THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

FINAL REPORT

Volume 6 Supporting Report
Appendices to Manuals

Part 6-1	Appendices to O&M Manual-Small Hydros
Part 6-2	Appendices to Design Manual-Small Hydros
Part 6-3	**Appendices to Design Manual-Village Hydros**
Part 6-4	Appendices to Institutional and Financial Aspects

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES
IN RURAL AREAS IN MYANMAR

Final Report

Volume 6 Supporting Report

Appendices to Manuals

Part 6-3 Appendices to Design Manual-Village Hydros

LIST OF APPENDICES

Appendix 1 Introduction of LED Lighting

LED (Light Emitting Diode) uses diode in place of filament, of which WLED (White Light Emitting Diode) can provide rural families with a long life and safe of light. It has strong brilliance with small power. The life of lamps using LED is long, more than 100,000 hours generally. It emits little heat, thus it is safe in long hour lighting, and is different from candles and diesel lamp. It can focus lighting area. This improves condition of book reading for children..

It will be a help for lightings in rural electrification using renewable energies with small power output such as solar powered BCS (Battery Charging Station). It may be used as an alternative of tube light using battery.

The cost is high compared to other conventional lighting, though. It is new and rapidly improving technology and growing demand for these LEDs is likely to drive production up and thus reduce unit costs for products. Current pricing for 1 W LEDs is in the range of $2.50 - $4.50.

1 W and 2 W LEDs may be sourced from suppliers such as *Lumileds*. 0.1 W LEDs are available from any number of Asian suppliers such as *Nichia*..

The following tables are samples referring a LED electrification plan in India conducted in Jun 2003.

The first table is a design to provide at the lowest possible cost. It makes use of readily available low cost WLEDs. These LEDs run at close to 0.1 W each. The light is powered by a single AA battery and is recharged via a small embedded solar panel.

Component	Description	Price
LED Source	3x 0.1 Watt WLEDs	$0.60 (3 @ $0.20)
PIC + Circuit	PIC controller and circuit to regulate current to LED and optimize power consumption	$0.80 - $1.00
PV Panel	0.6 Watt panel (supplied by Jai Wei, China) Silicon based panel encased in epoxy Requires 7 hours of light to charge 2x AA batteries	$1.50
Battery	One AA, 1800 mAh NiMH rechargeable batteries	$0.60
Casing	Injection molded polycarbonate, 2 piece casing, with snap fixing and securing screws	$1.00 - $1.40
Lens / optics	Simple clear plastic disk and reflector	$0.10 - $0.20
Switch	Robust, weatherproof on/off switch	$0.15 - $0.20
Assembly	Factory and assembly line to be determined	$0.40 - $0.75
Packaging	None	
Total		$5.15 - $6.25

Component	Description	Price
LED Source	1-watt Luxeon LED (supplied by Lumileds)	$2.50 - $2.75
PIC + Circuit	PIC controller and circuit to regulate current to LED and optimize light output while minimizing power consumption	$0.80 - $1.00
PV Panel	1.2watt panel (supplied by Jai Wei, China) Single-crystalline panel encased in epoxy Requires 7.2 hours of light to charge 2x AA batteries	$3.00
Batteries	2 x AA NIMH rechargeable batteries	$1.20 ($0.60 per battery)
Casing	Injection molded polycarbonate, 2 piece casing, with snap fixing and securing screws	$1.75 - $2.00
Lens / optics	Plastic rotate-able disk with columnator, reflector	$0.05 - $0.20
Grid power jack	Allows use of AC-DC converter	$0.10 - $0.15
Assembly	Factory and assembly line to be determined	$0.70 - $1.00
Packaging	Thin, triangular cardboard box with graphics	$0.10 - $0.15
Total		$10.35 - $11.65

Source: "Light Up the World – INDIA", Business Plan and Recommendations, Graduate School of Business, Graduate School of Engineering, Stanford University

This second table has been designed for home use such as reading, works, and social communication. It provides the choice of either ambient lighting or a focused task light from a single 1 W white LED. Integrated into the light is a 1.2 W photovoltaic (PV) panel and two size-AA rechargeable batteries.

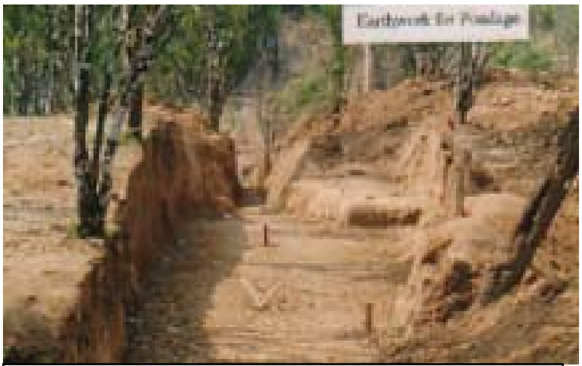
Appendix 2 Project Examples

Appendix 2-1 Sem Pai Village Hydro Project Using Grass Root Grant

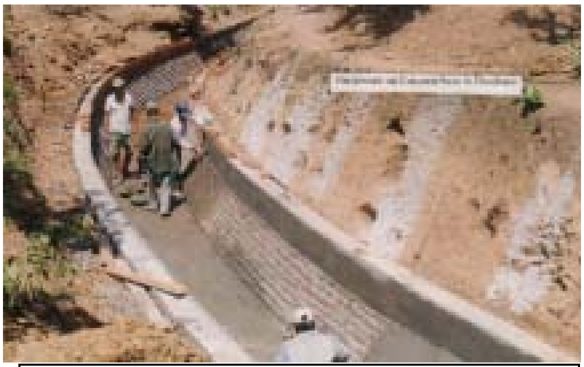
Items	Description
Location	Sempai and Naung –An Village, His Paw Township, Northern Shan State (N22°36’ E97°24’)
Output	● Installed capacity: 30 kW x 2 nos. ● Annual energy: 228,000 kWh
Specifications	● Penstock D 500mm x t 6 mm x 1 nos ● Canal slope: 1/300, 66.8 m ● Forebay: 6.75 m^3 with chute spillway ● Turbine: Crossflow controlled with mechanical governor, output at 30 kW, 2nos. 1unit is from China, 1unit is Myanmar made. ● Generator: 1000 rpm. PF0.8, 3 ph, 4 wire, 400V, output at 30 kW ● Transformer: main 75 kVA, step down 11/0.4, 30 kVA x 2 nos. ● Transmission line: 11 kV, 1.92 km, 3 phase ● Distribution line: 400 V, single phase
Basic Features	● Nampwat Stream ● Catchment area: 108 km^2 ● Design discharge: 0.35 m^3/s ● Gross head: 12.74m, Effective head:12.16 m
Commissioned in	Nov. 2002
Nos. of consumers	150 households x 2 villages
Peak load	● 300 hh x 3 nos x 60 W = 54 kW
Operation and organisation	● 5 operators and 5 maintenance persons, shift in charge ● Fund will be collected from uses if repair is needed ● 10 VPDC persons work in VEC as volunteers
Construction costs and monthly tariff	● Construction: US$83,300 by Japanese grant ● K2,000 for 3 tube lights per household (Mar ’03)
Experts	● Aung Pyi Tun Co., Ltd
Current condition and Issues	● Meters have already installed in half of customers. Tariff will be charged according to the consumption. ● Operated only in nighttime while it can supply power for cottage industry and rice/oil mills in daytime. ● Capacity of step-down transformer needs to be increased to meet increasing demand

Earthwork of the weir

R.C.C weir and intake wingwall work



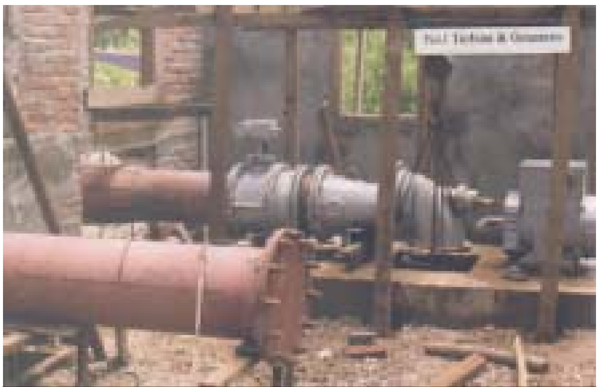
Earthwork of headtank and canal



Brickwork for the base of headrace

Penstock and powerhouse construction

Powerhouse and penstock branch



Installation of turbine and generator

Intake gate and penstock anchor

Screen in the pondage

Concrete-lined headtank and waterway

Penstock and powerhouse

Expansion joint in penstock

75 kVA Main transformer

Penstock reducing works

Turbine and generator room

Appendix 2-2 Micro Hydro Project in Thale Oo Village

2.1 Project Features

Items	Description
Location	Shan State, 10 miles from Nyaung Shwe by Boat
Capacity of generator	20 kW
Specifications	● Penstock D 380 mm, L 13 m ● Open-type Crossflow turbine ● Indo-koyo generator of 20 kVA, 1500/1800 rpm, with stepup trans-former to 400 V ● L 4,530 m single phase lines of 16 mm^2 ACSR
Commissioned in	12.9.2001
Nos. of consumers	81 household out of 118
Peak load	● 240 tube lights + 30 TV + 24 streetlights → 8.3 kW + line losses
Operation	● 6:00 p.m. to 6:00 a.m. ● 3 operators per shift (1 chief + 2 helper), all households in turn ● Operators stay at station all night.
Village Electrification Committee	● Chairman is a monk.
Present conditions	● Voltage drops from 240 V to about 200 V, to cause line losses.
Experts	● Guided and managed by U Khun Kaw
Judgment and Issues	Can be good sample for Village Scheme on Self-help Basis

2.2 Study of Power Transmission Capacity of Thale Oo Scheme

2.2.1. Present Situation

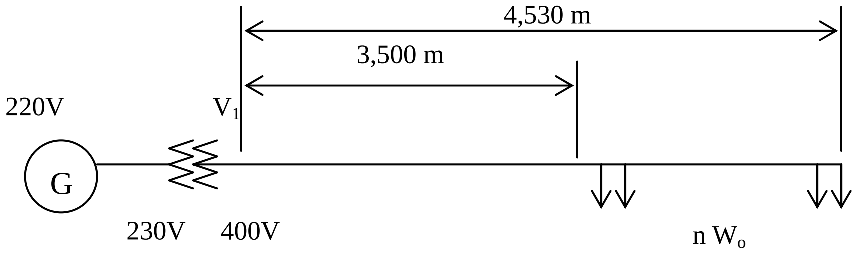


Figure 1 Transmission Line (assumed)

(1) Electrical constants of tube lights

Rated power consumption 20 W, Voltage 220 V, Power factor (PF) 0.6

$W_o = V I_o \cos\phi$

$$I = \frac{W_o}{V \cos\phi} = \frac{20}{220 \times 0.6} = 0.1515$$

$$\text{Impedance } Z_o = \frac{V}{I_o} = \frac{220}{0.1515} = 1452\ \Omega$$

Resistance $r_o = Z_o \cos\phi = 871.2\ \Omega$

Reactance $x_o = Z_o \sin\phi = 1161.7\ \Omega$

(2) Electrical constants of transmission lines

Electric wire ACSR, cross sectional area of wire A = 16 mm^2

$$\text{Resistance of Aluminum wire} = \frac{29.45}{A} = 1.84\ \Omega / \text{km}$$

Length of the lines = 4530 m

Resistance of total wire = $1.84 \times 4530 \times 10^{-3} = 8.34\ \Omega$

Resistance of wire up to load point R = $1.84 \times 3500 \times 10^{-3} = 6.44\ \Omega$

(Note: Reactance is neglected)

(3) Electrical constants of load (Concentrated equivalent constant)

Total Load $W = n W_o$

$$\text{Impedance } Z = \frac{Z_o}{n}$$

Voltage at receiving end V_2 ,

Load current $I = \frac{V_2}{Z} = \frac{nV_2}{Z_o}$

(4) Relationship between nos. of load tube lights and voltage at receiving end

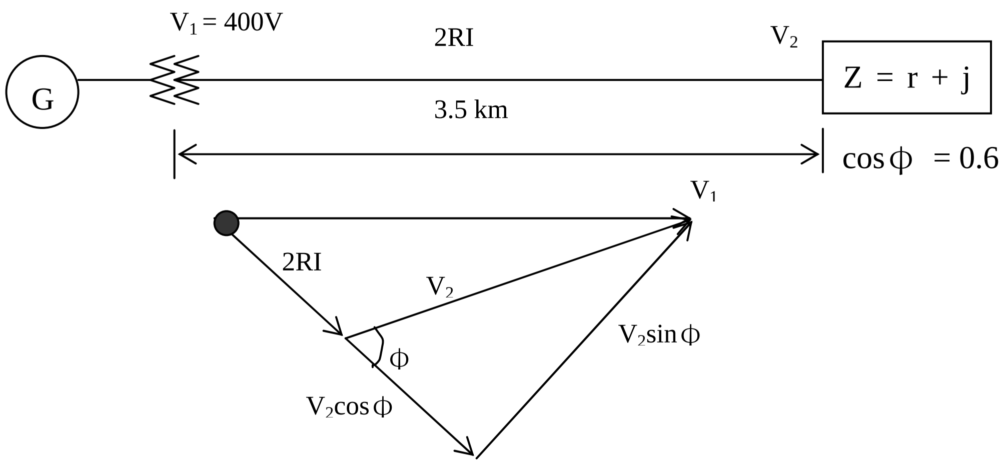


Figure 2 Vectors of Sent and Received Electricity

$$I = \frac{nV_2}{Z_o}$$

$\cos\phi = 0.6$, $\sin\phi = 0.8$

$$V_1^2 = (2\,RI + V_2\cos\phi)^2 + (V_2\sin\phi)^2$$

$$= 4R^2\ I^2 + 2.4\,R\,I\,V_2 + 0.36V_2^2 + 0.64V_2^2$$

$$= 4R^2\left(\frac{nV_2}{Z_o}\right)^2 + 2.4\,R\,\frac{n}{Z_o}\,V_2^2 + V_2^2$$

$$= \left(4R^2\,\frac{n^2}{Z_o^2} + 2.4\,R\,\frac{n}{Z_o} + 1\right)V_2^2 = K\,V_2^2$$

$$V_2 = V_1 / \sqrt{K}$$

Where V_1 = 400 V, R = 6.44 Ω, Z_o = 1,452 Ω ,

n	100	150	(165)	200
$\sqrt{K}$	1.69	2.09	(2.21)	2.50
V_2	237	192	(181)	160

Note. $K = 7.87 \times 10^{-5}\,n^2 + 1.06 \times 10^{-2}\,n + 1$

Thus, the limit nos. of tube light is considered to be <u>180</u> under the current conditions of the power transmission.

2.2.2 Case with Further Step-up Transformer

Assume the voltage be further stepped up to the limit of low tension line without replacing the existing insulators as it is:

$$V_1'^2 = (2RI + V_2'\cos\phi)^2 + (V_2'\sin\phi)^2$$

$$= \left(2R\frac{nV_2}{3Z_0} + 3V_2\cos\phi\right)^2 + (3V_2\sin\phi)^2$$

$$= \left(\frac{4}{9}R^2\frac{n^2}{Z_0^{\ 2}} + 2.4R\frac{n}{Z_o} + 3.24 + 5.76\right)V_2^{\ 2} = KV_2^{\ 2}$$

$V_2 = V_1'/\sqrt{K}$ $\quad$ ($\because$ $K = 8.74 \times 10^{-6}n^2 + 1.064 \times 10^{-2}n + 9$)

n	100	200	300	400	(470)	600
$\sqrt{K}$	3.19	3.39	3.60	3.83	(3.99)	4.30
V_2	226	213	200	188	(180)	167

[note]

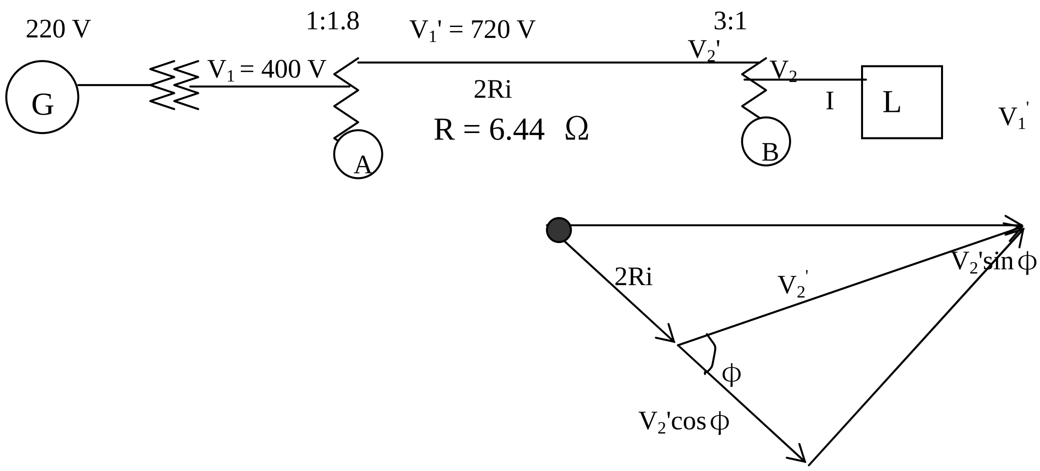


Figure 3 Transmission and Electricity Vectors When Further Stepped-up

	Name	Capacity	Primary voltage	Secondary voltage
(A)	Autotransformer	7 kVA	400 V	720 V
(B)	Autotransformer	12 kVA	720 V	240 V

From the table above, the maximum use of lights will increase to about 500 nos. if the transmission voltage is further stepped up to 720 V. Also fluctuation rate of voltage would become small against the load fluctuation.

2.2.3 Power Output at the Voltage Limit

	Present condition	Step-up	Calculation
Voltage limit V_2	181 V	177 V	
Nos. of light n	180	500	
Rated load (20 W x n)	3.6 kW	10 kW	W
Decrease by voltage	2.44 kW	6.47 kW	$W \times (V_2/220)^2$
Load current	22.4 A	61.0 A	$I = nV_2 / Z_0$
Line current	22.4 A	20.3 A	$i = I/\text{Ratio}$
Line loss	6.46 kW	5.2 kW	$2Ri_2$
Total power	8.9 kW	11.7 kW	
Miscellaneous loss	0.9 kW	1.2 kW	10%
Generator output	9.8 kW	12.9 kW	P_G
Generator efficiency	0.92	0.92	η_G
Belt transmission efficiency	0.9	0.9	η_B
Turbine output	11.8 kW	15.6 kW	$P_T = P_G / (\eta_G \eta_B)$

The generator can generate 12.9 kW if the transmission voltage is stepped up to 720 V since the generator capacity is 20 kW. However, the turbine output of 15.6 kW could not be achieved if the present discharge and nos. of turbine blades are taken into consideration. Careful consideration is needed for implementing further step up of the transmission voltage beyond 400 V.

2.3 Photos of Thale Oo Proiect


Site cleaning and preparation of waterway


Earth excavation for waterway


Construction of powerhouse


Installation of penstock


Pole standing up


Drawing wires by the manpower


Transportation of the generator

Intake with timber protection

Wooden intake gate

Screen made from bamboo

Open-type Crossflow turbine

Tailrace excavation and lining

Villagers watching TV after the electrification

Appendix 2-3. Village Hydro Projects in Kyauk Ye Oo and PaOh-Gawraka Village

3.1 Project Features

Items	Kyauk Ye Oo	PaOh Gawraka
Location	5 miles from Nyaung Shwe	2 miles from Nyaung Shwe
Output	Generator capacity 20 kW (Turbine output 23 kW if η_G=0.9)	Generator capacity:10 kW (Turbine output 11 kW if η_G=0.9)
Specifications	● Penstock D 450 mm, L 21 m ● W 460 mm, D 300 mm Banki turbine ● Chinese Mindong generator of 20 kVA at 1,500 rpm, output voltage at 230-300 V ● L 1,680 m single phase lines	● Penstock D 190 mm, L 13 m ● W 200 mm, D 360 mm Banki turbine ● Chinese Mindong generator of 10 kVA at 1,500 rpm, output voltage at 170 V at test on inspection ● L 1,740 m (even longer) single phase lines
Basic features	● Q =0.3 m^3/s (if turbine output is 23 kW and η=0.7) ● Effective Head is 11.1m	● Q is not known ● Head is 8.53 m
Commissioned in	March 2002	October 2002
Nos. of consumers	80 out of 144 household	40 out of 80 household
Peak load	● 20 W tube light x 2 nos. per household → 3.2 kW at max.	● 20 W tube light x 1 no. per household → 0.8 kW at max.
Operation and organisation	● 6:00 p.m. to 6:00 a.m. ● 7-men committee, 2 person per time, voluntary basis ● Operator not standby at station	● 6:00 p.m. to 6:00 a.m. ● Operation by 2 person per shift, villagers in turn ● No operator at night
Construction costs and monthly tariff	● K 2.5 million ● 300 Kyat per tube light per month	● Kyat 1.826 million plus villagers work force ● Monthly tariff not collected yet.
Present conditions and issues	● Difficult to estimate actual turbine capacity. ● Channel slope is too steep. ● Penstock is too big. ● Erosion occurs in the right side slope of the headtank. ● Wall top of the headtank was inclined. ● Overflow may cause erosion and soil wash out around penstock. ● Needs re-cabling with conductor of adequate size or step-up transformer. ● Voltage drops to 90-100 V at receiving end.	● 7-core-25mm^2 ACSR was disassembled. Each core was used as a single conductor. ● Voltage drops to 120 V at receiving end. ● Needs re-cabling with conductor of adequate size. ● No gate facility to block excess flow during flooding. ● Slope failure due to the overflow of the channel was seen. ● Headtank is too small and cannot work as desander. ● Penstock route formed a path for rainwater and will be eroded. Protection work is necessary. ● Necessary powerhouse is not built yet. ● Output is not sufficient for the demand.

3.2 Study on capacity of power transmission in PaOh Gawraka village

3.2.1 Current situation

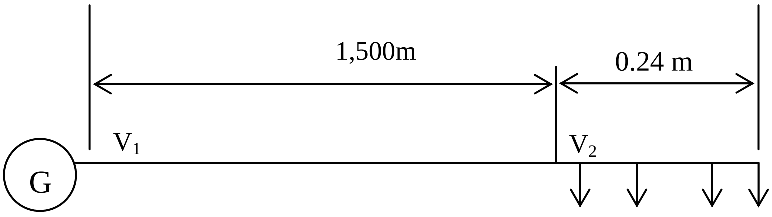


Figure 4 Assumed Transmission Line

(1) Electricity parameter of fluorescent light

Rated items : power consumption at 20 W, voltage at 220 V, and power factor 0.6

$W_0 = VI_0\cos\phi$, $\quad I = \dfrac{W}{V\cos\phi} = \dfrac{20}{220\times 0.6} = 0.1515\text{A}$

Impedance $\quad Z_0 = \dfrac{V}{I_0} = \dfrac{220}{0.152} = 1{,}452\ \Omega$

Resistance $\quad r_0 = Z_0\cos\phi = 871.2\ \Omega$

Reactance $\quad x_0 = Z_0\sin\phi = 1{,}161.7\ \Omega$

(2) Electricity parameter of the line

Disassembled wire of 25 mm^2 ACSR was used for the transmission line. Two patterns are were assumed for the present case study, one case is to use only Aluminum cores and the other case is to use also steel reinforcing wire in addition to the Aluminum wire. Both patterns are examined below:

- Case that all wires are made of Aluminum

  Area of the wire 25 / 6 4.17 mm2 = A

  Resistance of Aluminum wire 29.45 / A = 7.06 Ω/km

  Distance L = 1,740 m

  Resistance of total wire 7.06 x 1.74 = 12.3 Ω

  Resistance up to load point 7.06 x 1.5 = 10.6 Ω

- Case that aluminum wire and steel wire are mixed for the line

  Length of Aluminum wire = L x 6/7 , Length of steel core line = L x 1/7

  Resistance of steel core wire 184/A = 44.16 Ω/km (A is equal to Aluminum)

- Resistance up to load point

Aluminum wire 7.06 x 1.5 x 6/7 = 9.08 Ω

Steel core wire 44.16 x 1.5 x 1/7 = 9.46 Ω

Total 18.54 Ω (Reactance is neglected)

(3) Electricity load parameter (equivalent lumped parameter)

Total load $W = nW_0$

Impedance $Z = Z_0/n$

Voltage at receiving point V_2

Load currency $I = V_2/Z = nV_2/Z_0$

(4) Relationship between nos. of light load and voltage at receiving point

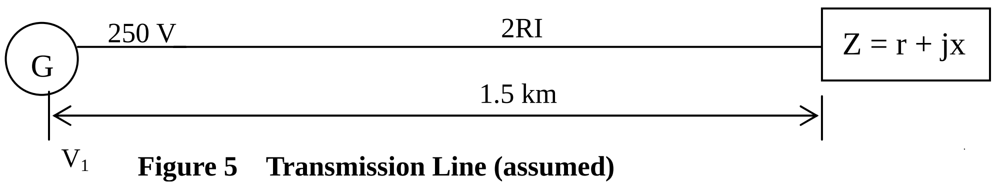
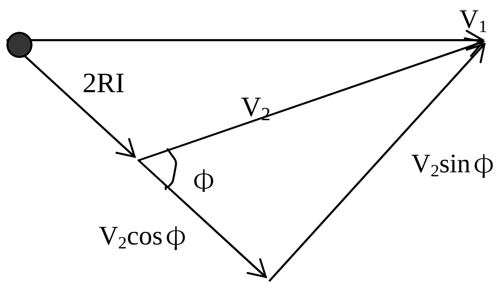


Figure 5 Transmission Line (assumed)

The rated voltage of the generator is 220 V, while it is operated at 250 V.



$\cos\phi = 0.6$

$\sin\phi = 0.8$

$V_1^2 = (2RI + V_2\cos\phi)^2 + (V_2\sin\phi)^2$ (substituting each parameter)

$$= \left(4R^2\frac{n^2}{Z_0{}^2} + 2.4R\frac{n}{Z_0} + 1\right)V_2{}^2 = KV_2^2 \qquad V_2 = V_1/\sqrt{K}$$

- Aluminum wire

n	10	20	30	(36)	50
$\sqrt{K}$	1.09	1.20	1.31	(1.38)	1.55
V_2	229	209	191	(181)	161

R = 10.6 Ω, V_1 = 250 V, Z_0 = 1,452 Ω, K = 2.132 x $10^{-4}n^2$ + 0.01752 n + 1

- Aluminum wire and steel core wire

n	10	(20)	25	30
$\sqrt{K}$	1.17	(1.37)	1.47	1.58
V_2	213	(183)	170	158

$R = 18.54\ \Omega$, $V_1 = 250$ V, $Z_0 = 1452\ \Omega$, $K = 6.52 \times 10^{-4} n^2 + 0.03064 n + 1$

(5) Case that 16 mm^2 ACSR is applied

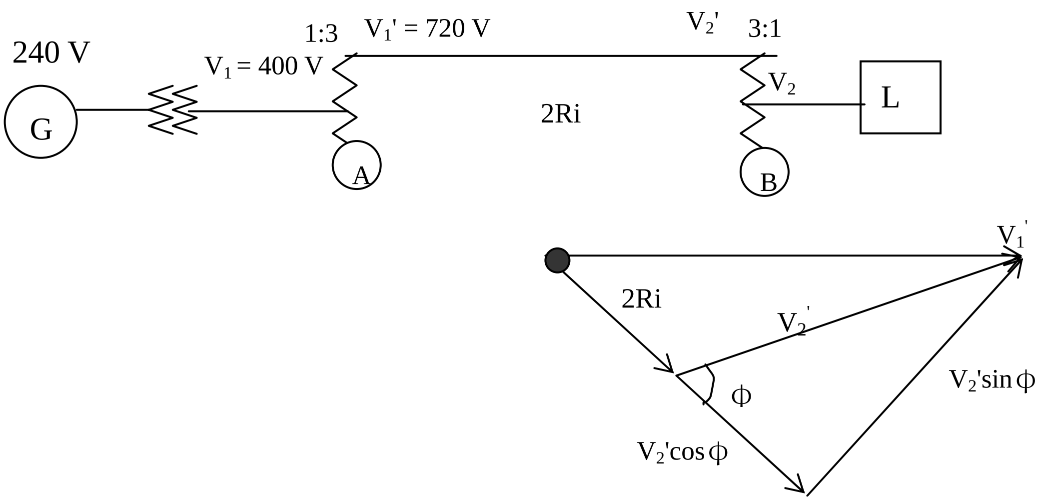


Figure 6 Transmission and Electricity Vectors When Stepped-up

$V_2' = 3V_2$, $i = I/3 = \dfrac{nV_2}{3Z_0}$

$$V_1'^2 = (2Ri + V'_2\cos\phi)^2 + (V'_2\sin\phi)^2$$

$$= \left(\frac{4}{9}R^2\frac{n^2}{Z_0^{\,2}} + 2.4R\frac{n}{Z_0} + 9\right)V_2^{\,2} = KV_2^2 \qquad V_2 = V_1'/\sqrt{K}$$

- Aluminum wire

n	60	100	(210)	300	400
$\sqrt{K}$	3.28	3.46	(3.98)	4.40	4.88
V_2	220	208	(181)	164	148

$R = 10.6\ \Omega$, $V_1 = 720$ V, $Z_0 = 1452\ \Omega$, $K = 2.369 \times 10^{-5} n^2 + 0.01752 n + 9$

- Aluminum wire and steel core wire

n	40	80	120	(165)	220
$\sqrt{K}$	3.22	3.45	3.70	(4.00)	4.39
V_2	224	209	194	(180)	164

R = 18.54 Ω, V_1 = 720 V, Z_0 = 1452, K = 7.246 x 10^{-5} n^2 + 0.03064 n + 9

(6) Case that 16 mm^2 ACSR is applied

Resistance of ACSR 16 mm^2 1.84 Ω/km

Resistance up to load point 1.84 x 1.5 km = 2.76 Ω

Applying the formula in A2.2.1.(4), the calculation would be as follows:

n	60	80	100	120	(140)	160
$\sqrt{K}$	1.15	1.21	1.27	1.32	(1.39)	1.45
V_2	217	207	198	189	(180)	173

R = 2.76 Ω, V_1 = 250 V, Z_0 = 1452 Ω, K = 1.445 x 10^{-5} n^2 + 0.00456 n + 1

The load increases in proportion to the number of households. It could supply up to 140 households. However, further consideration is needed on the structural strength of turbine, capacity of head tank and, channel, and so forth.

3.3 Photos in Kyauk Ye Oo

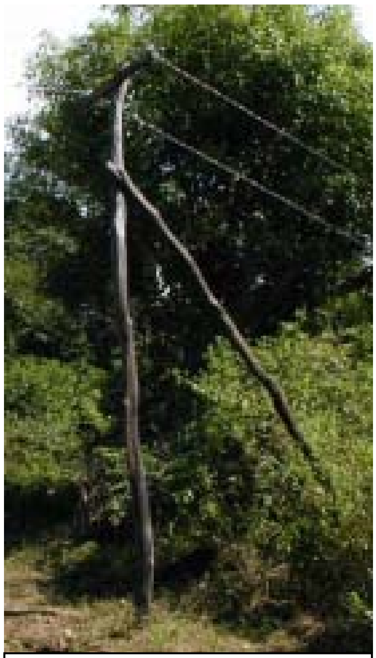

Intake gate with brick base, steel gate, wooden roller and bicycle chain


Earth canal with timber support and bamboo side wall protection


Headtank with bamboo screen


Banki-type turbine


Penstock and powerhouse


Wooden pole and distribution line with support


Village with line and poles


School children

3.4 Photos in PaOh Gawraka

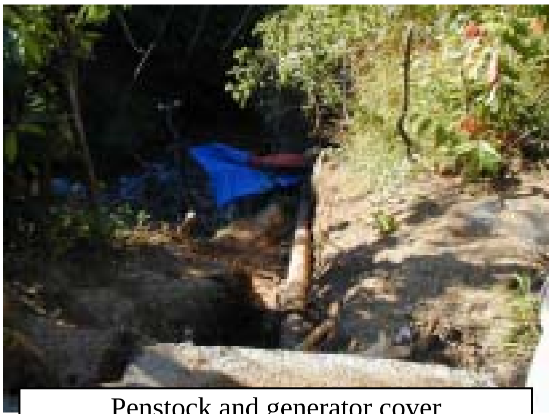
Intake site

Headrace and spillway

Headtank

Slope Failure below headrace

Distribution line from the generator



Penstock and generator cover (Powerhouse was not built)

Penstock end with reducer, turbine, and generator

Villagers in a meeting house

Appendix 2-4 Village Hydro Project in Hanpo Village

4.1 Project Features

Items	Description
Location	Shan State, 42 km from Taung Gyi by a car
Output/capacity	Generator capacity: 15 kW, turbine capacity 10 kW
Specifications	● Penstock ● Open-type Crossflow turbine ● Mindong generator of 15 kW, 1500/1800 rpm ● L 3.2 km lines of ACSR. ● L 7.6 m, 125 nos. of wooden poles ● 5 kVA transformer 230/280 V ● W 19.2m x h 1.8 m Intake weir
Basic features	● Q, H are not known
Commissioned in	March 2001
Nos. of consumers	74 households (population 379)
Peak load	● 148 tube lights + 25 cassette recorder → 3.7 kW + line losses
Operation and organisation	● Operation is only in the nighttime ● Operators stay in powerhouse shift in charge ● 5 committee members work for collection of tariff and operation and maintenance
Construction costs and monthly tariff	● Total US$8,152, contributed from Japanese ● Materials such as aggregate, sand, brick, and poles were provided by villagers. ● K5,000 to K30,000 were collected from each household for powerhouse building, in-house wiring, and lighting tools according to the income levels. ● Tariff is K50 per a tube light (Jul. 01)
Experts	● Guided and managed by U Khun Kaw
Present condition and issues	● 5 kVA transformer was installed, which will be replaced to 10 kVA one. ● 15 kVA Generator, bigger than required, was purchased just because it was available in the market when installation. ● Stepped-up 280 V drops to 230 V at users by natural voltage drop. ● Intake weir by sandbags have to be reinforced by concrete, according to the expert

4.2 Photos in Hanpo Village

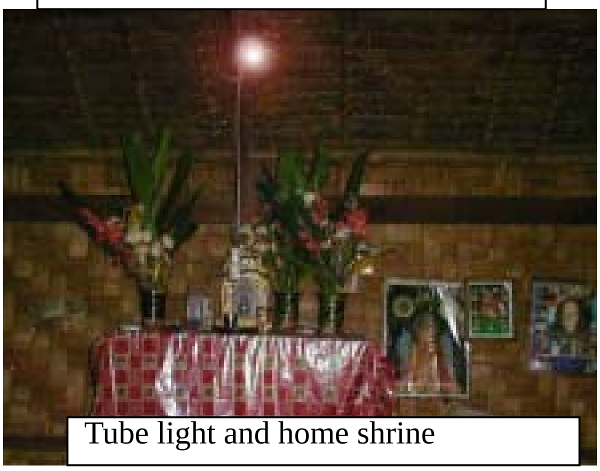
Hanpo villagers and distribution line

Hanpo village houses

Wooden pole and wire. Poles were prepared by villagers

Offering the light the spirits beside powerhouse

In-house wiring and voltage meter



Tube light and home shrine

Committee members in Hanpo and micro hydro expert

School children


Intake weir with sandbags


Intake screen


Rock was used for the brick work for structures. Bricks were prepared by villagers to save the material cost.


Waterway with side lining with brick


Crossflow turbine

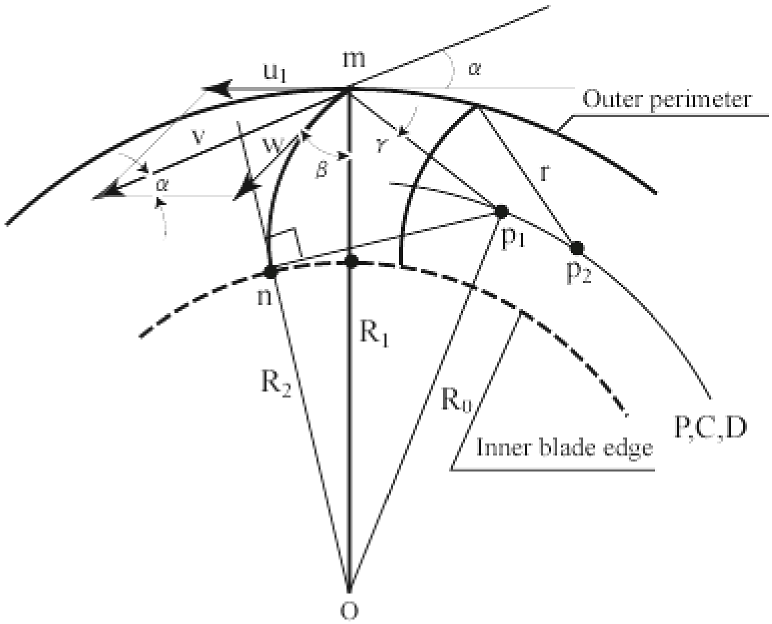

Penstock and powerhouse


China made generator and belt


Step-up transformer

Appendix 3 Design of Crossflow

Appendix 3-1 Design of Crossflow Turbine Blade



m : Inflow point　 α :Inflow angle

u_1 :Rotation velocity at entrance point

$= \pi D_1 N/60$

v : Velocity of water inflow

$= k_c \sqrt{2gH}$

D_1 : Outer radius of runner (m)

N : Rotation speed (min^{-1})

k_c : Water velocity coefficient

(0.98～0.95)

g : Gravity coefficient (9.8 m^2/s)

H : Effective head

n : End of blade

R_2 = on : Radius of blade edge

$= 2 \times D_1/3 \times 1/2 = D_1/3$ (m)

R_1 = om : Radius of entrance of blade edge　 $= D_1/2$ (m)

k_{u1} : Rotation velocity coefficient

$u_1/v = \pi D_1 N / (60 k_c \sqrt{2gH} = 0.5$ (Design coefficient) : $v = 2 u_1$

β : tan' $\{(v\cos\alpha - u_1) / v\sin\alpha\}$ = $\tan^{-1}\{(2\cos\alpha -1)/2\sin\alpha\}$

α : 16° (Design coeffecient)　 $\beta = \tan^{-1}\{(2\cos16-1)/2\sin16\}$　 59°

w : Relative inflow　 γ : Inflow angle　 $\gamma = 90° - \beta = 31°$

[Definition] Blade shape is to be an arc where a point of contact of w and on.

Radius of blade-shaped arc $mp_1 = r$ (m)

Radius of circle of center pitch of blade-shaped arch　 $op_1 = R_0$ (m)

At △omp_1,　 $R_0^2 = R_1^2 + r^2 - 2 \cdot R_1 \cdot r \cdot \cos\gamma$

At △onp_1,　 $R_0^2 = R_2^2 + r^2$

Thus,　 $r = 0.16 D_1$

$R_0 = \sqrt{\{(D_1/3)^2 + (0.16D_1)^2\}} = 0.37D_1$

Blade pitch　 $p_1p_2 = 2\pi R_0 / Z = 2.325 D_1 / Z$　 Z : nos of blade (standard ＞26)

[Method of drawing]

Set a center in the circle whose radius is $0.37D_1$, then draw the arc of $0.16D_1$ radius with pitch $2.325D_1/Z$

Crossflow Turbine Design Example

1. Outline

   Effective head : H = 15 m   Water velocity coefficient : $k_c = 0.97$

   Maximum discharge : Q = 0.5 m^3/s Rotation velocity coefficient : $k_{u1} = 0.5$

2. Design calculations

   a. Requested totation speed $n = 500\ min^{-1}$

   b. $D_1 = k_{u1}$ x 60 x $k_c \sqrt{2gH}$ / (π N)

      = 0.5 x 60 x 0.97 x $\sqrt{2x9.8x15}$ / (π x 500)

      = 0.418   = 0.32 m

   c. Maximum output （assuming the maximum efficiency η = 0.75）

      P = 9.8 HQη = 9.8 x 15 x 0.5 x 0.75 = 55 kW

   d. N_s

      $N_s = N\sqrt{P} ／H^{5/4}$ = 500 x $\sqrt{55}$ ／$15^{1.25}$ ＝ 126 m-kw

   e. Width of runner

      $B = (N_s/100)^2 D_1 = (126 / 100)^2$ x 0.32 = 0.508 m

      Assuming installation of two plates in middle and set the real width 10 % more.

      Set B_0 = 1.1 B = 0.559   <u>0.56 m</u>

   f. Runner blade

      Set the <u>blade nos 24</u>

      Radius of pitch circle $R_0 = 0.37\ D_1$ = 0.118 m = 118 mm

      Radius of blade-shaped arc $r = 0.16\ D_1$ = 0.051 m = 51mm

      Pitch $p = 2.325\ D_1 / Z$ = 0.031 m = 31 mm

Appendix 3-2 Effect of Nozzle Shape on the Turbine Performance

(Translation from a paper of Mr. J. Fukutomi, Tokushima University, et al., presented in No. 917 Lecture Paper No. 820-101982-9-2 of Japan Society of Mechanical Engineers)

1. Introduction

The characteristics of Crossflow turbine, one of the small hydro turbines, are as follows; (1) the structure is simple, (2) it is applicable to broad range of discharge, and (3) it has relatively high efficiency. Crossflow turbine is getting to be more attractive in terms of efficient utilization of energy. Although it has a long history, this turbine has not been studied in depth since it is used only for small power generation. The water partly fills the runner vanes and complex flow occurs inside the runner, which also caused the difficulty of the study. Only recently the experimental study about internal flow and its performance were reported. Especially, a study on turbine nozzle (water inlet to turbine) is hardly found despite its importance. The study reports on the effects of several shapes of nozzle on the internal flow and turbine performance, experimentally using model of the Crossflow turbine.

2. Equipment and method of the experiment

The water is first pumped up to a head tank with volute pump, kept there at constant level. The water then passes through nozzle and is guided to runner, crossing through the runner (enters into and comes out of runner), and is discharged into a channel where an overflow weir is provided. The shape of the turbine and nozzle is illustrated in Figure 1. In this experiment, guidevane is not provided to study only the nozzle effect on the turbine performance. The principal features of the model are:

Diameter of the runner: D_1 = 315 mm
Ratio of internal and external circles of runner blade: D_2/D_1 = 0.68
Blade angle at the inlet: 30 °
Blade angle at the exit: 90 °
Nos. of turbine blade: 26
Shape of the blade: arc
Thickness of the blade: 5.7 mm
Basic width of the turbine and nozzle on axis direction: 315 mm

To make the flow visible, the turbine shaft is of cantilever type, and the sidewall of nozzle and runner is made of acryl. Effective head H is the height from the runner shaft to the water level of the head tank. Discharge is measured with a square weir provided in the channel. Rotation speed is changed by load resistor connected to a DC generator and the value is measured with an electro-magnetic pickup attached to the shaft end. Torque measurement is made using a torque detector of torsion bar type. Velocity and pressure are measured with three-hole Pitot tube at the first step entrance and the second step exit of the runner, which is located at radius R = 158.5 mm from the shaft axis. The turbine performance is indicated with the parameters converted to unit head: discharge Q_1 (= Q / √ H), rotation speed N_1 (= N/ √ H), and output L_1 (= $L/H^{3/2}$). Figure 2 shows the principal parameters of the nozzle shape and their ranges of the experiment are as follows;

(1) Angle of nozzle opening δ :

δ = 30^o, 60^o, 90^o

(2) Ratio of nozzle width with runner width on shaft axis direction (B):

B = 40～100%

(3) Width of nozzle throat (S_0) :

S_0 / R_1 δ = 15.5 ～ 63.5%

(4) Shape of rear wall of nozzle : A, B, and C type (see Figure 6)

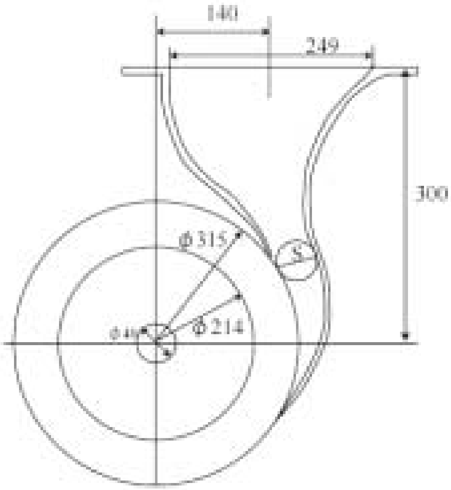


Figure 1 Experimental crossflow turbine

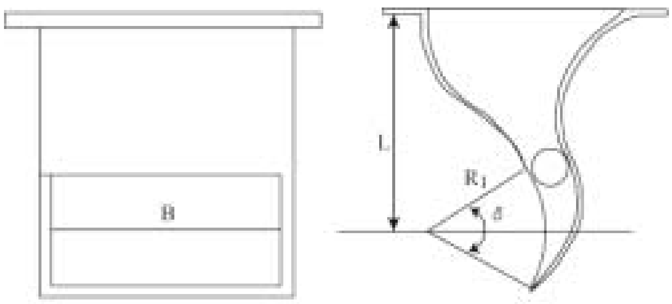


Figure 2 Shape of the nozzle and parameters of experiment
(S_0, L B and) Figure

3. Result and discussion

(1) Effect of the angle (δ) of nozzle opening

It is an important subject for the design with variable discharge, whether to change the nozzle width on the axis direction or to enlarge the angle of nozzle opening. Thus, the effect of δ on the turbine performance studied for three different angles of the nozzle opening. Figure 3 shows the characteristic performance around the maximum efficiency for δ = 30^o, 60^o, and 90^o. These curves are prepared by plotting those maximum efficiencies that were obtained for respective angles δ while changing the other parameters. The conditions of experiment are given

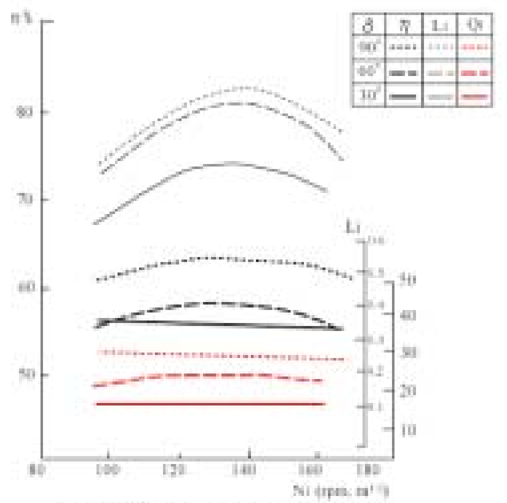


Figure 3 Effect of nozzle open angle

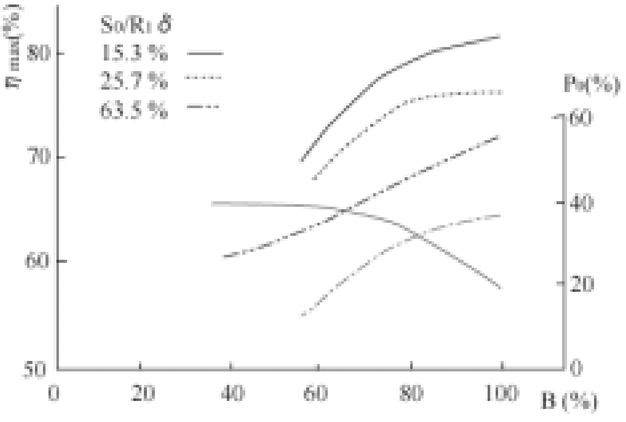


Figure 4 Effect of Nozzle Width
(δ =90° , type A)

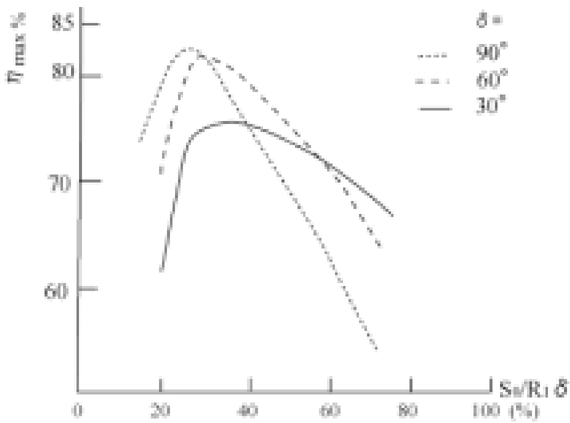


Figure 5 The effect of nozzle throat width
(B = 100%, Type A)

blow the title of Figure 3. Peak value of the efficiency increases accompanying to an increase of δ. The rotation speed that yields η_{max} is around 130 (rpm, m), and is close to the design value of N_1 = 139 (rpm, m). Discharge Q_1 slightly increases in linear according to degrease of N_1. The larger δ is, the larger the gradient of Q_1. N_1 that gives the maximum output (L_1) does not coincide with the rotation speed that gives the maximum efficiency but is slightly on the slower side.

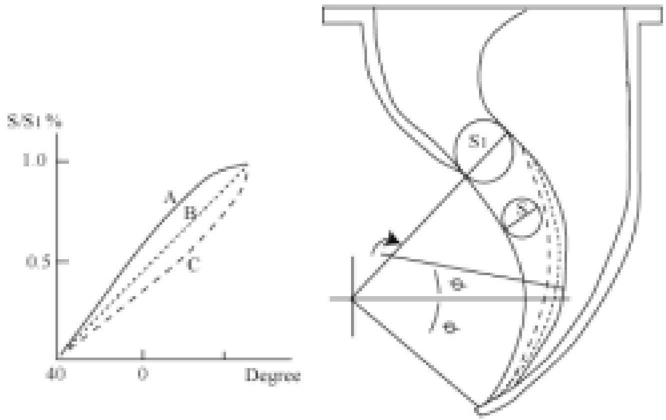


Figure 6 Shapes of nozzle back wall

(2) Effect of the nozzle width

Sonnek proposed that the width of nozzle should be narrower than width of the runner considering the thickness of runner vane. Thus, the effect on the turbine performance was studied for the ratio (B) of nozzle width to the runner width. Figure 4 (not presented here) shows turbine efficiency and static pressure at the nozzle exit according to chances of B. The value of η_{max} decreases according to decrease of nozzle width for such nozzle whose throat width is appropriate to yield high η_{max}. On the contrary, for wide throat and low η_{max}, the pressure at the nozzle exit decreases and the turbine efficiency increases along with reduction of the

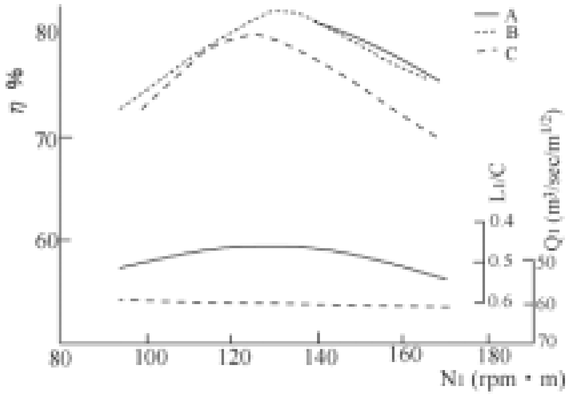


Figure 7 Effect of the shapes of nozzle back wall
(δ = 90° , S0/R δ = 25.7%, B = 100 %)

nozzle width.

Thus, when the width of the nozzle is narrowed, static pressure at the nozzle exit decreases, and the flow at the nozzle exist becomes like a free jet. However, when the width of nozzle throat is appropriate, there is little effect of narrowing the nozzle width compared to the runner width.

(3) Effect of nozzle throat width (S_0)

Figure 5 shows the change of η_{max} according to the change of the throat width ($S_0/R_1\delta$).

The value of $S_0/R_1\delta$ where η_{max} becomes peak is 25% - 30%, and it slightly decreases according to the increase of angle of nozzle opening (δ). Now, the equation of continuity at the nozzle throat and the nozzle exit can be expressed as follows:

$$v_0 \cdot S_0 \cdot B = v_1 \sin\alpha_1 \cdot R_1\delta \cdot B$$

where the subscript 0 denotes the nozzle throat and 1 the nozzle exit.

Assuming the water flows from the nozzle throat tot he nozzle exit at the same velocity, then $v_0 = v_1$ and $S_0/R_1\delta = \sin\alpha_1$. At the designed condition, $\alpha_1 = 15^o$, $S_0/R_1\delta = 0.26$, which are close to the experimental value.

(4) Effect of the shape of nozzle rear wall

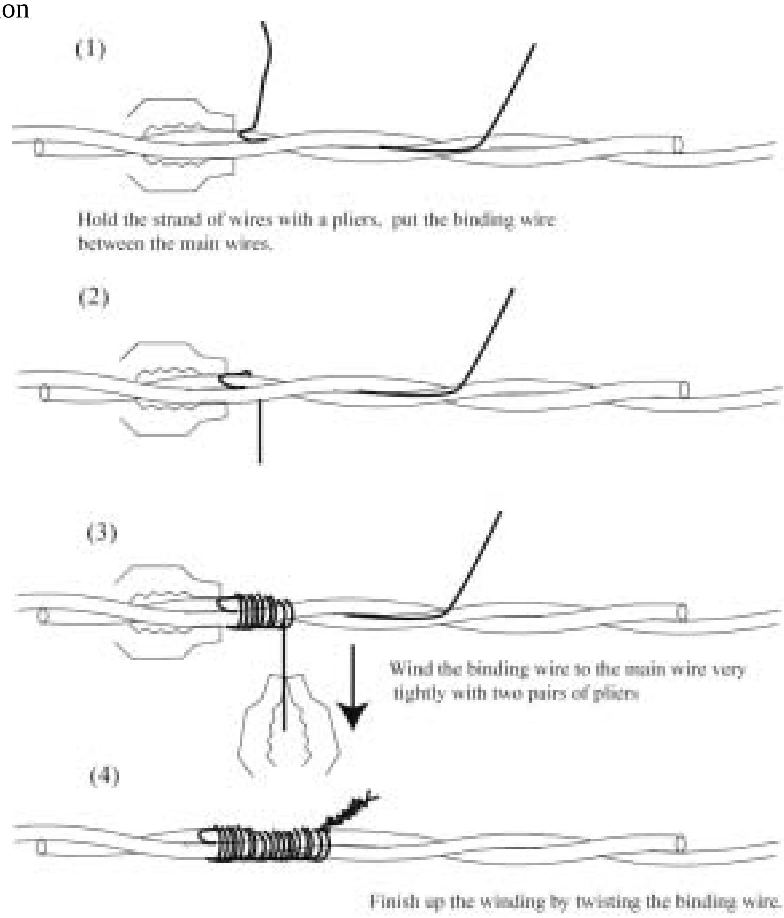
It is considered that the pressure distribution and speed distribution at the nozzle exit would vary by the shape of the nozzle rear wall even if the width of the nozzle throat (S_0) is kept constant. Thus, three deferent shapes of the nozzle rear walls were examined here. All of them are the nozzles that have the open angle of $\delta = 90^o$, and the width of nozzle throat is $S_0/R_1\delta = 25.7\%$, which yielded the maximum efficiency. The shapes of the rear walls are shown in Figure 6, as the width of the section (S/S_0) along the circumference at the nozzle exit. Type A is drawn as an arc having $\alpha_d = 15°$ at the nozzle end; type B is to make the width from the throat to the end linearly decreased; and type C is used for comparison. Figure 7 shows the performance characteristics of the three types. Types A and B show very similar characteristics, while the maximum efficiency of type C is lower by about 2 % than the other patterns. The characteristics of discharge and output are similar among the three types.

Appendix 4 Line Connection Work for Village Distribution Line

Loose line connection will cause a severe voltage drop. Below is a connection method that will temporarily improve the loose contact between the two wires. The method of proper line connection should follow that of MEPE.

Local technician, who managed a few village schemes of micro hydro in Shan State, had the lecture of line connection

Outcome of the training of line works



Improvement of Contacts between Wires by the Winding

Appendix 5 Cost for House Wiring

Cost for house wiring per household is about K10,000 equipped with several electric appliances hsuch as TV and fan, K7,500 for middle standard, and K5,000 for the simplest installation with a few lightings, as of Nov 2001 in Shan State. The detail items are shown in the table below.

Price List of In-house Wiring Materials in Nam Lan (Shan State), as of Nov. 2001

Item	Cost (Kyat)	Unit	Note
Cable (internal wiring)	2,500	100 yard	up to 500V
Flexible wire	1,200	300 ft	
Main switch	1,800	1 nos.	
Volt meter	400	1 nos.	
Knife switch	300	1 nos.	
Circuit breaker	350	1 nos.	
Wall wiring cover, 1inch length	50	6 feet	
Wall wiring cover, 1.5inch leng	60	6 feet	
Meter cover box	500	1 nos.	A meter is provided by MEPE
Switch	100	1 nos.	
Wall switch	200	1 nos.	
Socket (single)	150	1 nos.	
Socket (double)	80	1 nos.	
Plug	60	1 nos.	
3 pin socket	150	1 nos.	
3 pin plug	100	1 nos.	
60 W milky bulb	100	1 nos.	
2 feet fluorescent light	1,500	1 nos.	20 W
4 feet fluorescent light	2,200	1 nos.	40 W
Fluorescent bulb	400	1 nos.	50-100 W
Lamp holder	70	1 nos.	
Ceiling type lamp holder	90	1 nos.	
Fuse holder	100	1 nos.	copper line is used for fuse

Figure Wiring Materials sold in a Shop in Nam Lan

Below is another example of price of house wiring material and electric appliances in Myitkyina, Kachin State

Items	Price (Kyat)	Made in
Fluorescent bulb (15 W)	400	China
Fluorescent bulb (20 W)	400	China
2 ft fluorescent tube light (20 W)	500	China
4 ft Fluorescent tube light (40W)	650	China
Extension code with 6 multi plugs	500	China
Extension code with 8 multi plugs and voltage meter	700	China
Watt-h meter	4,200	China
Inverter (1000 W)	3,500	China
Small fan	11,000	Thailand
Board with voltage meter, 3 plugs, 1 switch, and 1 bulb socket	2,400	
In-house wire (per 100 m)		
1/C 3029 (3 lines-0.29mm^2)	4,035	
1/C 7074	20.280	
2/C 3029	5,300	
2/C 7044	21,850	
2/C 7083	62,680	

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

FINAL REPORT

Volume 6　Supporting Report
Appendices to Manuals

Part 6-1	Appendices to O&M Manual-Small Hydros
Part 6-2	Appendices to Design Manual-Small Hydros
Part 6-3	Appendices to Design Manual-Village Hydros
Part 6-4	**Appendices to Institutional and Financial Aspects**

STUDY ON INTRODUCTION OF RENEWABLE ENERGIES
IN RURAL AREAS IN MYANMAR

Final Report

Volume 6 Supporting Report

Appendices to Manuals

Part 6-4 Appendices to Institutional and Financial Aspects

LIST OF APPENDICES

Appendix 1 Case Study 1 - Kalaymyo RE Scheme Served by Zi Chaung Hydro

Background data

Kalay Town is in Sagaing Division, the main industries are agriculture and bottling of water. Total number of MEPE consumers is approximately 3,000 (of which domestic consumers = 2,066 in Nov 2002) and there are a total of 826 streetlights. 5 Quarters in the town (Karton, Pin Lon, Nyaung Pin Thar, Aung Mingalar, and Aung Thit Sar) are receiving electricity and some villages are also supplied. The total demand is said to be 1.8 MW.

Kalay Town has two sources of electricity supply - Zi Chaung hydropower scheme + a diesel engine power station located in the MEPE compound on the east side of the town. Zi Chaung hydropower scheme is south west of the town and about 1 hour by road. The scheme was commissioned in 1996 and incorporates 2 No. 630 kW Jinhua generators. The present day generating capacity for No.1 = 550 kW and No.2 = 350 kW (total = 900 kW)

Normally power is sent to the town grid and meets the “daytime” basic needs. During the evening peak and during the dry season the diesel engines are operated. The diesel engine power station has 3 units:

- Caterpillar 320 kVA (installed 1996)
- Skoda 860 kVA (installed 1985)
- Skoda 608 kVA (installed 1985)

Peak supply capacity of these is said to be 1,300 kW. The units are only operated in the evening for 3 hours.

The breakdown of the annual operating expenditure for year 2002 was:

	Kyats
Staff / labour	3,035,509
Diesel	9,782,495
Repairs	3,156,472

	15,735,763

Income from tariff for the same year was: K11,542,563

Average Unit Revenue for the period was K3.21 / kWh. Revenue from March to June 2002 decreased due to the low river flow in the dry season (only one hydro turbine unit was operated in this period). Average monthly expenditure of MEPE Kalaymyo for 2002 was K13.4 million, while average monthly revenue was K9.7 million.

The overall scope of electricity supply operations being overseen by the MEPE Township Engineer is shown in the schematic diagram overleaf.

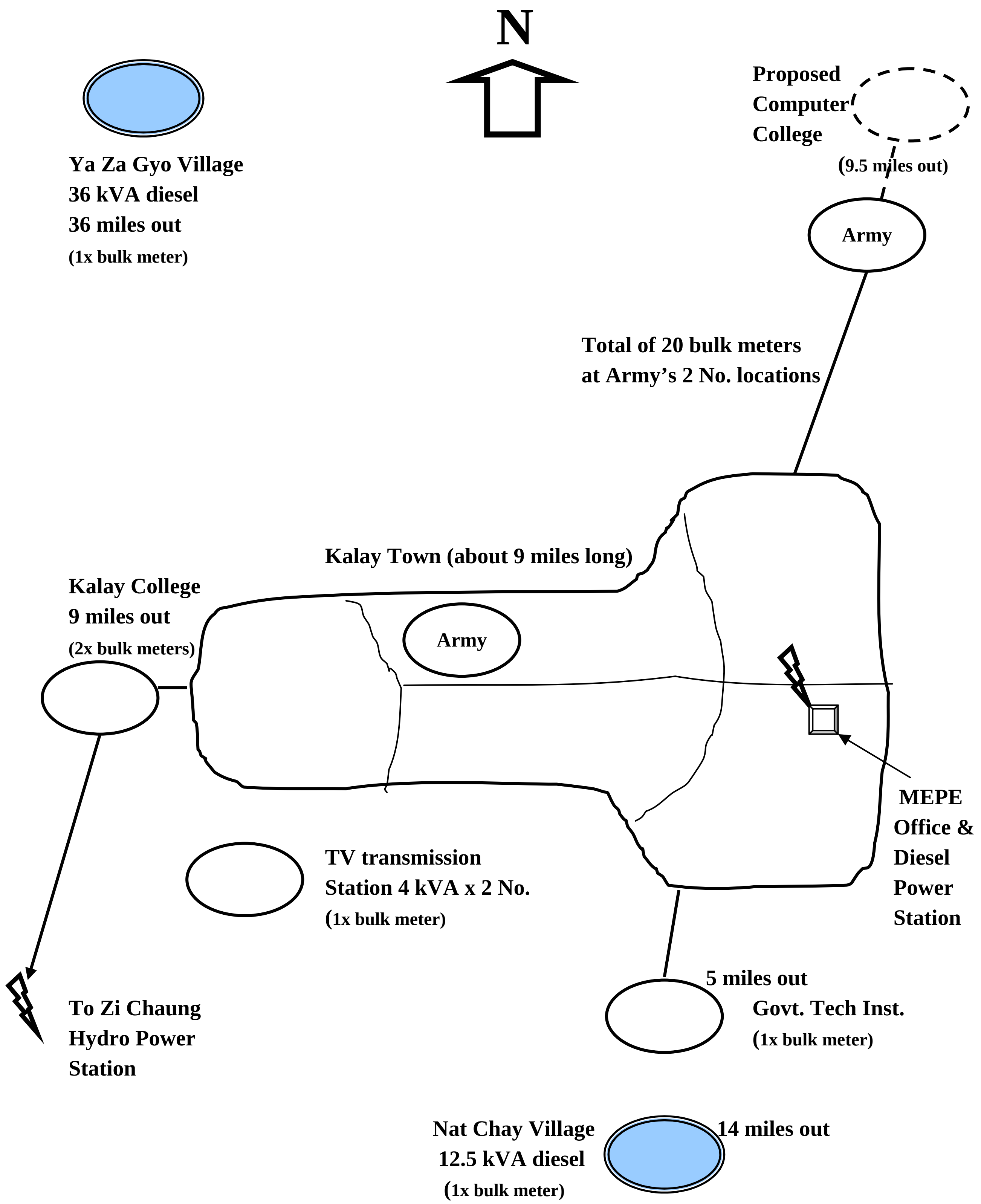
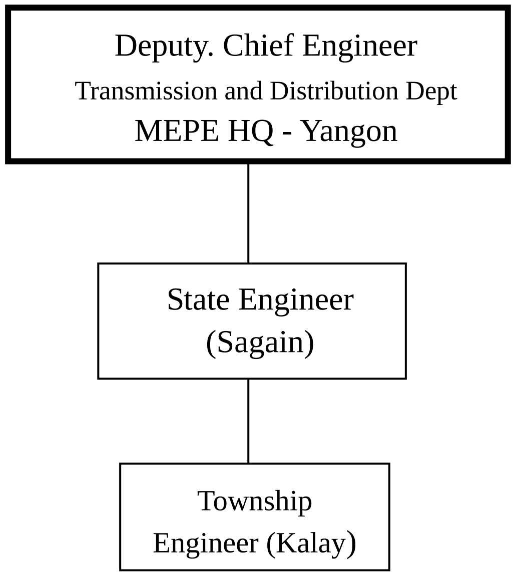


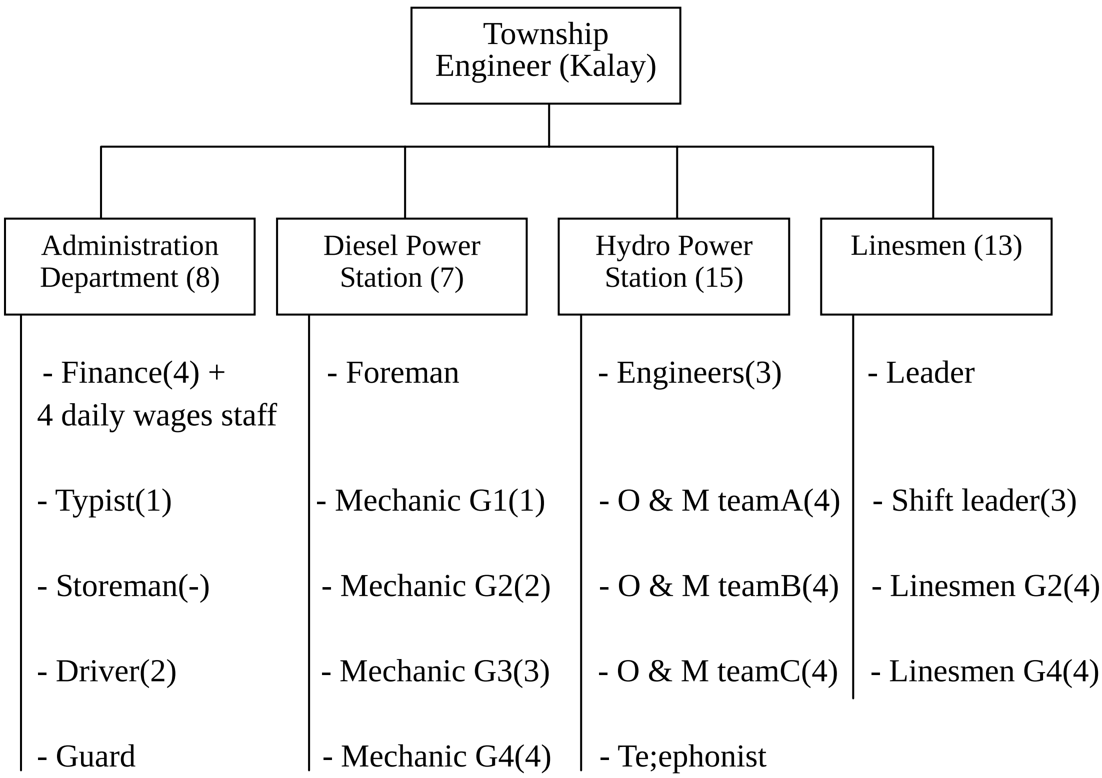
Figure 1 Schematic diagram of electricity supply by MEPE at Kalay Township (NTS)

<u>Institutional / organisational aspects</u>

The MEPE regional structure and the organisational diagram of the establishment of the Kalay town MEPE Township Engineer are shown below:



Fugure 1 MEPE regional structure



Fugure 2 MEPE Kalay Township Engineer's organisational structure

The staffing arrangements for the O & M of the small hydro-power station at Zi Chaung are as follows:

Total permanent staff = 3 engineers (2 No. Engineers / SAE and 1 No. G1 Engineer /Technician) + 12 support staff on shift work. In addition some 50 to 60 casual workers are employed once a year to remove large accumulations of silt and sand in the storage pond above the power house.

The 3 engineers take turns to lead a 12 hour shift. The supporting staff mainly carry out tasks such data recording and are divided into 3 teams to work on the shifts. They comprise:

1 No. G2 labourers / operative

2 No. G3 labourers / operatives

9 No. G4 labourers / operatives

The actual shift / rota system operated at Zi Chaung is as follows:

Day	Daytime shift	Night-time shift	Off
1	A	B	C
2	A	B	C
3	C	A	B
4	C	A	B
5	B	C	A
6	B	C	A

<u>Operational problems observed</u>

In terms of levels of service, the following statistics for the 12 month period up to 30/11/2002 demonstrate the disruption to supply experienced by consumers.

Total number of power cuts = 124 No.

Cumulative duration of power cuts = 545 hours

Average number of hours of power cut / month = 45 hours / month

Worst month for power cuts = September (115 hours)

The small hydro power scheme at Zi Chaung is now working at a much lower efficiency than when installed in 1996 and has a significantly reduced output. Even if it could develop full power it would only meet 66% of the current estimated peak demand of Kalay town. However, Zi Chaung can only generate 900 kW which is just under 50% of the peak demand. The shortfall in power supply is met by the MEPE thermo-electric power station. An operational constraint is that the output from all these power sources cannot be fully combined / synchronised.

In terms of O & M the main difficulties with the current arrangements are assessed to be as follows:

- No separation of the operation and maintenance roles
- No preventive maintenance

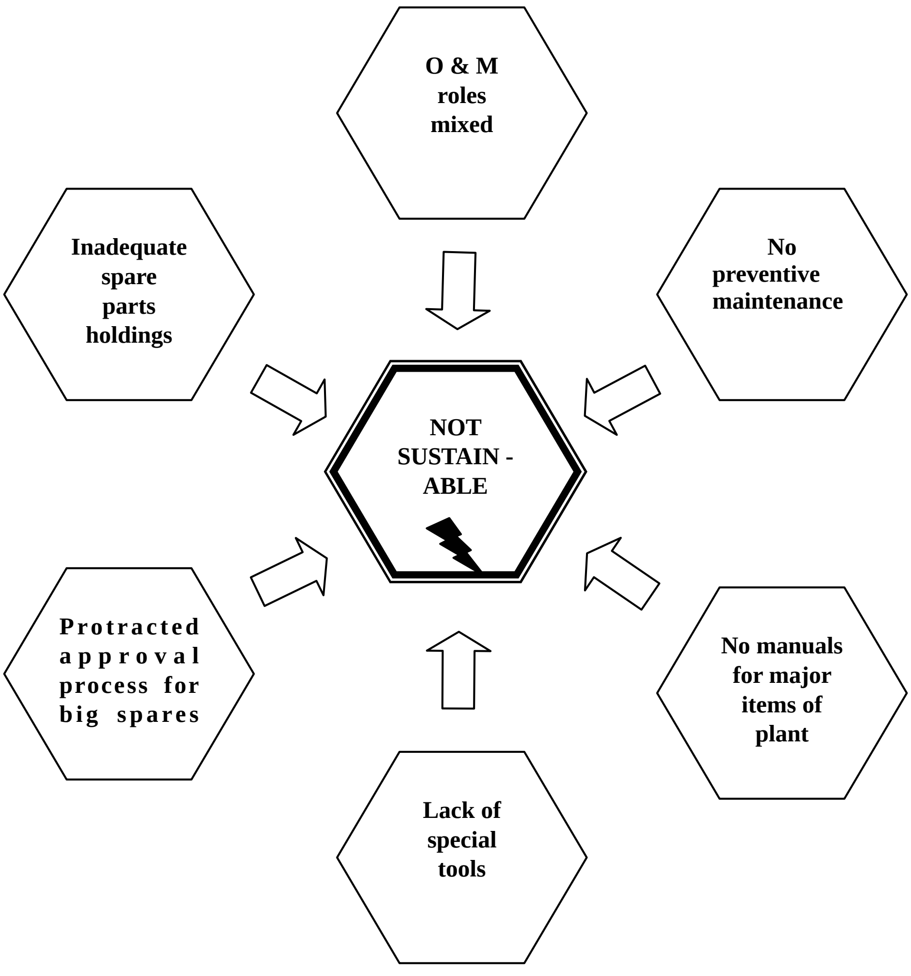
- Lack of special tools
- No manuals for all main items of plant
- Inadequate holdings of spare parts
- Long delays by MEPE HQ in approving purchase major items of spares

There appears to have been an inadequate hand-over from the contractor at the time of plant commissioning and apart from a few drawings no other documentation to facilitate O & M was given to the MEPE staff.

In addition, in terms of safety / ease of access to different components of the Zi Chaung scheme for O & M work, the following points should be noted:

- Poor quality access road to the hydro power station from Kalay town
- Inadequate access along much the route of the main canal for inspection purposes (also occasional landslides affect parts of main canal)
- No safety chains in the main canal downstream of the dam / takeoff

All of the above factors contribute together to create a situation where the operation is unsustainable as illustrated in the diagram below.



Fugure3 Factors causing unsustainability – Zi Chaung Hydro

Basis of the findings

The basis of the findings at Zi Chaung was a field trip undertaken by the Institutional Expert between 16-18 February 2003. A detailed questionnaire was prepared and the completed version developed over the course of several interviews of key MEPE staff is included at the end of this paper.

Suggestions / proposals related to institutional / organisational aspects

Consumers place considerable importance and value on having a reliable electricity supply. In order to improve operational efficiency of an isolated power supply system such as Zi Chaung and move to a more sustainable form of operations a number of key factors need to be in place, such as:

- a properly set up operational management organisation
- separation of the “operating” and the “maintenance” roles
- O & M manuals and guidelines are available and on site for reference
- O & M staff are properly trained
- availability of spare parts and maintenance materials
- adequate funding
- appropriate and equitable tariff structure
- efficient billing and collection procedures
- transparency in financial matters
- good communications with consumers
- monitoring and evaluation procedures covering whole process
- records are properly maintained and archived

It is also important that there is feedback from the operation and maintenance process to the design and construction processes. By this means the lessons learned during the working life of a renewable energy RE scheme can lead to future improvements in these areas and produce more efficiency and improve sustainability.

Questionnaire for Interviews/Field Surveys

Subject	**Questionnaire for Zi Chaung field trip (16 – 18 Feb 03)**		
Date	**14 February 2003**	**Prepared by**	**Roger Harris**
Filename		**File Ref. No.**	

Task / question list

Summary of the key technical data	Daytime maximum demand – 800 kW Max demand year round – 1,860 kW Zi Chaung hydro scheme built 1996 Installed capacity 1260 kW Max output now available from Zi Chaung (i.e. much less efficient than early years, full power for only first 4 years) is as follows: 900 kW – wet season (140 cusecs) 450 kW – dry season (50 cusecs) Kalay Town diesel power station engines (3 No.) are operated from 6pm to 11pm. Two of the engines were out of commission and under repair (both of the Skodas). Typical current outputs from the 3 engines are: Caterpillar 320 kVA = 200 Skoda 860 kVA = 330 Skoda 608 kVA = 240 In addition to supplying electricity to Kalay Town, MEPE supplies some outlying institutions which are connected to the town grid. MEPE also operates and maintains independent diesel power plants serving the TV transmitter and two outlying villages (Ya Za Gyo with 36 kVA generator and Nat Chay with 12.5kVA). Both villages have VECs.
Do they have a copy of the MEPE Regulations? - Administration - Financial - Engineering	NO) NO) but State Engineer was said to hold NO) a copy of these
Have detailed operating instructions been issued by the State Engineer at various times?	NO
How are their activities audited by MEPE?	Township auditing office visits twice a year Monthly reporting to State Engineer

Are there any other regulations or manuals used? If YES, give details (e.g. manufacturer's manuals)	YES Electricity Law and the associated Ministry of Industry Regulations No manufacturer's manuals held
Do staff have written job descriptions	NO but they are given on-the-job training
Has any formal training been given to any staff or operatives in past 2 years? Hydro power station Diesel power station Office If YES, give details	YES NO YES One SAE undergoing training at Yangon currently. Admin / finance staff participate in Township accounts training programme
What is your assessment of the training needs? Hydro power station Diesel power station Office	None specifically None specifically None specifically
Have there been any significant accidents during operations in past 5 years? Hydro power station Diesel power station Office	NO NO NO
Are there consumer representative groups	NO
Are there any independent village electrification schemes nearby If YES, give details If YES do you give any practical help or assistance to it If YES, are there electrification associations (VECs) for same If YES and known, give details	YES 160 villages under the Kalay Township. Most have diesel generators. Usually 2 to 3 per village. Could be a total of 500 units, of which biggest is 7.5 Kw and smallest 2 kW. Also 12 units of 7.5 kW hydropower Technical advice when requested which is said to be often The villages with small hydropower schemes may have VEC's but this cannot be confirmed No details available. However, the two outlying villages served by independent MEPE diesel engines have VECs. These only meet when necessary and meetings are not attended by the Township Engineer. VECs arrange for charging villagers based on lights used as there is only a bulk meter Yes, by giving technical advice

If NO, would they feel able to help in any way if a nearby “village scheme” was proposed in the future	
Are any NGOs active in the region in relation to rural electrification?	NO
What is your assessment of the ability and willingness to pay for electricity?	They can pay a lot more – some people pay 300K per unit
Are there any significant operational problems currently at the hydro power station? If YES give details	YES 1 Waiting for permission to get spare parts – particularly the large items – these may take 3 months to get permission as the request has to go to Head Office. 2 No manuals 3 Occasional landslides 4 Storage pond silts and requires annual emptying 5 Chinese contractor did not give proper handover 6 No preventive maintenance (but do daily checks) 7 Minimal and inadequate spares holding 8 Problems with excitation equipment
Are there any significant operational problems currently at the diesel power station? If YES details	YES 1 Waiting for permission to get spare parts – particularly the large items – these may take 3 months to get permission as the request has to go to Head Office. 2 Inadequate tools (but linesmen’s tools OK) 3 No preventive maintenance or split between operating and maintaining (but do daily checks) 4 No spare parts 5 No manufacturer’s manuals 6 Two of the engines (the Skodas) are old– cannot get spares –have to get pattern parts made – these are usually of poorer quality = short working life 7 Poor quality floor
Is the standard government (MEPE) tariff applied	YES – to the Town, i.e. 1 – 50 units 0.5K / unit 51-200 units 10K / unit 201+ units 25K / unit However villagers pay 25K / unit for bulk metered usage and VEC collects charges based

	on number of lights Villagers therefore pay a disproportionately high tariff compared to town dwellers and on top of this they have to pay for minor maintenance as MEPE only do the big jobs Example:- 10 people in town using 30 kW pay K150 10 people in village with bulk meter pay K7,500 = 50 times as much
Is payment of bills at MEPE office?	YES – after MEPE delivers bill to consumer
What is the average monthly collection?	K1.3 million
What is the collection efficiency	Nearly 100%
What is the experience of MEPE's Township Engineer (U Aung Thit) Years MEPE service? Years at Kalaymyo? Qualifications? Who does he report to?	19 years 5 Years AGTI (Associate of Government Tech. Inst.) Divisional Engineer at Sagain
How many staff are actually employed? + what is the nominal establishment?	Full-time / Casual / Establishment
Hydro power station	3 + 12 on shift / 50-60* / 24
Diesel power station	7 / / 10
Office (includes Township Engineer)	8 + 4 on daily wages / / 11
Linesmen	13 / / 15
Total	**43** / / **60**
	* these labourers are employed once a year for one or two weeks to remove silt and sand sediments from the storage pond feeding the power station Reason given for shortfall between actual staff and the approved establishment was that no authority had been given to make the outstanding appointments Note: From 10/2/03 approval has been given to appoint 11 staff 3 at the office(office assistant, guard / timekeeper and storekeeper) 3 at the diesel power station 5 at the hydro power station Those at the power stations are proposed to be trained on the job to do mechanical tasks

Staffing details - hydro power station	Total = 3 + 12 on shift work + 50 to 60 casual workers employed once a year 2 Engineers (SAE) 1 No. G1 Engineer/Technician -- 1 No. G2) 2 No. G3) Labourers / operatives 9 No. G4) (doing data recording) *Rota system:* Day Daytime shift night shift Off 1 A B C 2 A B C 3 C A B 4 C A B 5 B C A 6 B C A
Staffing details - diesel power station	Total = 7 1 Foreman 1 No. G1) 1 No. G2) Mechanics (but not qualified) 2 No. G3) 2 No. G4)
Staffing details - office	Total = 8 + 4 Finance (4) + 4 daily wages staff Typist (1) Store (-) Driver (2) Guard (-)
Staffing details - linesmen	Total = 13 4 No. G1 – 1 Leader + 3 Shift leaders 4 No. G2* 1 No. G3 (telephone operator) 4 No. G4* * means 1No. of each is stationed in Tahan quarter at the opposite end of the Township to the MEPE compound (8 miles East).
Do all staff generally have adequate experience and skills and qualifications for the job	Township Engineer says YES

Are there difficulties getting properly experienced and qualified staff?	Township Engineer only has authority to appoint labour State Engineer chooses and sends other staff
What are the key areas of weakness?	Low level of education Lack of qualifications
How many bulk meters? How many consumer meters? Give details of other meters Give details of customers Does the total number of customers include nearby villages?	30 (Jan 03) 2029 - domestic 15 – small industries power meter 1 – street lighting ------------------- Total = 2075 meters / customers Details of industrial customers: (e.g. Rice or oil mills or other major industries) No major industries only light industry such as oil mill, ice tube maker, distilled water production, small machinery Other groups of customers are Army establishments and colleges YES – the 2No.with diesel engines maintained by MEPE - both have bulk meters
Is there a meter repair / recalibration workshop	NO
Average monthly consumption ? Load shedding takes place between?	Approximately 300MWH 18.00 to 23.00 hrs.
What is the organisational structure of MEPE regionally	See attached diagram
What is MEPE Township Engineer's organisation structure at Kalay Town for:- • Overall organisation • Hydro power station • Diesel power station • Office	See attached diagrams
Are detailed monthly report submitted to the State Divisional Engineer? If YES are following 5 pro-formas utilised:- Demand summary Income / outgoings Demand / supply	YES YES YES YES YES

Transformer data Collection data	YES YES
What is my assessment of the standard of record keeping at the following locations. Hydro power station Diesel power station Office	Not seen None evident Information available but storage poor – shelves stacked with old paper records - fire hazard
What are the communication facilities between the 2 main locations	Telephone

Appendix 2 Case study 2 - Village RE schemes

A number of villages have been visited during the course of the study and interviews held. Initially this was related to the social survey and then subsequently it was to assess different types of NGO facilitated or cooperative built RE schemes using renewable energy.

The villages visited covered a wide and representative geographic area and 3 different forms of renewable energy application were being utilised;

- Micro hydro
- Biogas / rice husk
- Solar power

As an example (and to show the progress already being made in the form of self-help RE schemes) six case studies are presented on the following pages.

A summary of the key aspects of these six Village RE / VEC case studies is included at the end.

***VEC Case Study A** – Bambawe Village, Shan State*

The demographic data for this village is 4,600 population – 730 households. 35% of the population are farmers. Population breakdown is: 50% Shan / 30% Myanmar / 5% Chinese / 5% Indian / 10% Other Indian. The findings are tabulated below:

Details of VEC	12 members; copy of regulations provided; not a cooperative.
Population served	Some 200 households are electrified.
Power generation/source	Bulk supply taken from the grid
Project cost data	30 Lakh
Time to construct project	One month.
Aspects of community participation	Village bought own equipment and installed same in 1998 using own labour.
Organisations that assisted project	MEPE gave technical assistance during planning and construction.
Method of funding capital cost	VEC took one year to collect the 30 Lakh for the scheme before commencement
Tariff structure	Standard MEPE tariffs are applied. VEC add 5% to cover their admin costs. VEC read meters then calculate bills and submit drafts to MEPE Township Engineer at Naung Cho. MEPE check total consumption against bulk meter reading for the village supply and issues one bill to VEC. Maximum consumer bill is normally K100 / month. Costs is K25 per night for lights if rechargeable batteries used.
Usage of electricity	Lighting - all houses are metered.
Aspects of willingness and ability to pay	The non-electrified are willing to pay the same as those currently electrified. Average income is between K100,000 to 400,000 / annum. Savings are K30,000 to K100,000 / annum. K10,000 per household this year to build pagoda
Problems experienced by village	Water shortage in summer, low % of electrification, inadequate high school building. Priorities are: Electricity / Education - School buildings / Health
Other organisations active in the village	6 No. i.e. VPDC, USDA, MCS, VPA, VFA (a cooperative) and VWSDC

***VEC Case Study B** - Alatchaung Quarter (in Kyimyindine Township)*

This community is located west of Yangon city, on the other side of the river where there is no electricity. The community decided to implement its own RE scheme in 1991 and used an existing cooperative, Alatchaung Trading Cooperative Ltd. (ATCL) as the body to do so. Alatchaung Quarter has a total population of 4,500 persons and some 950 families. There are 500-550 members in ATCL. 50% of workforce go to Yangon to work. Some 10% are said to be farmers. Some are boatmen / fisherman. The findings are tabulated below:

Details of VEC	3 voluntary members on ATCL's Board of Directors. 2 auditors (also voluntary). No Annual report to MOC but annual meeting held and representative from MOC Township office invited. ATCL audited annually by latter office and inspected quarterly.
Population served	80 household connections were made initially. Now 180.
Power generation/source	Red Flag (Chinese) generator of 15 kW capacity. The original diesel engine, is currently under repair and replaced by a temporary unit.
Operational cost data	At least 3.5 gallons of diesel are used each evening (normal operation period). Operator's wages are K8,000 per month.
Community participation	The whole system was installed on a community participation basis. All necessary skills were available in the village.
Technical assistance	No external technical assistance for the project was received.
Method of funding capital cost	A loan of K200,000 was given through the Township Cooperative Office. K30,000 remains outstanding. ATCL pay off loan when they can. Such loans not now normally available.
Tariff structure	K25 per day per lamp. No bills are issued. No extra charge if a TV is used. ATCL have a consumer list. Tariff increased to present level in 1999. Monthly collection is K50,000 (mostly spent on diesel fuel). ATCL use Myanmar Economic Bank across the river.
Usage of electricity	ATCL only supplies domestic usage. Normally each household uses one 2 foot fluorescent lamp, some houses also use TV and have a battery to charge and enable its use during the day. About 40 fluorescent "street lights" are also run from the system (free)
Willingness and ability to pay	ATCL have no plans to expand the electricity system. Demand is said to be there if they had the capacity to fulfill it.
Problems experienced by village	The main issue is the high cost of diesel (K5-600 per gallon) as it has to be bought on the open market. Also a logistical problem as it is transported over the river in cans on the small ferry boats.

VEC Case Study C - Heya Ywama Village, Inle Lake

The total number of households in this village is 1,000. The findings are tabulated below:

Details of VEC	Heya Ywama Electrification Committee (HYEC) has 23 members (all voluntary) in the central committee. HYEC established in 1992 when village first electrified. Present Chairman since 1995. HYEC employ 2 meter readers / billers at K3,500 per month and have a small office where the monthly payments are made.. Formal rules and regulations established 1992 and revised 1995.
Population served	Initially there were 501 consumers, this increased to 797 in 1995 and is now 800. Therefore village is 80% electrified.
Power generation/source	Initially (1992) a diesel engine powered system that was subsequently upgraded (1995) to supply by the National Grid.
Project cost data	Total cost of the upgrading was K13.5 million. Originally no agreement that government gives funding. Eventually they contributed K90 million.
Aspects of community participation	Construction of upgrading scheme jointly by MEPE and HYEC. HYEC provided skilled (e.g. carpenters) and unskilled workers. Former paid K200 / day and latter K100 / day (today = 600/300)
Organisations that assisted project	Technical assistance from MEPE but no guidance or assistance was received for the setting up of HYEC
Method of funding capital cost	Government promoted initial (1992) electrification due to wish to electrify nearby famous Phang Daw Oo pagoda for tourism and funded the diesel powered station and some of the 0.4 KV distribution system. Balance funded by villagers. Upgrading to National Grid connection involved a 9 mile extension of 11 KV transmission line plus transformer plus additional distribution.
Tariff structure	Up to 1996 there was only a bulk meter and consumer charges were K150 per household per month. After 1996 individual meters were installed. There are also 2 bulk meters. Highest monthly bill is K5,000, lowest is K30. Standard government tariffs used as basis and surcharge added to cover operational cost of HYEC plus system losses. Surcharge K1 per unit in 1995, K2 per unit since 1999.
Usage of electricity	The village's initial priority was lighting but now it is for single phase motors for water pumping and grinding / milling.
Aspects of willingness and ability to pay	Balance of upgrading cost (K4.5 million) raised by HYEC. Cost spread over the 797 consumers equally. 67% paid outright. Remainder paid in installments over one year. Everyone paid their share.
Other organisations active in the village	HYEC's central committee runs 16 sub committees.

VEC Case Study D - Younetalin Village, Hentada Township, Ayeyarwaddy Division

Electrifying villages in the Division is being spearheaded by the Area Commander (good example of "champion" role). There are plans to electrify 26 more villages using the same concept. Younetalin village was first to be electrified. There are 1100 households in the village. The findings are tabulated below:

Details of VEC	Scheme conceived January 2001, VEC formed then. 12 members. Head is Head of Village. 1 member oversees power plant operations (voluntarily), 1 does accounting and 5 act as collectors. 4 operatives employed. Each receives K2,500 / 10 days. No formal rules yet.
Population served	420 households have been electrified
Power generation/source	Biomass is the energy source for power generation. The waste (burnt rice husk) is used by villagers for different purposes.
Project cost data	Scheme cost was K4 million (15 power plant + 25 distribution system) for materials only. Power plant is 140 HP / 135 KVA. Running costs = oil and rice husk (K5,000 to K8,000 / 10 days) + staff costs.
Time to construct project	Scheme commenced operation 15 April, i.e. 3.5 months to arrange funding and build. Power generation plant took 10 days to install.
Community participation	Members of VEC are volunteers. Self funded scheme.
Organisations that assisted project	MEPE constructed the distribution system free of charge and this component was completed in 2 weeks.
Method of funding capital cost	Villagers initially contributed K20,000 to K40,000 per household (paid in 3 installments). Balance covered by interest free 12 month loan from Area Commander of Division. Repayments made when possible. After paying off loan, any surplus income will be used for further development of the village
Tariff structure	2 foot fluorescent light K10 / night (4 foot = K15 / night) Television K15 / night Charges collected every 10 days and amount to K60,000. 15 street lights also supplied (no charge). The school also has a free supply.
Usage of electricity	Electricity only be used for domestic lighting (maximum of 3 lights per household) or TV / radio. The supply is from 18 to23:00 hours.
Willingness and ability to pay	The villagers are funding the scheme and outstanding payments were expected to be made shortly.
Problems experienced by village	2 similar but larger plant were also visited (both industrial applications). Poor safety levels observed on all 3 power plants i.e. many pulley belts but no guards installed to protect the operatives.

***VEC Case Study E** - Saung Po village group*

Saung Po village group comprises 21 villages. 5 villages are in the electrification scheme: Total households 730 / population 3160. The findings are tabulated below:

Details of VEC	VEC represents all 5 villages. First set up in 1985 (temporary basis) Formally re-established 1995 (under pressure from Pa O National Army leader). PNO assisted with rules. 6 members meet monthly.
Population served	All 5 villages are 100% electrified.
Power generation/source	Micro-hydro. Generation capacity is 75 kW. Water source also used for irrigation. Operation at full capacity started in 1997.
Project cost data	Total cost was 150 LEK of which the hardware contract was for 45 LEK. Scheme operator is paid 6,000K per month.
Time to construct project	Scheme first conceived in 1985. Took 11 years to complete because of politics (commissioned Feb 96). Should have taken 1 year.
Community participation	Self funded and village participated in construction
Organisations that assisted project	REAM, PNO
Method of funding capital cost	No debt outstanding. No loan provided. Villagers classified into 6 income groups and made monthly contributions. Average annual income K100,000. Highest contribution K10,000 / month..
Tariff structure	Tariffs for the first 3 years were: 10 W tube K10K per month (20 W = K20) TV K500 per month Business K1,000 per month Tariffs for lights were doubled 1 year ago and plans are in hand to increase the other tariffs. Electricity for the teacher, monastery, pagodas, health service and school is free. 50 No. 20 W street lights in the 5 villages are also supplied free. K21,900 / month collected.
Usage of electricity	Hours of supply 6pm to 6am. In Saung Po South there are 3no. 20W lights per house + radio cassette. 5 houses have colour TV and 2 have B/W TV. Electricity also supplied to monastery, 4 pagodas, 4 video houses and 2 karaoke bars. Balance from collection, K14,000 to be spare parts / maintenance fund and distribution line repairs.
Willingness and ability to pay	As a model the scheme encouraged 3 more medium size schemes to start plus several small schemes (20-30 households served)
Problems experienced	There has been some post renewal over the 4 years operation because they are softwood (20 out of 150).

***VEC Case Study F** - Pin Pu village, Hlaing Thar Village Tract*

This village comprises 86 households (total population 640). The findings are tabulated below:

Details of VEC	VEC formed in December 1999. Originally established with UNDP / REAM assistance and has its own regulations. 2 of the VEC Executive Members are Linesmen and also act as bill collectors.
Population served	After the upgrade by this project 42 households were electrified This has subsequently been increased to 55.
Power generation/source	Pico-hydro. Originally the village had constructed a dam and were using an inefficient water wheel. The project involved increasing dam height, renovating / extending powerhouse, a balancing tank + transmission / distribution lines. Scheme generates 3kW using a crossflow turbine (designed for 14 kW ready for future upgrades).
Project cost data	Total cost of this upgrade was US$ 7,000. Outgoings are K3,000 per month for the operative / watchman who runs the power plant plus K300 per month to the 2 VEC Members (Linesmen / Collectors). Total 3,600 per month
Time to construct project	Started January 2000 and finished in December 2000.
Community participation	Original scheme started in 1984. Monastery initiated and managed the work and spent K400,000. Villagers gave their labour free.
Organisations that assisted project	Monastery originally, UNDP, REAM and EOJ subsequently
Method of funding capital cost	For the upgrading, aid was provided under Japan's Grass Roots Scheme but the village contributed K60,000.
Tariff structure	K90 per month for every household in village for public lighting + K200 per "electrified household" where lighting is installed + K150 per "electrified household" where TV is installed. Total monthly income K11,500. Excess funds banked at Yuma in VEC's account.
Usage of electricity	Most houses have one 10 W light, three have 2 lights, three B/W TVs. Power also supplied to monastery and 4 pagodas and 48 street lights provide some degree of lighting for the poorer households.
Willingness and ability to pay	Villagers collected K60,000 for upgrading. (average annual income of farmer's household is only K50,000 and others = K20,000)
Problems experienced by village	After commissioning the system was sometimes overloaded due to poor operation (due to rotating the role among inexperienced persons). Resolved by having a permanent employee.

Summary of key aspects of VEC Case Studies

Case Study Ref	Name of village	Total population	Population Electrified	Source of power	Cost of scheme + (date built)	Funding arrangements
A	*Bambawe Village, Shan State*	4,600 population – 730 households	200 households	Bulk supply taken from the grid	K3 million (1998)	VEC took one year to collect the K3 million for the scheme before commencement
B	*Alatchaung Quarter (in Kyimyindine Township)*	4,500 persons 950 families	80 household connections initially. Now 180.	Diesel engine powered Chinese generator of 15 kW capacity.	K200,000 (1991)	A loan of K200,000 was given by Township Cooperative Office. K30,000remains outstanding
C	Heya Ywama Village, Inle Lake	1000 households	Initially 501 consumers, 797 in 1995 now 800.	Initially (1992) diesel engine upgraded (1995) to National Grid.	Total upgrading cost K13.5 million. Govt. contributed K9 million	Balance of upgrading cost (K4.5 million) was raised by VEC by spreading cost equally over the 797 consumers. .
D	Younetalin Village, Hentada Township, Ayeyarwaddy Division	1100 households	420 households	Biomass (rice husk)	K4 million: = 1.5 for generation + 2.5 for distribution (2001)	K20,000 to K40,000 initially contributed per household. Balance of cost covered by loan from Area Commander (interest free)
E	*Saung Po village group*	5 villages total = 3,160 pop 730 hh	All 5 villages are 100% electrified.	Micro-hydro scheme (75 kW) Operation at full capacity began 97.	Total = K15 million Hardware element= K4.5 million (1996)	Villagers made monthly contributions (classified into 6 income groups) Av. =K100,000/annum. Highest contribution level was K10,000 per month.
F	Pin Pu village, Hlaing Thar Village Tract	640 population. 86 households	42 households after upgrade Now increased to 55.	Pico-hydro. (Originally village constructed dam + water wheel).	Upgrade cost = US$ 7,000. (2000)	For the upgrading, aid was provided under Japan's Grass Roots Scheme but the village contributed K60,000