	-	-	83	0	-	-	-	-	-	-	-	-	-
4Cx70sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	39	-	-	12	0	-	-	-	-	-	-	-	-	-
4Cx50sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	2	0	39	-	-	12	0	0	78	-	-	25	0	78	25	103
4Cx35sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	28	0	39	-	-	12	0	1	1,086	-	-	349	2	1,087	350	1,438
4Cx25sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	39	-	-	12	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu Cable 600/1000VTerminations and Joints per Conductor	-	0	6	-	-	2	0	-	-	-	-	-	-	-	-	-
4Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	6	0	6	-	-	2	0	0	39	-	-	12	0	39	13	51
2Cx6sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	290	0	6	-	-	2	0	2	1,875	-	-	602	3	1,877	605	2,482
2Cx2.5sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	6	0	6	-	-	2	0	0	39	-	-	12	0	39	13	51
GRP Distribution Box complete	15	8	780	-	-	149	16	121	11,701	-	-	2,241	241	11,822	2,483	14,304
CIVIL WORKS								-	-	15309	-	168960	1812	1600	186081	187681
SPARES								-	1,446	-	-	-	8	1,446	8	**2,334**
TOOLS								**-**	7,497	-	**-**	**-**	48	7,497	48	**7,546**
TOTAL 2004 PRICES								**1,616**	**159,780**	**15,309**	**-**	**193,843**	**5,364**	**162,996**	**214,516**	**378,393**
INFLATION 1 YEAR @ 2.5% PA								**82**	**8089**	**775**	-	**9813**	**272**	**8252**	**10860**	**19156**
TOTAL 2005 PRICES								**1698**	**167869**	**16084**	-	**203657**	**5636**	**171248**	**225376**	**397549**

Table L.9: Capital Cost, AUS$, for Mukurimagu Synchronising (Digital) and Reviewed Distribution Design

Description	Qty	Estimated Unit Price						Estimated Total Price								
		Design	Material		Labour		F & I	Design	Material		Labour		F & I	Intern'l	Local	Total
		Intern'l	CIF	Local	Intern'l	Local	Local	Intern'l	CIF	Local	Intern'l	Local	Local			
CIVIL WORKS								**-**	**-**	**15,175**	**-**	**136,631**	**1,772**	**-**	**153,578**	**156,018**
Site preparation including road, parking area, drainage	-	-	-	-	-	11,984	-	-	-	-	-	-	-	-	-	-
Power station modification	-	-	-	-	-	103,502	-	-	-	-	-	-	-	-	-	-
Power station structure, cladding, roofing required interior lining. (without control room)	0.8	-	-	-	-	124,272	-	-	-	-	-	99,418	-	-	99,418	99,418
Power station slab and foundations (without control room)	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Generating set foundations	3	-	-	-	-	7,925	-	-	-	-	-	23,776	-	-	23,776	23,776
Concrete Foundations only for bulk fuel storage	1	-	-	-	-	3,040	-	-	-	-	-	3,040	-	-	3,040	3,040
Bulk Fuel Tanks	1	-	-	15,175	-	2,251	1,412	-	-	15,175	-	2,251	1,412	-	18,838	18,838
Toilet, washbasin, shower, septic tank, soakage, drainage, plumbing.	-	-	-	-	-	4,257	-	-	-	-	-	-	-	-	-	-
Rain water collection, water tank, water pump, and reticulation.	-	-	-	-	-	7,558	94	-	-	-	-	-	-	-	-	-
Power station light and power, distribution box and cabling.	1	-	-	-	-	4,864	253	-	-	-	-	4,864	253	-	5,117	5,117
Fire extinguishers	1	-	-	-	-	3,282	107	-	-	-	-	3,282	107	-	3,389	3,389
Lightning Protection	1	267	1,333	133	-	667	40	267	1,333	133	-	667	40	1,600	840	2,440
MECHANICAL AND ELECTRICAL GENERATION WORKS								1,044	80,938	-	-	15,426	2,209	81,982	17,635	**99,618**
Supply and Install 40 kW diesel generator set with cabling and wiring.	2	265	19,956	-	-	3,020	499	531	39,913	-	-	6,040	998	40,444	7,038	47,482
Relocate and install 84 kW diesel generator from exiting Power station, associated power cabling and control wiring.	1	-	-	-	-	2,035	-	-	-	-	-	2,035	-	-	2,035	2,035
Daily fuel tank and fuel lines per machine	3	30.47	2,955	-	-	382	74	91	91	-	-	1,146	222	183	1,368	1,551
Control Equipment with synchronising (Digital)	3	102.80	9,971	-	-	1,901	249	308	29,914	-	-	5,702	748	30,223	6,450	36,673
Feeder Panel, 5 feeders, 100Amps MCB	1	33.99	3,297	-	-	503	82	34	3,297	-	-	503	82	3,331	585	3,917
Remote Electronic Governors & AVRs	2	26.54	2,574	-	-	-	53	53	5,148	-	-	-	106	5,201	106	5,307
Remote Governor & AVR for existing machines	1	26.54	2,574	-	-	-	53	27	2,574	-	-	-	53	2,600	53	2,654
DISTRIBUTION WORKS								497	51,050	-	-	8,120	993	51,546	9,113	**60,659**
4Cx150sq.mm Cu/PVC/SWA/PVC Underground Cable	-	1	49	-	-	2	1	-	-	-	-	-	-	-	-	-
4Cx120sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	38	-	-	2	1	-	-	-	-	-	-	-	-	-
4Cx95sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	30	-	-	2	1	-	-	-	-	-	-	-	-	-
4Cx70sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	22	-	-	1	0	-	-	-	-	-	-	-	-	-
4Cx50sq.mm Cu/PVC/SWA/PVC Underground Cable	278	0	16	-	-	1	0	45	4,381	-	-	173	90	4,426	264	4,690
4Cx35sq.mm Cu/PVC/SWA/PVC Underground Cable	1,990	0	13	-	-	1	0	266	25,841	-	-	1,239	533	26,107	1,772	27,879
4Cx25sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	10	-	-	1	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu/PVC/SWA/PVC Underground Cable	-	0	9	-	-	0	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu/PVC/PVC Underground Cable	100	0	7	-	-	0	0	8	728	-	-	42	15	735	57	792
2Cx6sq.mm Cu/PVC/PVC Underground Cable	7,250	0	1	-	-	0	0	37	3,628	-	-	3,009	75	3,666	3,084	6,750
2Cx2.5sq.mm Cu/PVC/PVC Cable 600/1000V c/w lugs, sleeves joints.	1,000	0	2	-	-	0	0	17	1,653	-	-	415	34	1,670	449	2,120
4Cx150sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	259	-	-	83	0	-	-	-	-	-	-	-	-	-
4Cx120sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	259	-	-	83	0	-	-	-	-	-	-	-	-	-
4Cx95sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	259	-	-	83	0	-	-	-	-	-	-	-	-	-
4Cx70sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	39	-	-	12	0	-	-	-	-	-	-	-	-	-
4Cx50sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	2	0	39	-	-	12	0	0	78	-	-	25	0	78	25	103
4Cx35sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	28	0	39	-	-	12	0	1	1,086	-	-	349	2	1,087	350	1,438
4Cx25sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	-	0	39	-	-	12	0	-	-	-	-	-	-	-	-	-
4Cx16sq.mm Cu Cable 600/1000VTerminations and Joints per Conductor	-	0	6	-	-	2	0	-	-	-	-	-	-	-	-	-
4Cx6sq.mm CuCable 600/1000V Terminations and Joints per Conductor	6	0	6	-	-	2	0	0	39	-	-	12	0	39	13	51
2Cx6sq.mm CuCable 600/1000V Terminations and Joints per Conductor	290	0	6	-	-	2	0	2	1,875	-	-	602	3	1,877	605	2,482
2Cx2.5sq.mm Cu Cable 600/1000V Terminations and Joints per Conductor	6	0	6	-	-	2	0	0	39	-	-	12	0	39	13	51
GRP Distribution Boxcomplete	15	8	780	-	-	149	16	121	11,701	-	-	2,241	241	11,822	2,483	14,304
SPARES								-	1,446	-	-	-	8	1,446	8	**2,334**
TOOLS								**-**	7,497	-	**-**	**-**	48	7,497	48	**7,546**
TOTAL 2004 PRICES								**1,541**	**140,931**	**15,175**	**-**	**160,177**	**5,030**	**142,472**	**180,382**	**326,174**
INFLATION 1 YEAR @ 2.5% PA								**78**	**7,135**	**768**	**-**	**8,109**	**255**	**7,213**	**9,132**	**16,513**
TOTAL 2005 PRICES								**1,619**	**148,065**	**15,944**	**-**	**168,286**	**5,285**	**149,684**	**189,514**	**342,687**