Annex - 1-3

Ministry of Industry, Mines and Energy of Kingdom of Cambodia

The Project for Operation and Maintenance of Rural Electrification on Micro-hydropower in Mondul Kiri

Guidelines and Manuals for Operation and Maintenance of the Electric Unit of Mondul Kiri Province

Volume III

(Reference Data)

February 2011

Japan International Cooperation Agency

Electric Power Development Co.,Ltd.

The Chugoku Electric Power Co.,Inc

Contents Volume III
(Reference Data)

Reference 1: Administration

(No reference data in the first version, only numbering for the futures.)

Reference 2: Civil Structure

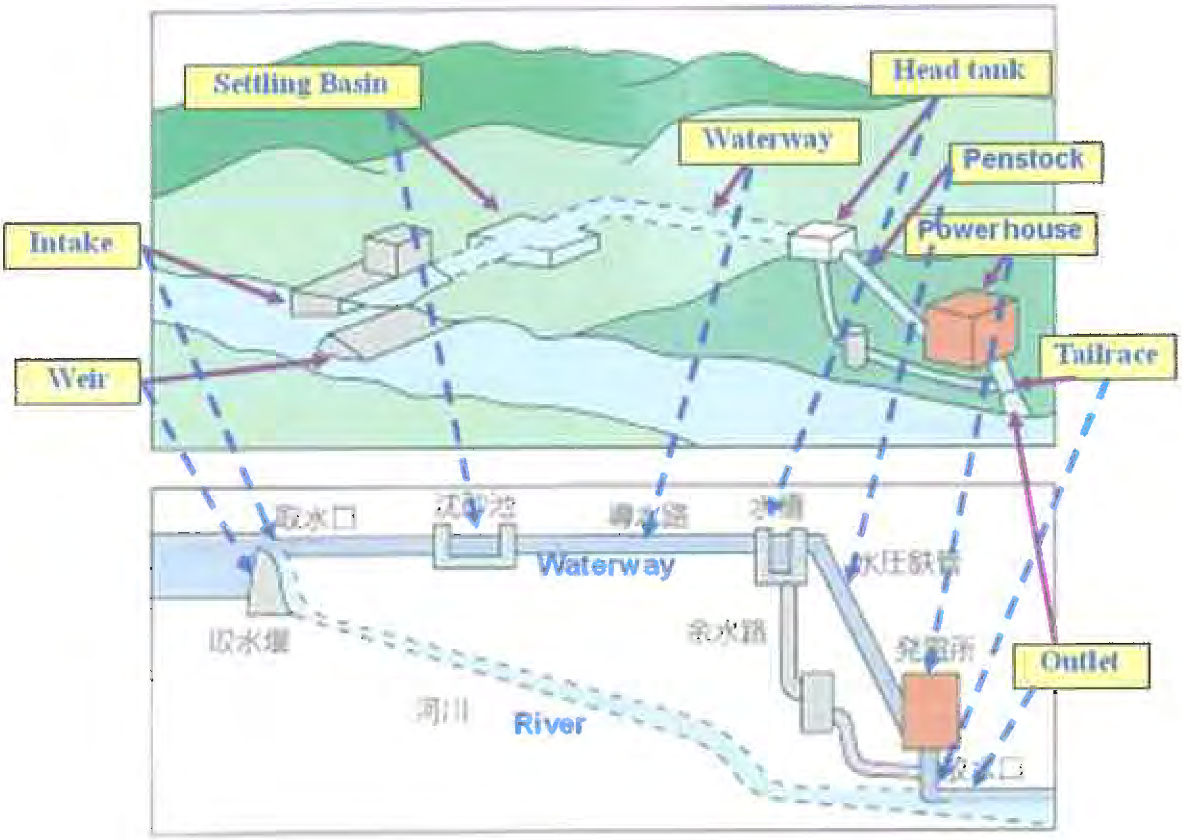
R-2-1 Basic knowledge about the civil structure of hydropower station

R-2-1

Textbook of the basic knowledge about the civil structure of hydropower station for Mondul Kiri Electrification Project

1. Components of civil structures for hydropower

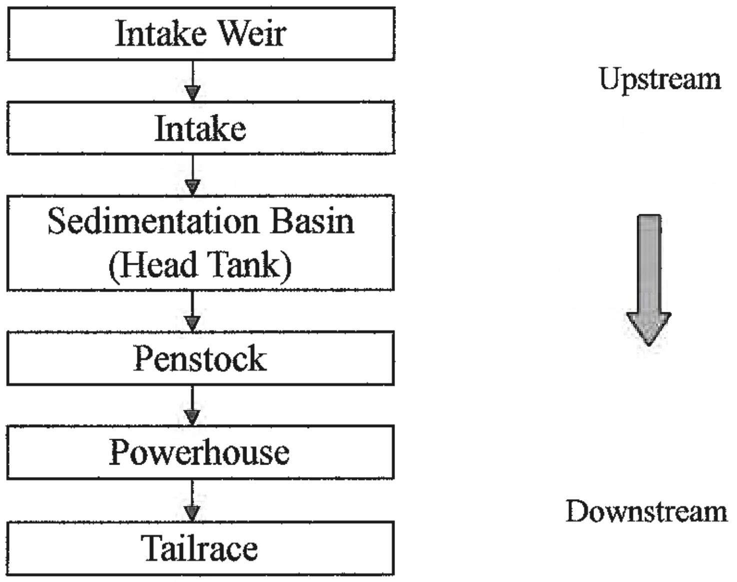
In most case of small hydropower station, when civil structures are arranged from the upstream by its function, it is consisted of intake weir, intake, sedimentation basin, waterway, head tank, penstock, powerhouse, tailrace and outlet (See the figure bellow). Some structures can be curtailed by economical design or another reasons.



2. Components of each hydropower station

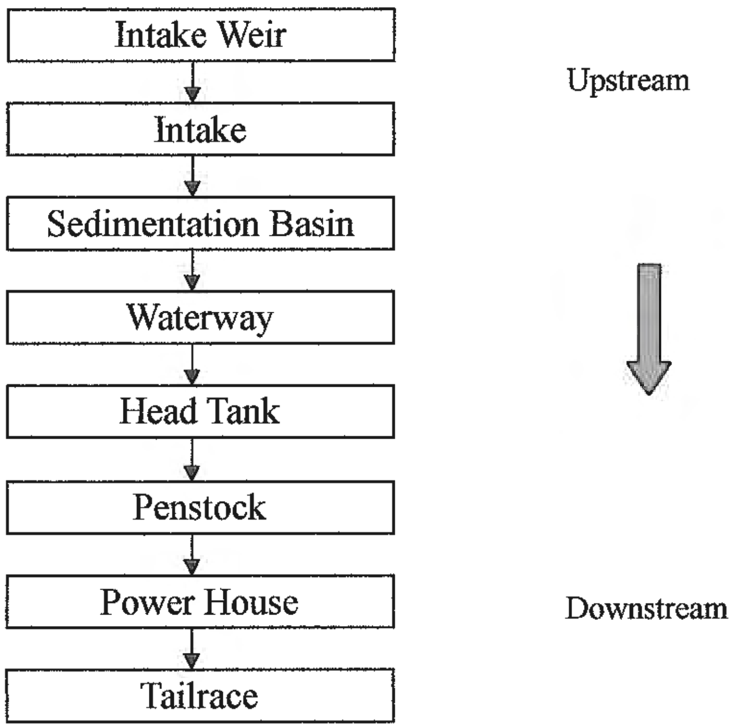
(1) O'Moleng Hydropower Station

O'Moleng Power Station consists of the following civil structures.



(2) O'Romis Hydropower Station

O'Romis Power Station consists of the following civil structures.



3. Function of each Structures

(1) Intake weir

Intake weirs are low dams that take the river water into the waterway efficiently. The height of the intake weir should be adequate so that the water depth in front of the intake will enable the intake to get the maximum plant discharge. That makes it easy to lead the river water to the intake.

Intake weir should be stable enough (or to have enough weight) against the water pressure during flood or the seismic movement of earthquake. Basically intake weir is built on the sound rock surface for dam safety (See the example photo of O'Romis Power station).

Intake weirs are classified into gated type and gravity type with no gate. In many cases, concrete gravity type with no gate like O'Moleng or O'Romis Power station is used. One of the merits of no gate type is that complex gate operation to control the discharging flow from the spillway is not needed during the flood.

Downstream aprons or other protection facilities are necessary to prevent the scouring just downstream of intake weir.

Sand flushing gate is an appurtenant facility to prevent sediments flowing into the waterway. If sediments come into intake, it decreases the capacity of waterway or causes the erosion of turbine. Sand flushing gate is located near the intake side of intake weir and is used to flush sediments in front of intake to downstream.

Example photo of intake weir basement (O'Moleng site)

Intake Weir of O'Moleng Power Station

Intake Weir of O'Romis Power Station

Explanation

- Width and length of the intake weir of O'Moleng site are 5.2m and 60m respectively.
- Width and length of the intake weir of O'Romis site are 4.3m and 41m respectively.
- If the flood comes, excess water is safely discharged to the downstream through the overflow section of the intake weir.
- Riprap is a river bed protection by putting crashed stone.

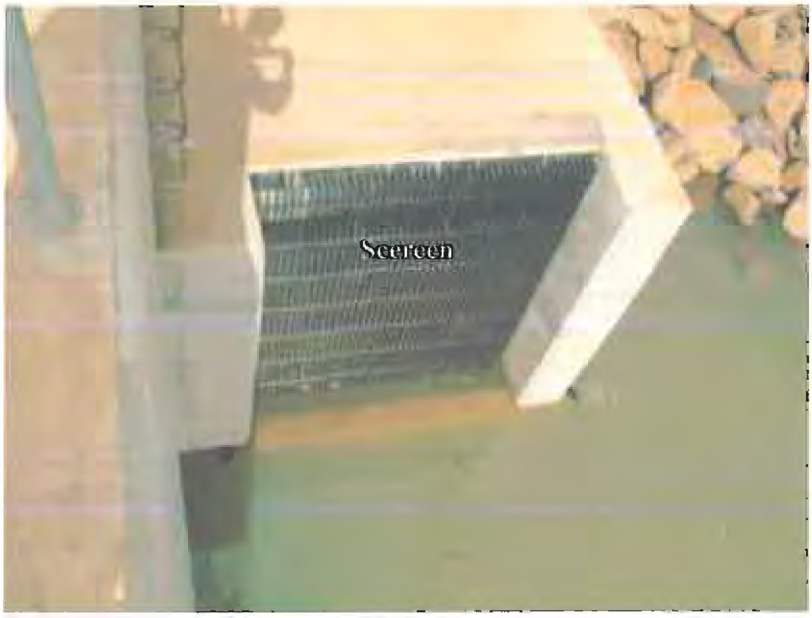
(2) Intake

An Intake is a structure to divert water from the river to the waterway. Intake has a gate to close the waterway for maintenance (inspection or repair).

Screens are installed on the front of the intake to prevent intrusion of driftwood and other debris. As debris remaining on the screen causes the decrease of output (the decrease of inflow water into waterway), debris should be removed from the screen timely. For the small intake like O'Moleng or O'Romis Power station, debris are often removed manually with a rake.

Generally an inflow velocity of the intake is designed approximately from 0.3m/s to 1.0m/s. For safety reason man or boat should be kept off from the intake or intake weir not to be drawn in.

Intake of O'Moleng Power Station



Intake of O'Moleg Power Station

Intake of O'Moleng Power Station

Status of debris on screen of O'Moleng Power Station

Explanation

- Intake and sand flash gate are installed together with intake weir structure.
- Intake has a screen to prevent the debris coming into the water way. If the screen is clogged with debris like the photo above, debris must be removed by hand with rake.
- Width and height of the intake mouth are 2.0m and 2.0m respectively both O'Moleng and O'Romis power station.

(3) Sedimentation Basin

River water contains a certain volume of suspended sediment. During flood, sediment concentration increases substantially. In run-of-river type hydropower station, suspended sediment deposits in the waterway and chokes its sectional area. It is also the cause of erosion of the penstock or turbine. To settle and flush this sediment, it is necessary to install a sedimentation basin close to the intake.

Sand drain should be installed to remove the deposited sand on the bottom of sedimentation basin.

Sedimentation basin of O'Moleng Power Station

Sedimentation basin of O'Romis Power Station

Explanation

- Width and length of sedimentation basin of O'Moleng Power station are 4.0m and 23.0m respectively.
- Width and length of sedimentation basin of O'Romis Power station are 3.0m and 20.2m respectively.
- Sedimentation basin at O'Moleng power station also has a function of head tank. Penstock is directly connected to sedimentation basin.
- If sediments accumulated to some extent, it should be removed through sand drain.

(4) Waterway

Waterway leads water from sedimentation basin to the head tank.

There are some types of waterway by its structure; those are open-channel, covered channel, culvert and tunnel etc.

O'Romis power station has covered channel type waterway.

Waterway of O'Romis Power Station

Inside of waterway of O'Romis Power Station

Explanation

- Width, height and length of the waterway are 1.0m, 1.4m and 1,015m respectively.
- O'Romis Power station has covered type waterway made by concrete.
- For structural safety, water depth in the waterway should be kept less than 80% of its height (that is approximately 1.1m).

(5) Head tank

The pondage installed between the end of headrace and the entrance of penstock is called head tank. Head tank regulates the difference between the penstock flow and the headrace flow due to load change. Screen is installed to remove debris.

The spillway outlet is designed so that the surplus water can be safely discharged when all loads are shut down.

The water depth should be kept deep enough to prevent air entrainment into the penstock by vortex.

Head tank of O'Romis Power Station

Head tank of O'Romis Power Station (No water)

Explanation

- Width, depth and length of the head tank are 1.0-4.0m, 1.6-5.0m and 20m respectively.

(6) Spillway

The spillway discharges the overflow water from the spillway outlet of the head tank into the river. Open-channel, covered channel, and pipe conduit (steel pipe, fiber reinforced plastic pipe, etc.) types are used.

Spillway of O'Romis Power Station

Explanation

- Width, height and length of spillway of O'Romis Power Station are 1.0m, 1.4m and 92m respectively.
- Spillway of O'Romis Power Station leads the excess water from head tank to small stream near head tank safely.

(7) Penstock

The pipe conduit between head tank and turbine is called penstock. Inside the penstock, water pressure is so high that strong material like steel is often used for penstock material.

Penstock of O'Moleng Power Station (Exposed section)

Penstock of O'Moleng Power Station (Buried section; under construction)

Penstock of O'Romis Power Station

Explanation

- Penstock of O'Moleng Power Station is buried type. Its diameter and total length of penstock are 700-1,200mm and 415m respectively.
- Penstock of O'Romis Power Station is exposed type. Its diameter and total length of penstock are 600-800mm and 63m respectively.
- Anchor blocks must be stable against loads, sliding of the foundation, shear strength of the foundation to fix penstock on the ground.
- Expansion joint is installed between the anchor blocks to absorb the shrinkage or expanse of the steel penstock.

(8) Powerhouse

Powerhouse is a building where the generating equipment or facilities are installed. Its main function is to protect generating equipment or facilities from rain or intruders etc.

Powerhouse of O'Moleng Power Station

Turbine generator of O'Moleng Power Station

Powerhouse of O'Romis Power Station

Turbine generator of O'Romis Power Station

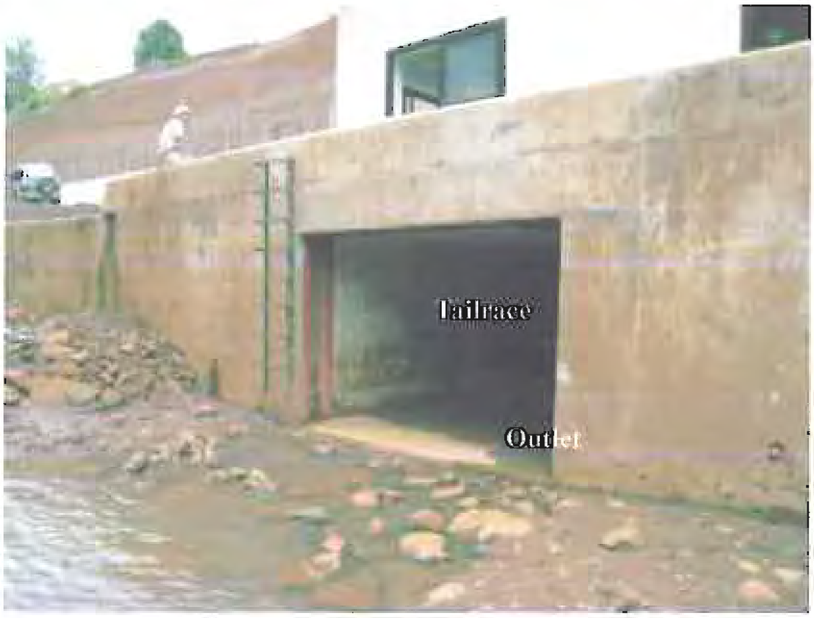
Explanation

- Floor area of each powerhouse building is 56m2.
- Output of each power station is 185kW.
- Building is necessary for protecting turbine generator from wind and rain or for security reasons.

(9) Tailrace

Tailrace is a channel to divert the water to the outlet. Tailrace is often built together with the outlet. Outlet is an exit of tailrace.

Tailrace of O'Moleng Power Station



Tailrace of O'Romis Power Station

Explanation

- Length of the tailrace of O'Moleng and O'Romis power station are 6.7m.
- Width and height of outlet of O'Moleng and O'Romis Power station are 3m and 2m respectively.

R-2-2 Key points of patrol regarding the civil facilities

Key Points of the patrol regarding the civil facilities

1. Access Path

Access path should be kept good condition because EUMP has to reach the powerhouse every time, every day. Checking points and its aim are as follows;

(1) Slope protection

Check the condition of the slope if there is some warning of landslide or not. Key points are to check if there are some clacks on the surface of the slope and some water coming out from the ground of the slope or not. If there are some clacks and rain water goes into the ground through the clacks, it may cause the safety of the slope lower. In worst case, landslide will occur. If the landslide occurs, the access path is filled with mad and soil and EUMP cannot reach the powerhouse by car.

If some clacks of that width are over 1cm as tentative standard are detected by the patrol, some countermeasures should be done. For example, put the crashed stone or spread the vinyl sheet to cover the clacks and to keep the rain off.

(2) Side ditch

Side ditch should be kept clean in order to drain away the rain water smoothly and safely. If there are some soil and mad in the ditch, it hinders the smooth drainage and the water spills out from the ditch. Spilled water may flow to the access path or other facilities and make some damage.

Check the condition of the side ditch periodically. And if mad, soil or falling leaves accumulated in the side ditch, remove them to ensure the function of the side ditch.

(3) Road surface

Road surface of the access path should be kept well maintained in order to enable pickup track running smoothly at any time. When the surface is dug by the traffic badly, it should be repaired by filling the additional crushing stone and make the surface of the road flat.

And the shoulder of the access path should be watched carefully if there is some warning of landslide or not. If there is, some countermeasure should be done ,for example, putting the sandbag.

(4) Weeding

Bushes along the access path of around the building should be cut in order to keep the sight well.

2. Intake Weir

Intake should be kept good condition in order to get water for generation safely and effectively at any time. Checking points and its aim are as follows;

(1) Intake screen

Garbage on the screen should be removed properly. Garbage on the screen hinders the intake to get water effectively. Garbage should be removed immediately when head difference between backside and forth side of the screen can be seen.

(2) Sedimentation

Sedimentation in the reservoir will be increasing with time. Sedimentation gives some influence on the turbine, so influx of sedimentation through the intake should be avoided. Periodically, for example, one time per month, depth of the sedimentation in front of the intake should be measured.

If there can be seen a risk that sedimentation in front of the intake comes into the intake, sedimentation should be removed through the sand flushing gate.

The work of removing the sedimentation should be done during the flood in order to remove the sedimentation effectively.

(3) Gate

Intake gate and sand flushing gate should be maintained well in order that EUMP can operate the gate surely at every time. It is necessary to put the grease oil on the gear periodically for keeping good condition.

(4) Locking

Handle of intake gate and sand flushing gate or gate of the fence etc should be surely locked in order to keep outsiders off or avoid the mischief by outsiders

(5) Concrete structure

Concrete structure like intake weir is as it were semi-permanent facilities if it is well maintained. If some warning of trouble can be seen, some examination should be done with the results and, if necessary, proper repairing work should be planned and done.

It should be checked if there are any water leakage from the joint or body, if there are remarkable cracks on the body or if some deformation can be seen, or not.

3. Sedimentation Basin

Sedimentation basin should be kept good condition in order to remove the sand in the discharged water from the intake and to spill the excess water out to the river safely.

(1) Screen

Same as the description of the intake screen of the intake weir.

(2) Sedimentation

Sedimentation of the sedimentation basin should be removed through the sand flushing gate periodically. If the sedimentation comes into the waterway (or penstock) and reaches to the turbine, it may cause the wear of the vane.

(3) Concrete structure

Same as the description of concrete structure of intake weir

4. Water way (O'Romis Hydropower Station)

Water way should be kept good condition in order to convey the water for generation from the sedimentation basin to the head tank surely and safely.

(1) Concrete structure

It should be checked that there are some water leakage from the waterway or not. If the amount of water leaking from the water way is remarkable, it is necessary to stop the operation and to inspect the inside condition of the water way, for example, if there are some clacks or some deformation etc.

5. Head tank (O'Romis Hydropower Station)

Head tank should be kept good condition in order to take water for generation stably and safely.

(1) Screen

Same as the description of the intake screen of the intake weir.

(2) Sedimentation

Same as the description of the sedimentation of sedimentation basin.

(3)Concrete structure

Same as the description of concrete structure of intake weir

6. Spill way (O'Romis Hydropower Station)

Spill way should be kept good condition in order to spill out the excess water from the head tank to the river surely and safely.

(1) Concrete structure

Same as the description of concrete structure of intake weir

(2) Obstacles

Obstacles in front of the exit of spill way should be removed.

7. Penstock

Penstock should be kept good condition to convey the water from the head tank (or sedimentation basin) to powerhouse surely.

(1) Vibration

Abnormal vibration and noise may be the warning of some serious troubles. If those are can be seen, inspection of whole penstock should be conducted.

(2) Bolt

Bolts should be kept fixed to prevent the abnormal vibration etc. If it can be loosen, fixed it surely.

8. Powerhouse

Powerhouse should be kept good condition in order to protect the turbine generator, control panel or any other electric devices from the rain or outsiders.

(1) Concrete structure

Same as the description of concrete structure of intake weir

(2) Building

Leaking water from the roof or breakage of the window, door or wall should be repaired rapidly.

9. Outlet

Outlet should be kept good condition in order to discharge the water after generation smoothly and safely to the river.

(1) Sedimentation etc

It should be checked that there are some obstacles like drifted wood, sand or mad etc that block the smooth discharge from the outlet. Something in front of the outlet that may block should be removed.

Reference 3 : Electromechanical Facilities

R-3-1 O&M Management

Operation and Maintenance Management for Mondul Kiri Electric Power Facilities

November 2009

Advisors by : Joint venture
J-Power (Electric Power Development Co., Ltd.) and
Chugoku Electric Power Co. Ltd., Japan

1

2

Operation and Maintenance Management for Mondul Kiri Power Station

Introduction:

- In the operation and safety control of a hydroelectric power station, it is necessary to predetermine basic safety items related to operation and maintenance management (O&M).
- Then, it is necessary to establish on the basis of these basic items, the operation procedure rule and patrol, inspection and measurement criteria by which the O&M must be carried out by the all staff, EUMP.

3

1. Operation of Small-scale Hydropower Station, Mondul Kiri (1)

- Operation should be carried out in accordance with the operation procedure, manuals, operation sequence and drawings at ordinary times, but taking measure at abnormal conditions at power station (P.S).
- The following items must be observed at ordinary times in order to take proper measures quickly and reliably after the occurrence of an accident:

1)To clearly know the power system inside and outside the P.S,

4

1. Operation of Small-scale Hydropower Station, Mondul Kiri (2)

2) To clearly know the power system inside and outside of P.S,

3) To have the full knowledge of provisions for operation rules,

4) To have the full knowledge of the performance and characteristics of equipment,

5) To have the full knowledge of control, protection circuits, piping system and auxiliary equipment,

6) To make study by using reference books at ordinary times.

5

1. Operation of Small-scale Hydropower Station, Mondul Kiri (3)

- Main precautionary items in daily operation are listed below:

1) To observe the situation of trash at intake screen,

2) To observe temperatures at bearing, winding and elsewhere,

3) To observe vibration, abnormal sound and smell at rotating machines,

4) To check load conditions such as voltage (V), current (A), output (kW), and power factor (%), etc. of generator during operation,

6

1. Operation of Small-scale Hydropower Station, Mondul Kiri (4)

5) To observe the conditions of inside and outside equipment such as step-up transformers, distribution transformers, transmission / distribution lines and substation switchgears.

- In addition, to the above, low load operation should be avoided causes low efficiency and prevention of vibration as much as possible.

7

2. O&M for Civil Facilities, Mondul Kiri (1)

- For assuring the stable operation of hydropower station, the civil facilities must be properly maintained to prevent accidents.
- To maintain the functions, the civil facilities should be periodically patrolled, inspected and measured, then the results be recorded.
- It is also important to arrange the procedures for taking emergency measures in case of emergency event.
- An operation and maintenance standards should be in accordance with O&M manuals.

8

2. O&M for Civil Facilities, Mondul Kiri (2)

- Main inspection and patrol items for civil facilities are:

1) Weir and Dam

(1) Situation of deterioration due to aging, cracks and settlement of concrete structures,

(2) Situation of damage to the top or rear surface due to debris-flow, and of scouring at revetment and apron,

(3) Situation of fluctuation in guts upstream and downstream of weir,

(4) Water leakage at the abutments and at the toe of dam,

9

2. O&M for Civil Facilities, Mondul Kiri (3)

(5) Sedimentation condition in reservoir or regulating dam.

2) Intake

(1) Situation of deterioration due to aging, cracks and settlement of concrete structures,

(2) Situation of the function of screen, control gates, etc.,

(3) Situation of sedimentation in front of the intake, and the securing in the foundation of structures,

(4) Presence of damages to screen, gates, etc, due to flood.

11

2. O&M for Civil Facilities, Mondul Kiri (4)

3) Sedimentation

(1) Situation of sand deposit, cracks, settlement, erosion and leakage of structures,

(2) Situation of settling capacity, affection and sand removing functions

4) Waterway (headrace)

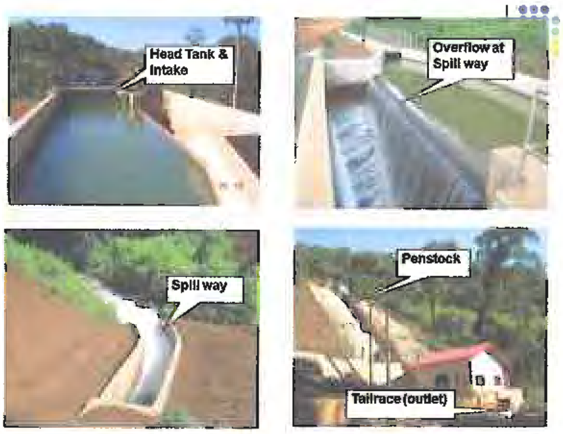
(1) Situation of leakage from concrete cracks and joints,

(2) Presence of landslide, depression and land failure in the surrounding,

(3) Situation of slope

(4) Presence of obstacles such as muck.

12



2. O&M for Civil Facilities, Mondul Kiri (4)

5) Head Tank

(1) Situation of leakage from concrete cracks and joints of structures,
(2) Presence of sedimentation in the head tank,
(3) Situation of trash.

6) Gate

(1) Situation of gates body and gates sheet,
(2) Function of gate open/close,
(3) Situation of leakage from the watertight portions,
(4) painting conditions.

14

2. O&M for Civil Facilities, Mondul Kiri (5)

7) Penstock

(1) Situation of abrasion and paint condition,
(2) Situation of vibration and noises and expansion joints around penstock,
(3) Situation of water leakage,
(4) Situation of cracks and settlement of the anchor block and saddles on the penstock.

8) Spillway and Tailrace (Out let)

(1) Situation of cracks, settlement, erosion of structures,
(2) Situation of securing and sedimentation,

15

2. O&M for Civil Facilities, Mondul Kiri (6)

(3) Situation of slope protection works such as masonry and protection fences, etc.
(4) Situation of flow condition into the main stream.

9) Foundation of the Power Station

(1) Situation of leakage and vibration around main equipment with auxiliary and inlet valve, etc.,
(2) Presence of danger such as rock fall, spring water, landslides and concrete cracks in near by nature ground.

16

2. Maintenance of Generating Facilities, Mondul Kiri (1)

1) Water Turbine

(1) Daily inspection: Generally precautions should be taken for abnormal sound, offensive, odors (smell) and vibration, the following items should be inspected.
- a) Guide vane (G.V) operation with clogging
- b) Leakage around G.V stem and joints
- c) Oil level and grease condition
- d) Temperatures
- e) Abnormal sound, vibration and smell, etc.
- f) Control panel and wirings

17

2. Maintenance of Generating Facilities, Mondul Kiri (2)

2) Inlet Valve (I.V)

(1) Butterfly valve

Daily inspection: Generally precautions should be taken for abnormal conditions.

a) Lubrication to bearing

b) Leakage around I.V and joints

c) Opening/closing operation conditions with limit switches

d) Abnormal sound and vibration

19

2. Maintenance of Generating Facilities, Mondul Kiri (3)

3) Dummy Load Governor (GOV.)

(1) Dummy load

a) Abnormal sound and vibration

b) Earthling of wirings or resistances

c) Presence of water flow inside of pit

(2) GOV. control panel

a) Checking of NFB, wirings and relays

b) Chattering of magnetic relay (on/off switch) for dummy load

c) Comparison of generating output (kW) and sending output (kW) by dummy load

20

2. Maintenance of Generating Facilities, Mondul Kiri (4)

4) Generator

(1) Purpose of daily patrol and inspection is to determine overall conditions of the equipment at ordinary times as follows.

a) Any deviation of voltage, frequency, power factor (lagging) of generator compared to rated values by meters on the panel

b) Vibration, sound, temperatures rise, abnormal smell, etc.

21

2. Maintenance of Generating Facilities, Mondul Kiri (5)

5) Control panel

(1) Mounted parts such as circuit breaker (MCCB), relays, meters and switches outside and inside of the panel should be inspected about operation conditions everyday.

a) Visual inspection for vibration, sound, smell and temperature rise, etc.

b) Indication status (lamps) on the panel

c) Mounted condition of MCCB on the panel

6) Diesel generator for Supplementary Power Source (300kW) of the Power System

23

R-3-2 Technical Term

Technical Terms of Electrical Engineering
Mondul Kiri Electrification Project,

October 2008

Advisors by : Joint venture
J-Power (Electric Power Development Co., Ltd.) and
Chugoku Electric Power Co. Ltd., Japan

1. Electrical Power System

1. Load dispatching
Generation plan of daily, weekly, monthly and yearly based on The consumers and the water inflow

2. Load dispatching guides
Guidance for the role and Regulation of plants and transmission lines operation

3. Switching operational guides
Guidance for operation method Of power plants and transmission lines

4. Gross out put
Generated out put at generator terminal

5. Net out put :
Sending out put excepting Station service load

6. Load at receiving end
End terminal load excepting transmission losses

7. System capacity
Total out put (kW) of generation terminal in the power system

8. Daily load curve
Consuming daily load per hour

9. Peak load
Maximum load at daily, monthly and yearly in the power system

10. Off peak load
Load excepting peak time

11. Night load
Minimum load at night time

1. Electrical Power System

12. Natural inflow
Inflow of dependable out put

13. Wet season
water flow abundant in the river

14. Dry season
A shortage of water in the year

15. Service reliability
Degree of supply the power
(220V & 50Hz) to the Consumers

16. Electrical power supply capability
Available generation out put

17. Marginal supply capability
Surpluses of generation out put

18. Cold reserve
Standby plant (e.g. : diesel generator unit)

19. Hot reserve
Partial load operation unit

20. Spinning reserve
Governor free operation
(dummy load of hydropower plants)

21. Available out put
Generated power depending on the inflow

22. Average available hydropower
Average of available generated power for a month

1. Electrical Power System

23. Duration curve of available hydropower
Curve of dependable Power (kW)-days with inflow

24. River inflow duration curve
Curve of inflow- days for a year

25. Flow rate based on capacity
% = Average available out put
(kW) **/** Installed capacity (kW)

26. Transmission loss energy
Losses of electrical facilities

27. Station service losses
Load of auxiliary equipment
and lighting, etc.

28. Spilled power
Spilled water corresponding to
generated power during
stoppage by inspection or plant

29. Capacity factor
% = Average of out put (kW) **/** installed capacity (kW)

2. Demand and Supply

30. Average power
= Total generated energy (kWh) **/** total operation hours

31. Maximum power
Max. generated out put for a period

32. Average of maximum power
= Total max. power (kW) **/** total operation days

33. Load factor
= Average of total power (kW) / total max. power (kW)

34. Periodic inspection/Overhaul
Scheduled inspection or repairing for power plants in monthly and yearly

35. Ordinary inspection
Maintenance inspection for daily, weekly and monthly

36. Unscheduled outage
Un-expected outage due to plant failure or repairing in emergency, etc.

37. Annual energy production
Total generated energy per year (kWh)

38. System operation
Operation of power system with stable and economical supply to the consumers

39. Load forecast
Plan of demand & supply curve in forecasting of weekly , monthly and yearly

3. System Operation

40. Load dispatching
Reasonable operation of the power stations with stable and economical supply to the power system

41. Nominal power frequency
Frequency to be maintained of the power system = 49.5- 50Hz- 50.5

42. Operating standard voltage
Voltage to be maintained of the power system
= 360- 400V- 424 and/or
= 207- 220V- 244

43. Low power factor operation (var operation)
Operation of lagging power factor (less 0.8lag) due to rise up system voltage with over exciting of AVR

44. Lead power factor operation (lead operation)
Operation of leading power factor (over 1.0 lead) due to go down system voltage with under exciting of AVR

45. Power flow control
Active and reactive powers flow with voltage adjustment in the power system

46. Phase difference
There is a phase difference between voltage and current in the every points

3. System Operation

47. Impedance map
The map of power system consist of generators, transformers, transmission lines, etc. as shown on impedance values (p.u)

48. Radial system
Power system is consisted with radial connection

49. Loop system
Power system is consisted with loop connection

50. Load shedding
The limiting load supply to the Consumers due to the lack of supply power or failure

51. Power swing or hunting
Swinging the power due to unbalance of input-output in the synchronous generator

52. Step out
Synchronous generator can not Parallel running from the power system due to disturbance of load

53. Synchronism detection
Comparison with frequency and voltage both power system

54. Parallel operation
Synchronous generator is connected with the power system under the frequency and voltage

55. Parallel-off
Synchronous generator is not connected with the power system

56. Isolated operation
Generator is operating in solo in the separated network due to inspection or system failure

3. System Operation

57. Phase fault (short circuit)
To short the 2 points in circuit in abnormal

58. Ground fault
To ground the point in circuit in abnormal

59. Faulty phase
Phase of the fault in circuit in abnormal

60. Sound phase
The phases excepting fault in Circuit in abnormal

61. System separation
To disconnect the part of network in parallel operation

62. Shot circuit capacity
Fault capacity (kVA) = $\sqrt{3}$ V x I

63. Protective Relay setting
System coordination of relays (tap and lever) for operation

64. Potential instrument
(Current transformer and Voltage transformer)

65. Technical losses
Consist of losses of transmission, Transformer, distribution and station service losses

66. Commercial losses
Un-technical losses such as malfunction meter, no payable consumer, stealing electricity (no meter) and public use, etc.

3. System Operation

67. Supply terminal or Metering point
Energy supply or receiving points at wh-meter

68. Billing of electric charge
Accounting of electric charge between customers and supplier

69. Rules and rates for electric service
Regulation of energy supply and Tariff to the customers

70. Black start
Self starting of the generator into the power system due to the black out of whole system

4. Hydropower Plant

71. Installed capacity or Authorized out put (kW)
Maximum out put = 200kW
Rated out put = 185kW
Minimum out put = 60kW

72. Available out put
Generation power to depend on the inflow

73. Run-of-river power station
No reservoir or pond for water storage, only run off river water

74. Poundage type power station
Poundage for water storage

75. Reservoir type power station
Reservoir for water storage

76. Energy conversion factor of discharge
Generated power per discharge (1m3/s)

77. West discharge
Spilled water corresponding to generated power during stoppage by inspection or Plant failure

78. Gate control (or spillway gate)
Balance of inflow control for generation and head tank level

79. Governor free operation
Frequency (load) control by governor continuously

80. Load limiting operation
Operation of constant out put (kW) without governor free

81. Constant voltage operation (AVR operation)
To keep the constant voltage at generator terminal

4. Hydropower Plant

82. Constant power factor operation (APFR operation)
To keep the constant power factor of generator

83. Fixed excitation operation
To keep the constant field Current of exciter

84. Minimum load operation
Allowable min. out put (kW) for Hydro turbine

85. Rated effective head (m)
Useful water for generation = Rated water level – turbine center – penstock losses

86. Rated discharge (m3/s)
Using water for generation at rated out put

87. Rated out put (kW)
Generation at rated discharge and rated head

88. Turbine/generator efficiency
Ratio = output/input (%)

89. Power factor (cos θ)
Ratio = active power (kW) **/** apparent power (kVA)

90.Active power (kW)
= apparent power x power factor (cos **θ**) at alternative current(AC)

91. Reactive power (kVar)
= apparent power (kVA) x sin **θ**

92. Transformer tap
To change the transformer voltage by tap ratio (±2.5%)

5. International Standards

1) JIS: Japanese Industrial Standard
2) JEC: Japanese Electro technical Commission
3) JEAC: Japan Electric Association
4) JEM: The Japan Electrical Manufactures' Association
5) JCS: Japanese Cable Standard
6) ISO: International Standard Organization
7) IEC: International Electro technical Commission
8) IEEE: Institute of Electrical and Electronics Engineers
9)NEMA: National Electrical Manufactures Association
10) ANSI: American National Standards Institute
11)ASTM: American Society for testing and Materials

12. International Standards

12)AWS: American Welding Society

13)ASME: American Society of Mechanical Engineers

14)ASA: American Standard Association

15)EN: European Standard

16) DIN: Deutsches Institute Fur Normung

17)VDE: Verbard Deutscher Elektrotechniker

18)BS: British Standard

19)NF: Norme Francaise

20)API: American Petroleum Institute

R-3-3 Technique of Trouble Shooting

Technique of Trouble Shooting for Mondul Kiri Electrification Project

July 2008

Consultants by : Joint venture
J-Power (Electric Power Development Co., Ltd.) and
Nippon Koei Co., Ltd., Japan

1

Project Summary

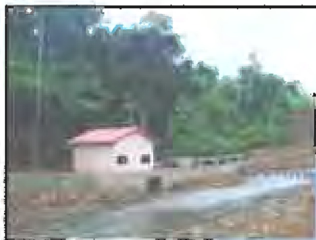
- 1) Hydropower Plant :
- Turbine Type: Cross-flow (Tanaka Suiryoku)
- Turbine out put : O'Moleng 185kW
- O'Romis 185kW
- Generator Type : Synchronous 3-phases generator (Yawata Electric)
- Generator out put : 250kVA, 1,000rpm

2

Project Summary

- 2) Diesel Generating Plant :
- Diesel Engine Type: 6DL-16 4cycle (Daihatsu)
- Diesel out put : 322kW, 1,000 rpm
- Generator Type : Synchronous 3-phases generator (Taiyo Electric)
- Generator out put : 375kVA, 1,000rpm
- 3) Transmission Line
- 22kV Transmission lines : 28km
- 400V Distribution lines : 33km

3



O'Moleng P.S

O'Romis P.S

O'Romis Turbine (above)

O'Moleng Turbine (left)

5

Shop test (Guide vanes)

Inlet valve

1. Five (5) Senses

- Recently, it can be easy operation for the plants or machines with the push bottoms or automatic controller without recourse to the five senses and skilled control.
- However, in case of the short time stoppage of the plants and machines, there would be big losses and decrease the reliability to the customers.

10

1. Five (5) Senses

- Under these circumstance, the maintenance staff or operators are required to prevent the troubles which would be found at a initial fail on the machines.
- In order to find the initial troubles, we can check the data by the daily and periodical inspections and/ or information from the operators.

11

1. Five (5) Senses

- However, recently, they are luck of scent due to their work experience by automatic control system or maintenance free equipment.
- This means that it is not necessary skilled operators, but necessary skilled maintenance staff.

12

1. Five (5) Senses

- The diagnosis technique is recently advanced by the computer system, but human five senses can judge it more easy, speedy and flexible.
- The five senses of eye, ear, hand and nose are corresponding to the sound, vibration, smell, color and temperature, etc.
- This sense is a universal method for the diagnostic prevention.

13

1. Five (5) Senses

- Five Senses Technique

The diagnosis is possible by two steps as "Finding" and "Judging".

➢Procedures
➢Skilled & Senses
(check sheets)

➢Criteria & Standards
➢Statistical Data
(inspection records)

14

2. Sounds and Vibrations

We can find the sound and vibration by the five sense as below:

- Hearing the sounds directly
- Hearing the sound by acoustic instrument such as driver and wood, etc.
- Hearing the sound by inspection hummer
- Touching by hand

15

2. Sounds and Vibrations

1)Sound and vibration from motors

- Insufficient alignment of base, foundation or coupling connection
- Defective bearings
- Vibration of load unbalance

2)Abnormal sound or vibration of transformers

3)Abnormal sound or vibration of instrument panels such as relays, magnetic coil and switches, etc.

16

2. Sounds and Vibrations

4) Trouble Shooting (for example)

- During patrol, there was a abnormal sound from motors, then he checked the motor bearing temperatures by hand, but its bearing was very heated.
- There was a vibration at wiring Amp-terminal due to looseness of bolts & nuts, then Amp-terminal was melted and wiring cut out.

17

3. Temperature

1) Allowable temperature rises (rotating motor coils)

Maximum temperature rises is different in applied insulating materials as Y to C class insulation(JEC-2130/146).

Insulated class	Y	A	E	B	F	H	C
Allowable temp. max. (℃)	90	105	120	130	155	180	180>

18

3. Temperature

2)Temperature rises (rotating bearings)

- Limit of temperature rise for bearings is 40 ℃, then the surface temperature of bearings must be within 80 ℃. in room temperature (approx. 40 ℃).
  So, checking luck of grease, lubrication oil, cooling water or miss-alignment, etc.
- Temperature of exhaust is also important to check the abnormal conditions due to dust choke the filters, overload, less cooling water, rust and dirt inside pipes, etc.

19

3. Temperature

3)Temperature rises in the control panel

Limit of temperature in the control panels is within +40 ℃ to - 5 ℃.
So, checking the inside temperature with thermometer and confirm cooling fans operating.

- Smell in melting or burning
  Carefully check the atmosphere in side of motor or panels when you come into the powerhouse.
  In rare case, coils, parts or wirings may change the color before burning it.

20

3. Temperature

4) Transformer temperature rise (at 40 ℃ in air)

(1) For oil immersed type transformer

Cooling type	Coil (self cooled)	Oil (self cooled)	Coil (forced cooled)	Oil (forced cooled)
Allowable temp. rise(℃)	55	60	50	55

(2) For dry type transformer

Insulated class	A	E	B	F	H
Allowable temp. rise (℃)	55	70	75	95	120

21

3. Temperature

5) Management values of Temperatures
To check and compare as recommended.

(JEAC 5503 at 40 (℃) in air)

Name of parts/ equipment	Measured parts	Max. allowable temp. (℃)
Disconnecting switch, Power fuse	Contactor Terminal Body	65 75 90
Circuit breaker	Terminal Body	75 110
Instrument transformers	Terminal Body	75 90
Oil immersed transformer	Terminal Body (oil)	75 90

22

3. Temperature

5) Management values of Temperatures
To check and compare as recommended.

Name of parts/ equipment	Measured parts	Max. allowable temp. (℃)
Dry type transformer	Terminal Body	75 As insulated class
Condenser	Terminal Body	75 70
Bus-bar and connector	H H,PH HAL TAL	75 90 90 150
Low voltage cubicle	Contactor Terminal	65 75

23

3. Temperature

6) Trouble Shooting (for example)

- Increasing temperature
  The parts are always heating and saturated within the rated design values by the current, but unusually, its temperature may increase in abnormal condition over the rated value, then the parts will be damaged and melted it.
  Therefore, operators are necessary to check the temperatures by hand, alcohol-thermometers or dial thermometers.

24

4. Leakage

Oil leakage of Transformers

Transformer oil may leak from tank and bushings little by little.

- Then you can check the oil level by indicator.
- Cleaning of insulators and tank

25

5. Cables

- **XLPE power cable (22kV and 400V)**

  Power cables are laid under ground or duct condition, but in rare case, the termination parts at outdoor may be damaged due to insulated trouble and penetration of water.

  Then you can check the cable termination as a heating it or not with color thermo labels and a vibration by looseness of support.

26

6. Contactors

- **Contactors of Relays and Breakers**

  Magnetic contactors are breaking the current on the relays and breakers during on-off operations, then contactors are easily dirty.

  Then you can check the contactors and clean up by sand paper or cleaner.

27

7. Spare Parts

- The spare parts must be managed by the spare parts list.
- For example:

To paste the label in the panel/equipment when you have replaced its spare part.

Date of Replacement	Spare Parts Number
2008. 11.22	H-001 Contactor
By Hiraga	Burning

28

7. Spare Parts

- **Management of Spare Parts List**

  To stick the list on the parts/equipment

Name of parts (Parts No.)	Contactors (H-001)	Date of management
Numbers of part (original)	6	2008.11.22
Consuming	1	2009.11.22
Remaining	5	By Hiraga

29

8. Megger

1) Insulation Resistance Tester (Megger)

To check the insulation resistance for parts/equipment circuit by Megger for one(1) minute (JIS C 1302)

Measuring tester	Measuring range	Applied equipment
500V 100MΩ	0.1~ 100MΩ	Low voltage circuit for general parts (less 300V)
1,000V 1,000MΩ	2~ 1,000MΩ	High voltage circuit for cable, bushing, insulator and equipment
2,000V 5,000MΩ	2~ 5,000MΩ	-Ditto-

30

8. Megger

2) Insulation Resistance Test by Megger

The min. insulated resistance must be more than

R(MΩ) = rated volt (kV)/rated output (kVA) + 1,000

(The parts of temp. must be measured during megger.)

Volt (kV) \ Temp.	20 (℃)	30 (℃)	40 (℃)	50 (℃)	60 (℃)
Over 66	1,200	600	300	150	75
22~44	1,000	500	250	125	65
6.6~19	800	400	200	100	50
Less 6.6	400	200	100	50	25

31

8. Megger

3) Polarization Index (P.I) Test by Megger

In case of equipment in large charging capacity circuit such as power cables can judge the insulated resistance by P.I test.(JEAC-5001)

P.I = Insulated resist. R10/ Insulated resist. R1

R10: after 10minute charging value,
R1: after 1 minute charging value

(The parts of temp. must be measured during megger.)

P.I	Insulated capability
3~4	Very good
1.5~3	Good
Less 1.5	Minimum

32

9. Resistance

1) Conversion of Measured Resistance

When measured resistance (R) must be converted corresponding to 20 (℃) in the following formula;

R20 (Ω)= (234.5 + 20/234.5 +t1) x Rt1

R20: corresponding to resistance at 20 (Ω)
Rt1: measured resistance at t1 (Ω)
t1: coil temperature to be measured (℃)

(The parts of temp. must be measured during test.)

33

10. Protection Relays

When protection relays operate, the operators must check the reasons why and how to take care the countermeasure it, immediately.

1) Emergency Trip Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Over current (51) Inst.: 10A Inv.: 4.5A and Over current ground (51G) Setting: 3.0A	Over current in generator circuit 1.Overload 2.Grounding of T/L 3.Short circuit of T/L 4.Grounding Gen.	1.Confirm the lamp & 51 relay operate and gen. stop 2.Check firing or not 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.

34

10. Protection Relays

2) Emergency Trip Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Under voltage (27) Setting: 90V, 2 sec.	Under voltage in generator voltage 1.Overload 2.Under excitation	1.Confirm the lamp & 27 relay operate and gen. stop 2.Check generator 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.

35

10. Protection Relays

3) Emergency Trip Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Over voltage (59) Setting: 120V, 2 sec.	Over voltage in generator voltage 1.Over voltage of power system 2.Grounding Gen. 3.Over excitation	1.Confirm the lamp & 27 relay operate and gen. stop 2.Check generator 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.
Reverse power (67P) Setting:10%, 5 sec.	Motoring of Gen. 1.Rever power	1.Confirm the lamp & 67P relay operate and gen. stop 2. ~ 5. same as above.

36

10. Protection Relays

4) Emergency Trip Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Incomplete sequence (48) Setting: 3 min.	Time delay for Gen. starting. 1.Incompleted sequence circuit 2.Starting relay (4) 3.Limit switches 4.Auxiliary relays	1.Confirm the lamp & 48 relay operate and gen. stop 2.Check preparation circuit 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.
Emergency trip (5E) Hand bottom	Emergency trip for Gen. 1.Firing 2.Leakage of water from penstock & flood 3.Mechanical trouble	1.To push the bottom 5E, And confirm the lamp & 5E Relay, then stop the Gen. 2. ~ 5. same as above.

37

10. Protection Relays

5) Emergency Trip Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Over speed (12) Setting: 150%	Over speed for Gen. 1.Trouble of speed detector 2.Relay miss setting 4.Auxiliary relays	1.Confirm the lamp & 12 relay operate and gen. stop 2.Check to speed detector 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.
Water pressure low 2nd. (63W2) Setting:	Penstock Pressure down in 2nd. Stage 1.Infow decrease 2.Leakage of water from penstock 3.Pressure switch	1.Confirm the lamp & 63W2 relay operate and gen. stop 2.Check to pressure switch 3. ~ 5. same as above.

38

10. Protection Relays

6) Emergency Trip Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
CB Trip (52-1T) And CB Trip (52-2T) Setting: Inst.	Emergency trip relays . 1.Fault of electric circuit 2.Grid voltage down (52-1 trip) 3.Contro source down (52-2 trip) 4.CB operation	1.Confirm the lamp & relays operate and gen. stop 2.Check to electric circuit 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.
Guide Vane trouble (74TF)	GV over torque 1.Potentio meter trouble 2.Open and close 3.Limit switches	1.Confirm the lamp & 74TF relay operate and gen. stop 2.Check to servo motor of GV 3. ~ 5. same as above.

39

10. Protection Relays

7) Emergency Trip Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Servo mechanism trouble (SALM)	Servo mechanism trouble 1.Limit switches trouble 2.Servi motor pressure down 3.Auxiliary relays	1.Confirm the lamp & relays operate and gen. stop 2.Check to limit SWs, relays 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.
Exciter source trouble (MCCB4)	Exciter power source down 1.AVR source trouble 2.Ex. Transformer trouble	1.Confirm the lamp & relay operate and gen. stop 2.Check to MCCB 4 and circuit 3. ~ 5. same as above.

40

10. Protection Relays

8) Alarm Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Water pressure low 1st (63W1) Setting:	Penstock Pressure down in 1st Stage 1.Infow decrease 2.Leakage of water from penstock 3.Pressure switch trouble	1.Confirm the lamp & 63W1 Relays operate 2.Check to pressure relay 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.
Magnetic Coil Circuit Breaker failure (MCCB1, 1A and 3)	Exciter power source down 1.AVR source trouble 2.Ex. Transformer source 3.Servo motor source	1.Confirm the lamp & relay operate 2.Check to MCCB and circuit 3. ~ 5. same as above.

41

10. Protection Relays

9) Alarm Relays

Relay Name (No.)	Operation & Reasons	Trouble Shooting
Temperature High (38SD) Setting: over 80(℃)	Speed changer high temp. oil 1.Oil temperature meter trouble 2.Leakage of oil 3.Pressure switch trouble	1.Confirm the lamp & 38SD Relays operate 2.Check to oil temperature 3.Try reset bottom ON 4.If, reset OK, to start GEN. again after confirmation 5.If remain the fault lamp, to take care the countermeasure.
Magnetic Coil Circuit Breaker failure (MCCB2 and CPFAN)	Power source down 1.Station service source trouble 2.Control panel fan source trouble	1.Confirm the lamp & relay operate 2.Check to MCCB and circuit 3. ~ 5. same as above.

42

11. Battery

1) Gravity of Electrolyte Acid

Conversion of gravity is calculated the following formula;

$$G20 = Gt + 0.0007 (t - 20)$$

G20: Gravity of standard temp. at 20℃

Gt : Gravity of measuring value at t (℃)

t : Measuring temp. of Electrolyte acid

43

12. International Standards

1) JIS: Japanese Industrial Standard
2) JEC: Japanese Electrotechnical Commission
3) JEAC: Japan Electric Association
4) JEM: The Japan Electrical Manufactures' Association
5) JCS: Japanese Cable Standard
6) ISO: International Standard Organization
7) IEC: International Electrotechnical Commission
8) IEEE: Institute of Electrical and Electronics Engineers
9)NEMA: National Electrical Manufactures Association

44

12. International Standards

10) ANSI: American National Standards Institute
11)ASTM: American Society for testing and Materials
12)AWS: American Welding Society
13)ASME: American Society of Mechanical Engineers
14)ASA: American Standard Association
15)EN: European Standard
16) DIN: Deutsches Institute Fur Normung
17)VDE: Verbard Deutscher Elektrotechniker
18)BS: British Standard
19)NF: Norme Francaise
20)API: American Petroleum Institute

45

Contents

Volume III Reference data

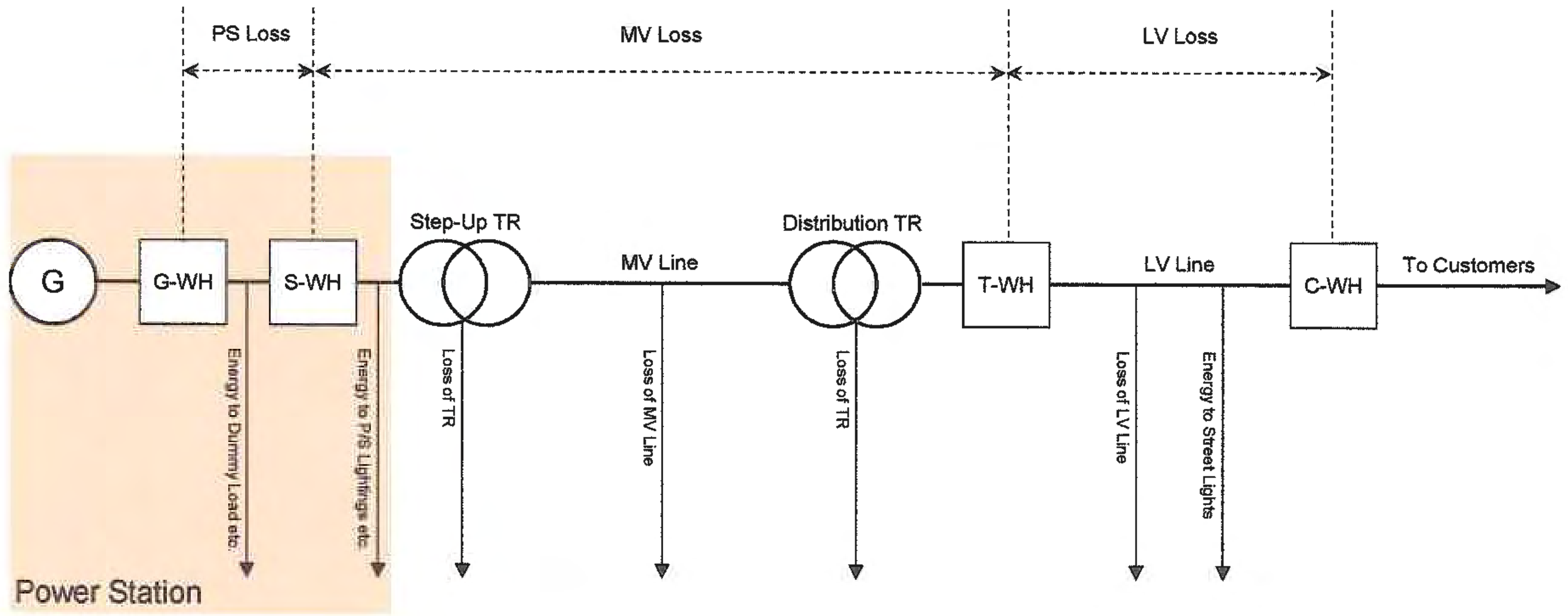
Documents for T&D

Reference 4: Transmission and Distribution Facilities

R-4-1 Explanation of Energy Loss

R-4-1 : Explanation of Energy Loss

NOTE: In EUMP's Grid,
"PS Loss" includes Energy to Dummy Load etc.
"MV Loss" includes Energy to P/S Lightings, Loss of TR, Loss of MV Line etc.
"LV Loss" includes Loss of LV Line, Energy to Street Lights.
EUMP CAN Measure
P/S Loss, MV Loss and LV Loss
EUMP CANNOT Measure (but May Estimate)
Energy to "P/S Lightings and Street Lights" and Loss of "TR,MV Line and LV Line"



Energy Loss of Calculation

Cumulative Total

Time	Date		GWH/10kWh				SWH/10kWh				TWH/kWh
			DG	O'Moleng	O'Romis	TOTAL	DG	O'Moleng	O'Romis	TOTAL	
24:00	20-Sep-08		-	-	-	-	-	-	-	-	No Data
24:00	20-Oct-08		-	1,072.2	845.9	1,918.1		166.3	186.8	353.1	No Data
24:00	20-Nov-08		567.6	7,537.7	7,363.7	15,469.0	567.6	2,553.4	3,087.0	6,208.0	No Data
24:00	20-Dec-08		626.4	15,328.6	14,825.1	30,780.1	626.4	6,487.5	7,069.9	14,183.8	No Data
24:00	20-Jan-09		2,009.9	21,435.2	20,864.9	44,310.0	2,009.9	10,400.6	11,152.7	23,563.2	193,248
24:00	20-Feb-09		6,570.6	24,495.8	24,412.3	55,478.7	6,570.6	13,014.6	14,402.5	33,987.7	280,535
24:00	20-Mar-09		12,488.5	26,944.3	26,744.9	66,177.7	12,488.5	15,062.2	16,572.5	44,123.2	366,260

Monthly Total

From	To	Day	GWH/kWh				SWH/kWh				TWH/kWh	CWH/kWh
			DG	O'Moleng	O'Romis	TOTAL	DG	O'Moleng	O'Romis	TOTAL		
21-Sep-08	20-Oct-08	30	-	10,722	8,459	19,181	-	1,663	1,868	3,531	#VALUE!	-
21-Oct-08	20-Nov-08	31	5,676	64,655	65,178	135,509	5,676	23,871	29,002	58,549	#VALUE!	27,840
21-Nov-08	20-Dec-08	30	588	77,909	74,614	153,111	588	39,341	39,829	79,758	#VALUE!	53,537
21-Dec-08	20-Jan-09	31	13,835	61,066	60,398	135,299	13,835	39,131	40,828	93,794	#VALUE!	74,118
21-Jan-09	20-Feb-09	31	45,607	30,606	35,474	111,687	45,607	26,140	32,498	104,245	87,287	82,567
21-Feb-09	20-Mar-09	28	59,179	24,485	23,326	106,990	59,179	20,476	21,700	101,355	85,725	77,379
												-
												-
												-
Total			124,885	269,443	267,449	661,777	124,885	150,622	165,725	441,232	#VALUE!	315,441

Energy Loss *Except PS Loss

From	To	Day	Energy Loss					% of Loss : for SWH				
			MV Loss	LV Loss			TOTAL	MV Loss	LV Loss			TOTAL
			Total	Street Light	Others	Total		Total	Street Light	Others	Total	
21-Sep-08	20-Oct-08	30										
21-Oct-08	20-Nov-08	31										
21-Nov-08	20-Dec-08	30		972			26,221		1.2%			32.9%
21-Dec-08	20-Jan-09	31		1,004			19,676		1.1%			21.0%
21-Jan-09	20-Feb-09	31	16,958	1,004	3,716	4,720	21,678	16.3%	1.0%	3.6%	4.5%	20.8%
21-Feb-09	20-Mar-09	28	15,630	907	7,439	8,346	23,976	15.4%	0.9%	7.3%	8.2%	23.7%

"Loss of TR" Estimation

NOTE: "Load Loss" means Loss for Rated Capacity of Transformer
ex: One of 10kVA Transformer loses 580W if apparent power is 10kVA.
"No Load Loss" means Loss for No Load.
ex: Even if there is no customer for a 10kVA Transformer, it loses 130W.

3 ϕ Transformer Specification (THIBIDI, Vietnam)

Capacity[kVA]	Load Loss at 75 ° C[W]	No Load Loss[W]
10	580	130
25	735	168
30	700	160
50	1,313	263
100	2,153	389
250	4,100	720
400	6,038	1,103

3 ϕ Transformer Specification (Full Light, Thai)

Capacity[kVA]	Load Loss at 75 ° C[W]	No Load Loss[W]
30	500	130

Please check the specification sheet of Transformer when installed.

Loss Estimation at full load

Nov 2008 – Feb 2009

Capacity[kVA]	Number	Load Loss[kW]	No Load Loss[kW]
10	8	4.6	1.0
25	16	11.8	2.7
50	9	11.8	2.4
100	4	8.6	1.6
250	2	8.2	1.4
400	1	6.0	1.1
Total		51.1	10.2
Monthly Estimate[kWh]: 30 da		36,768	7,340

Feb 2009 – May 2010

Capacity[kVA]	Number	Load Loss[kW]	No Load Loss[kW]
10	8	4.6	1.0
25	17	12.5	2.9
50	9	11.8	2.4
100	4	8.6	1.6
250	2	8.2	1.4
400	1	6.0	1.1
Total		51.8	10.4
Monthly Estimate[kWh]: 30 da		37,297	7,461

May 2010 –

Capacity[kVA]	Number	Load Loss[kW]	No Load Loss[kW]
10	8	4.6	1.0
25	17	12.5	2.9
30	2	1.2	0.3
50	9	11.8	2.4
100	4	8.6	1.6
250	2	8.2	1.4
400	1	6.0	1.1
Total		53.0	10.7
Monthly Estimate[kWh]: 30 da		38,161	7,669

R-4-2 Trial Charge Pattern Z:

(Most- Divided Pattern from DG)

R-4-2

Trial Charge Pattern Z: (Most- Divided Pattern from DG)

Transmission Line restoration process from Diels power station

1. Purpose

The purpose of this paper is to show the outline operation-procedure of Transmission line switchgears at restoration of 22kV system from Diesel power station in the whole power system interruption.

2. Principal of Medium-voltage switchgear operation

(1) To operate with- no-load condition

(2) Load side (low-voltage:400V) MCBs should be open before operation of Medium-voltage switchgears

(3) To operate Step by Step with the confirmation of Devices' reactions

(4) Operation of FCO(Fuse Cutout Switch) for Distribution Transformer station:

- It can break or close the transformer no-load (excitation) current.
- The operator shall close or open quickly to prevent the arcing.
- FCO operation with energized condition may reduce the life time of fuse, it is preferable to manage the operation with no-voltage condition)
- Do not break/close with load condition.

3. D/L switches operation procedure

(1) Step-1:Comparison of Total Generators capabilities and Demanded load

[1] Generation availabilities > Demand Load   to plane whole system restoration

[2] Generation availabilities < Demand Load   to plane partial area service interruption

Disconnection of Load circuit

(2) Step-2: Opening-Switch Operation of low-voltage MCBs on Tr-DB-boxes (for whole transformer stations)

[1] To open Main MCB(400V) in Tr-DB-Box (Distribution Transformer Distribution Box)

[2] To open Feeders' MCBs in Tr-DB-Box

[3] To continue to next Transformer station

[4] To confirm whole system condition from operators (all: Circuit of C13,C12, C11, C21,C22 and C23 , of low voltage MCBs are open.)

(3) Step-3: Opening-Switch Operation of Market cubicle

[1] To confirm the extinction of pilot lamp, then to open LBS TR-2

[2] To confirm the extinction of pilot lamp, then to open LBS TR-1

[3] To confirm the extinction of pilot lamp, then to open LBS F-3

[4] To confirm the extinction of pilot lamp, then to open LBS F-2

[5] To confirm the extinction of pilot lamp, then to open LBS F-1

** Operation orders of [1]~[5] are changeable.

(4) Step-4: Opening-Switch Operation of Hospital cubicle

[1] To confirm the extinction of pilot lamp, then to open LBS TR-2

[2] To confirm the extinction of pilot lamp, then to open LBS TR-1

[3] To confirm the extinction of pilot lamp, then to open LBS F-3

[4] To confirm the extinction of pilot lamp, then to open LBS F-2

[5] To confirm the extinction of pilot lamp, then to open LBS F-1

** Operation orders of [1]~[5] are changeable.

(5) Step-5: Opening-Switch Operation of Section Switches (LBS)

[1] To open LBS-2 at circuit C23

[2] To open LBS-1 near Diesel P/S (normally opened)

To keep original position of Medium-voltage (22kV) FCO for each Transformer station. (Normally closed)

** To keep the original position of Medium-voltage (22kV) FCO for each Transformer station to reduce the restoration time (Normally closed)

Starting Line Charge and excitation of Distribution transformers

(6) Step-6: To start Diesel Generator

[1] Bus-side400V CB is closed.

[2] To close Generator CB.

*** To refer the other document*

(7) Step-7: C13 D/L charging

[1] To confirm the condition of D/L line (Arcing, noise, smoke, and etc)

[2] To confirm the Transformer stations(PMT-14) connected C13 circuit. They are charged with no-load conditions.

(8) Step-8: Closing-Switch Operation-1/2 of Hospital 22kV cubicle <u>(charge of Main D/L:C11 for O'Romis P/S)</u>

[1] To confirm the lighting of pilot lamp at F-3(from Diesel P/S)

[2] To close the LBS F-3.

[3] Cubicle-Bus is charged.

[4] To close the LBS F-1. Circuit C11 is charged.

[5] To confirm the lighting of pilot lamp at F-1.

[6] To confirm the condition of D/L line of C11.

[7] To confirm the Three(3) Transformer stations (PMT-01,02,03) and Step-up-Tr. connected to C11 circuit. They are charged with no-load conditions.

(9) Step-9: To start O'Romis Generator

[1] Bus-side400V CB is closed.

[2] To close Generator CB. (Synchronizing)

*** To refer the other document*

(10) Step-10: Closing-Switch Operation-1/2 Operation of District Office 22kV cubicle (charge of Main D/L:C22 for O'Moleng P/S)

[1] To confirm the lighting of pilot lamp at F-2 (from Diesel P/S and Hospital cubicle)

[2] To close the LBS F-2.

[3] Cubicle-Bus is charged.

[4] To close the LBS F-1. Circuit C22 is charged.

[5] To confirm the lighting of pilot lamp at F-1.

[6] To confirm the condition of D/L line of C22.

[7] To confirm the twelve (12**) Transformer stations connected to C22 circuit. They are charged with no-load conditions.

**: PMT-17,18,19,20,21,22,23,24,25,26,27,28 and Step-up Tr.

(11) Step-11: To start O'Moleng Generator

[1] Bus-side400V CB is closed.

[2] To close Generator CB. (Synchronizing)

*** To refer the other document*

(12) Step-12: Closing-Switch Operation-2/2 of Hospital 22kV cubicle (charge of Circuit-C12 and local transformers)

[1] To close the LBS TR-2. (for Hospital Transformer:TR2)

[2] To confirm the lighting of pilot lamp at TR-2

[3] Hospital Transformer is charged.

[4] To close the LBS TR-1. (Local area service Transformer:TR1 is charged)

[5] To confirm the lighting of pilot lamp at TR-1.

[6] To close the LBS F-2. (for Distribution Transformers:PM-05,06,07,08)

[7] To confirm the lighting of pilot lamp at F-2

(13) Step-13: Closing-Switch Operation-2/2 of District Office 22kV cubicle (charge of Circuit-C21 and local transformers)

[1] To close the LBS TR-2. (for Market Transformer:TR2)

[2] To confirm the lighting of pilot lamp at TR-2

[3] Market area service Transformer is charged.

[4] To close the LBS TR-1. (Local area service Transformer:TR1 is charged)

[5] To confirm the lighting of pilot lamp at TR-1.

[6] To close the LBS F-3. (for Distribution Transformers:PM-09,10,11,12,13,15)

[7] To confirm the lighting of pilot lamp at F-3

(14) Step-14: Closing-Switch Operation of Section Switches (LBS) (charge of Main D/L:C23 and Distribution transformers)

[1] To close LBS-2 at circuit C23 ((for Distribution Transformers:PMT-29,30,31,32,33,34,35)

[2] To open LBS-1 near Diesel P/S (normally opened)

Connection of Load circuit

(15) Step-15: Closing-Switch Operation of low-voltage MCBs on Tr-DB-boxes (for whole transformer stations)

[1] To close Main MCB(400V) in Tr-DB-Box

[2] To close Feeders' MCBs in Tr-DB-Box

[3] To confirm the stability of transformer and low-voltage Feeder lines

[4] To continue to next Transformer station

[5] To confirm whole system condition from operators (all: Circuit of C11,C12, C13, C21,C22 and C23 , of low voltage MCBs are off.)

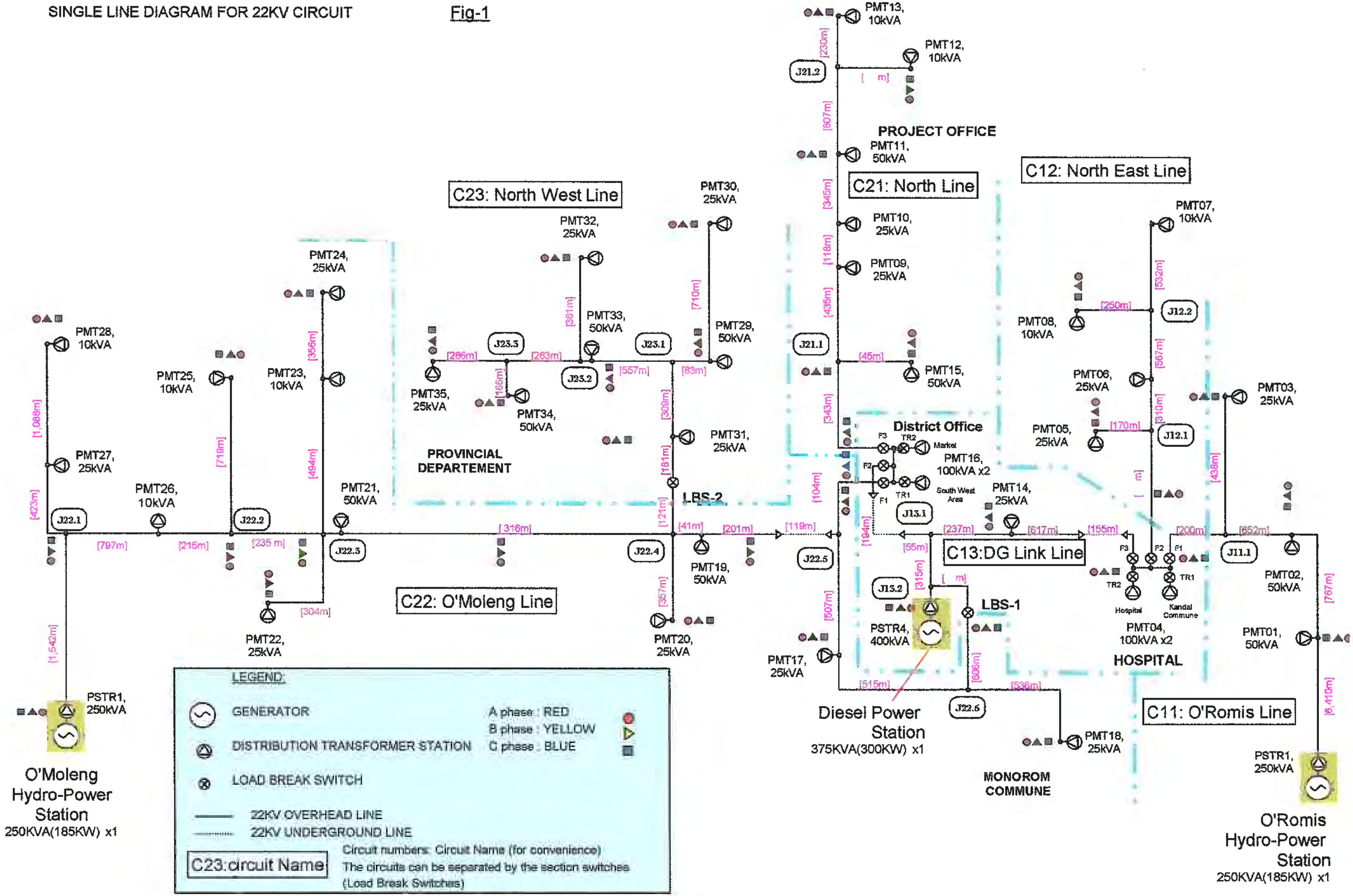
** Loading order may be prioritized from the needs of demand. It will be considered from the experience of operations.

Resume of Distribution Transformer Station

Order	Action
1	Confirm the Closing of 22kV FCOs
2	Confirm the Opening of all MCBs
3	Confirm the Main WH meter no-creeping and the indication values (to note)
4-1	To close Main MCB(MCCB1)
4-2	To confirm the stability of devices in the Box
5-1	To close Street light MCB(MCCB6)
5-2	To confirm the Timer movement and a timer-dial(time indication) position.
6-1	To close Feeder-1 MCB(MCCB3)
6-2	To confirm the stability f feeder-1 circuit.
7-1	To close Feeder-2 MCB(MCCB4)
7-2	To confirm the stability ffeeder-2 circuit.

SINGLE LINE DIAGRAM FOR 22KV CIRCUIT

Fig-1



Rererence diagrams for Line restration -1/2

Energized Line

Charged Transformer

Step-6: DG Start

Step-7: C13 Charging

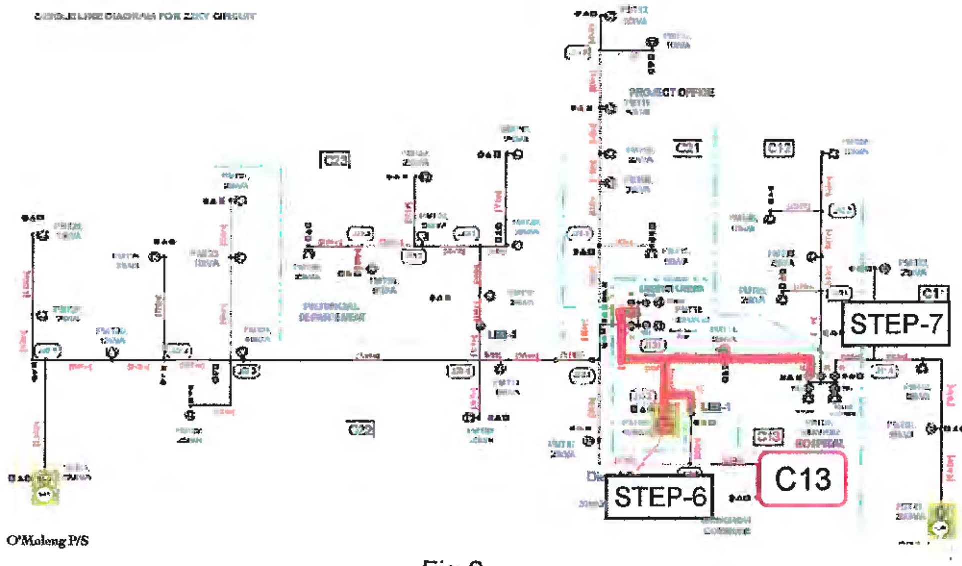


Fig-2

Step-8: C11 Charging

Step-9: O'Romis Start

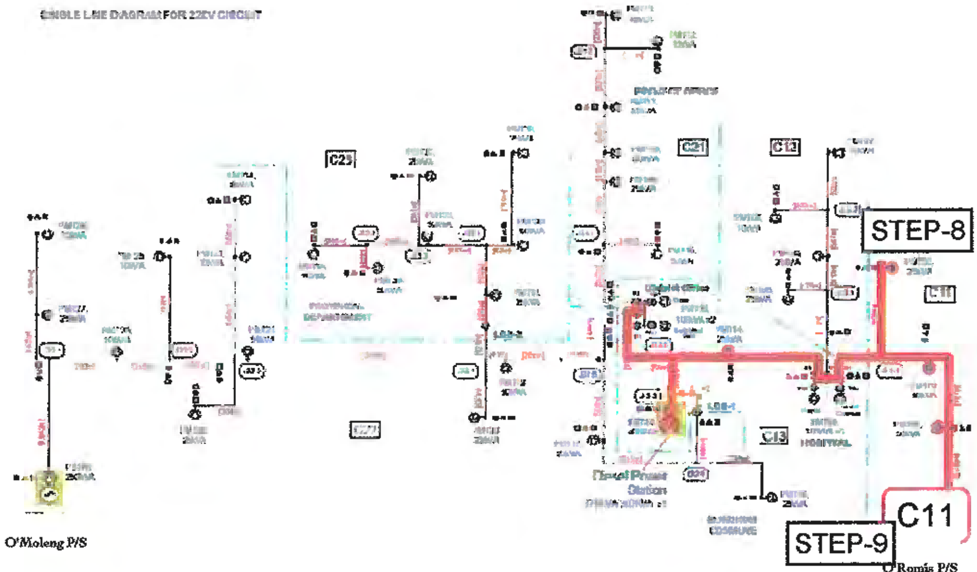


Fig-3

Step-10: C22 Charging

Step-11: O'Moleng Start

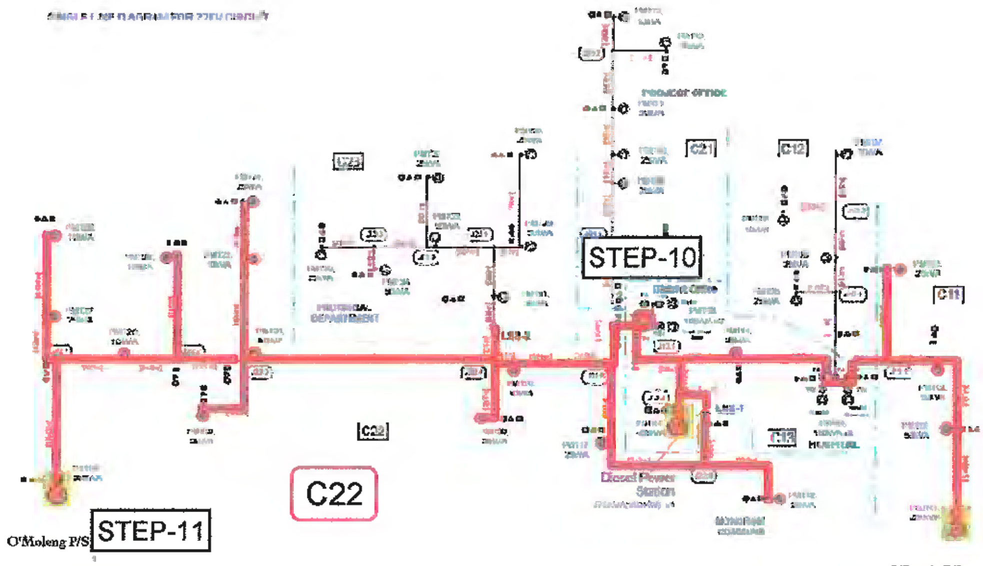


Fig-4

Rererence diagrams for Line restration -2/2

Energized Line
Charged Transformer

Step-12: C12 Charging

Hospital Service Transformer

Kandal Commune Service Transformer

C12:North East Area

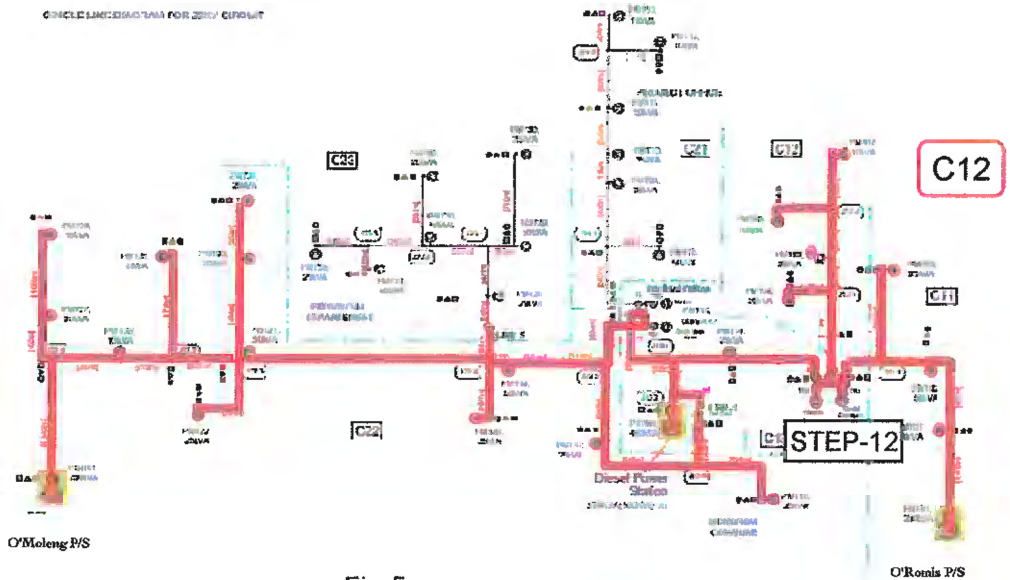


Fig-5

Step-13: C21 Charging

Market Service Transformer

South West Area from Market

C21:North Area

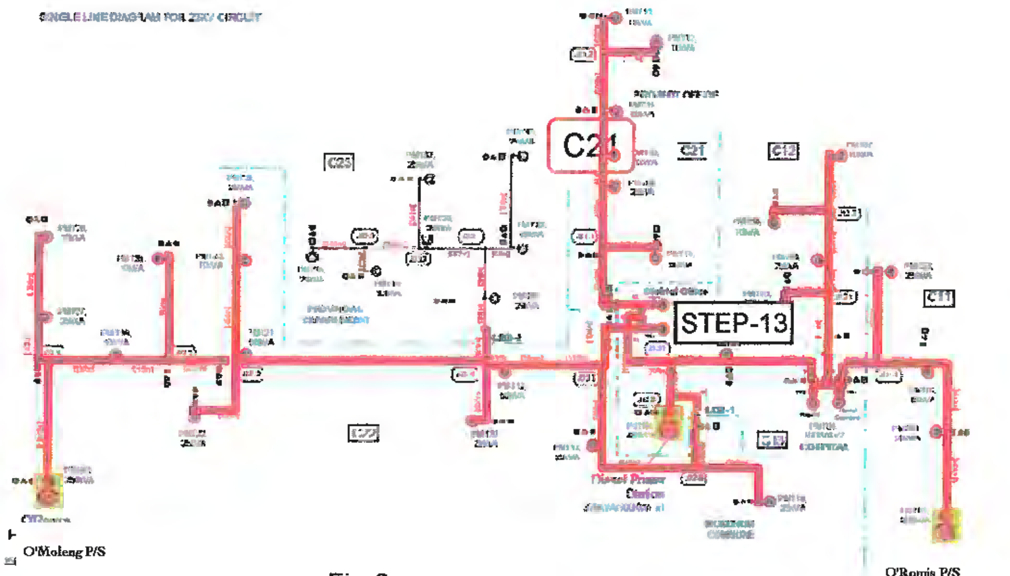


Fig-6

Step-14: C23 Charging

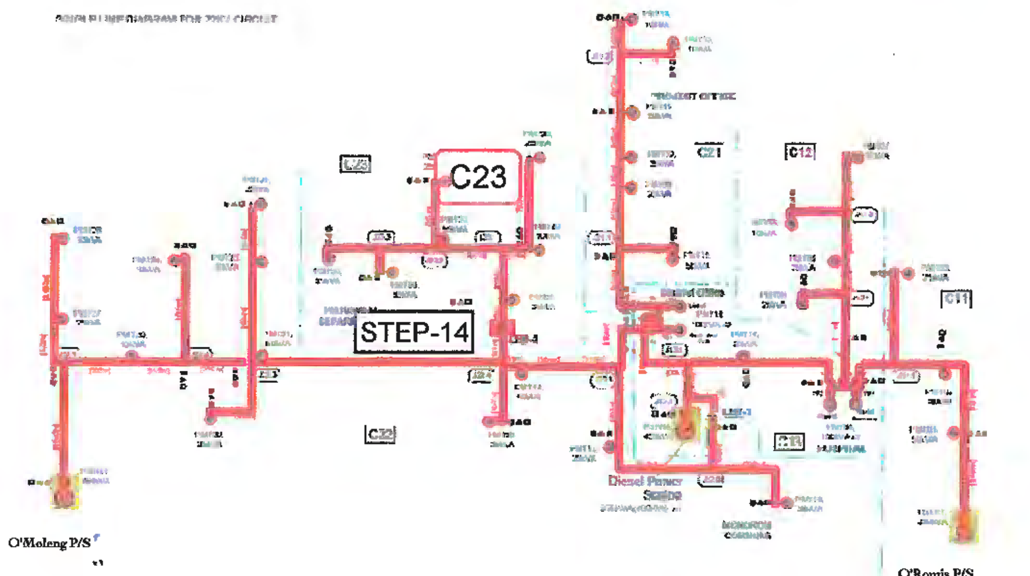


Fig-7

R-4-3 Removing an Obstacle from 22kV Overhead line (Example: The obstacle is on the 22kV line near the PMT-11 Transformer)

R-4-3

Removing an Obstacle from 22kV Overhead line (to refer Fig.-1).
(Example: The obstacle is on the 22kV line near the PMT-11 Transformer)

(1) **To interrupt the power supply** to the C21(North Line) by the LBS (Load Break Switch)-F3 in the District Office S/S Cubicle. (to refer Fig.-2)

[1] To open Line LBS-F3 (to refer Fig.-4)

[2] To confirm the LBS -Position indicator is Open Position. (to refer Fig.-4)

[3] To confirm the three (3) Pilot lamps are OFF.(to refer Fig.-4)

(2) **Take a lines Earthing** by using the Earthing Switch of LBS-F3. (to refer Fig.-5)

[1] To confirm the LBS -Position indicator is Erath Position. (to refer Fig.-5)

[2] The Earthling Switch should be continuously closed during the working.

Fig.-1: Obstacle on the line

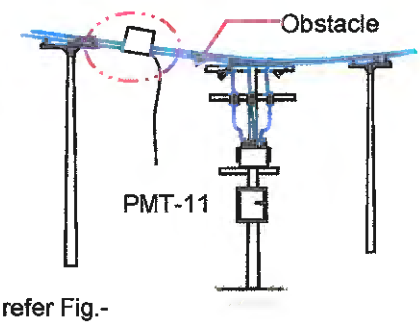
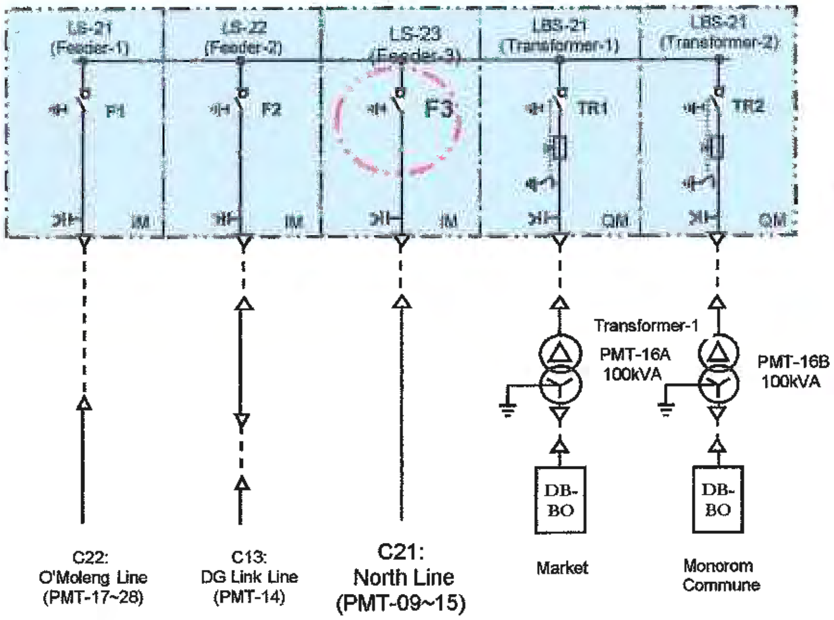


Fig.-2: Single Line Diargram of District Office S/S cubicle

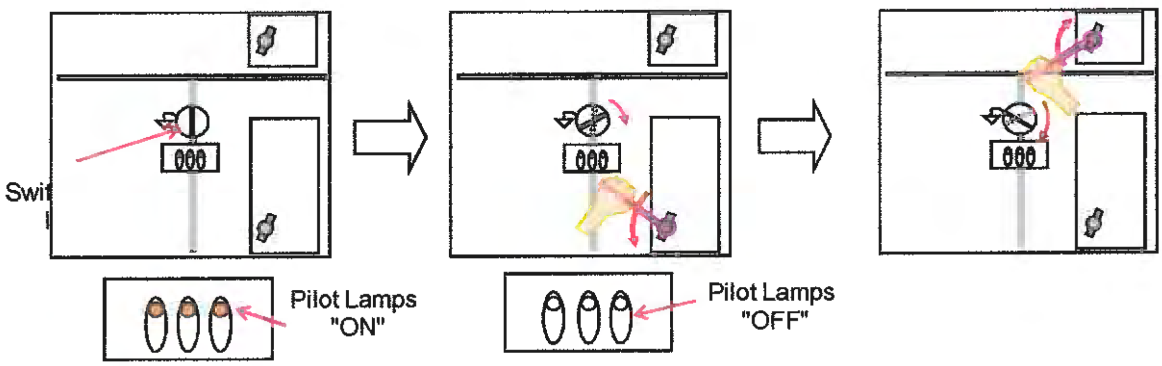


Transmission lines may remain the residual dc voltage after earthing in a few minute. (the decay time is changed by the atmosphere, it is not a constant.) Do not do the next action while discharging of residual voltages.

Fig.-3: LBS closed Position

Fig.-4: LBS Opening

Fig.-5: LBS Earthing

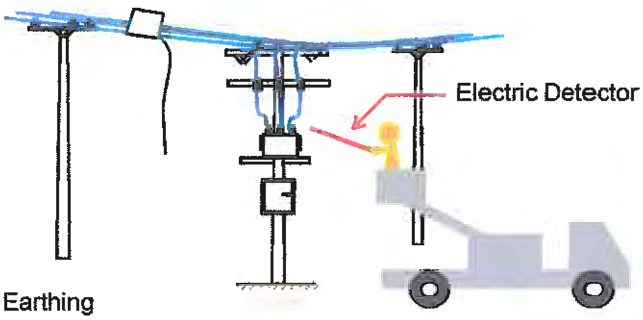


(3) Working at Obstacle

[1] To confirm the No-voltage on the lines by using the Electric-Detector. (This detector can detect the a.c. alternative current only.) (to refer Fig.-6)

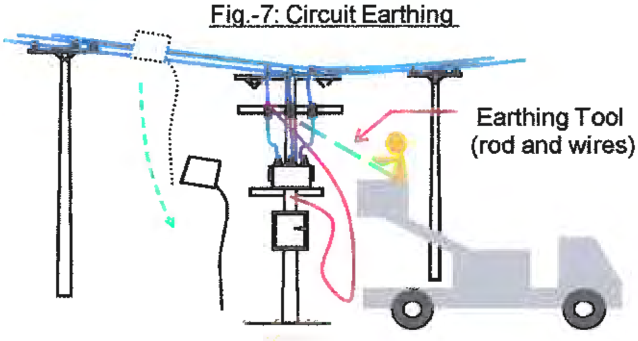
[2] If there is the voltage, to confirm the process until now. Do not proceed forward.

Fig.-6: Circuit Voltage Check



[3] To take the Earthing of lines by using Earthing tools. If there is no suitable Earthing conductor, then to take the Earth form the support structures. (to refer Fig.-7)

Fig.-7: Circuit Earthing



(4) **To remove the obstacle** from the lines.

(5) Line restoration

To remove the Earthing tools form the conductors. (to refer Fig.-8)

To open the Earthing Switch of F3 in the District Office S/S cubicle. (to refer Fig.-9)

To inform the finish of work to the Head office and the power stations, and to confirm the power-source condition.

To close the LBS:F3. (to refer Fig.-10)

To confirm the pilot lamps.

Fig.-8: Removing Earthing tools

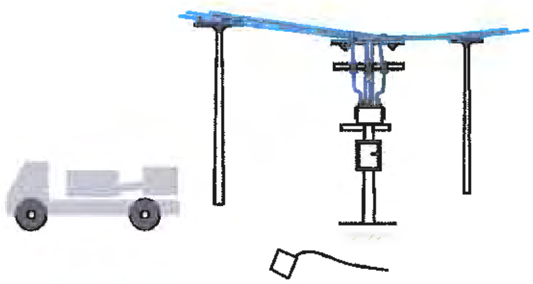


Fig.-9: Opening Earthing Switch

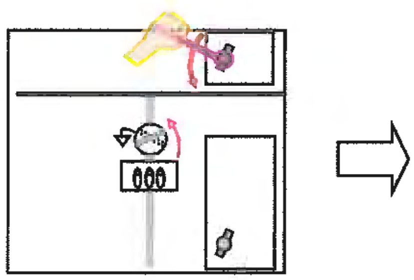
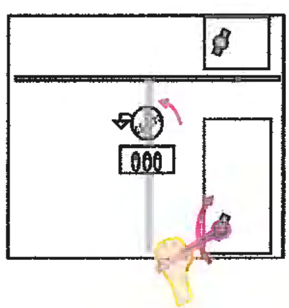


Fig.-10: Closing LBS:F3



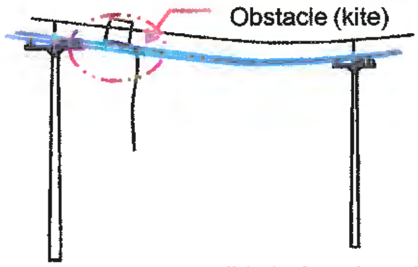
R-4-4 Removing an Obstacle from 22kV Overhead line
(Example: The obstacle is on the 22kV line from O'Romis Power Sta tion)

Removing an Obstacle from 22kV Overhead line (to refer Fig.-1).
(Example: The obstacle is on the 22kV line from O'Romis Power Station)

1.Situation:

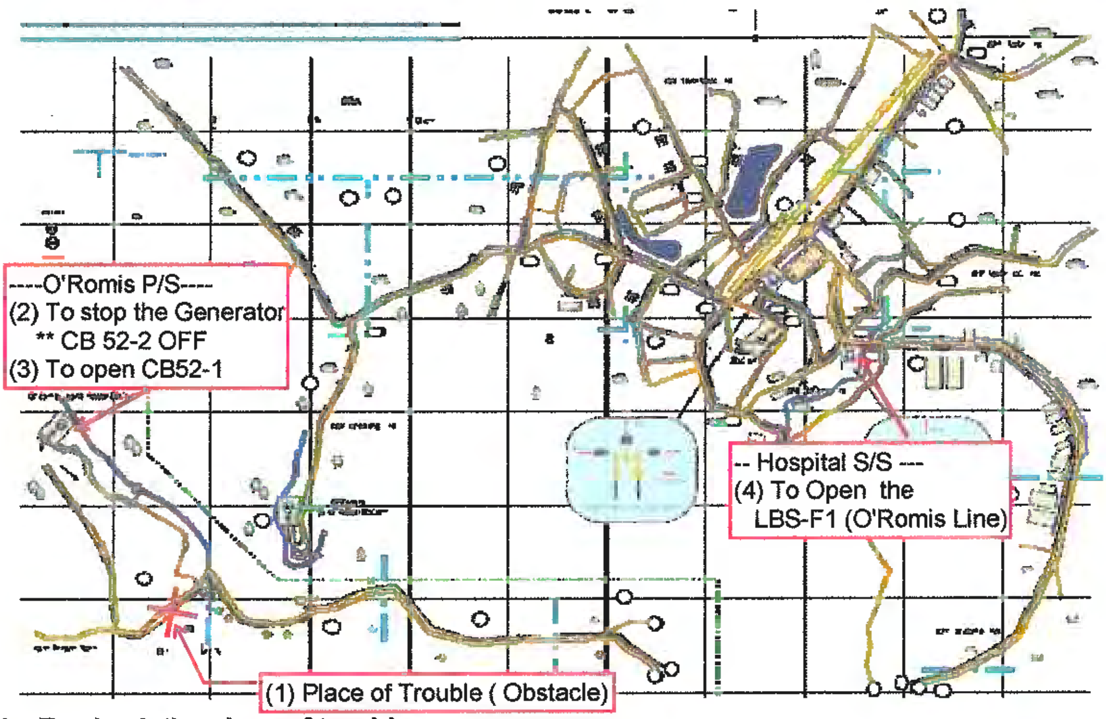
A kite is hanging on the overhead earth-wire. (Fig.-1) It seems not so big trouble. But, when the strong rain will come, this kite make a water rout form the earth-wire to the live conductors. (The kite will conduct the water-drop from the earth-wire to the live conductors. It has potential to bring an earth-fault or a short-circuit for the system.) (to refer Fig.-2)

Fig.-1: Obstacle on the line



From above reason, it is preferable to remove the obstacle (kite) as soon as possible before the rain will come.

Fig.-2: System Single line Diagram



(1) To check the place of trouble.

(2) To stop the Generator of O'Romis Power Station.

(3) To interrupt the power supply to the C11(O'Romis Line) by the LBS (Load Break Switch)-F1 in

[1] To open Line LBS-F1 (to refer Fig.-4)

[2] To confirm the LBS -Position indicator is Open Position. (to refer Fig.-4)

[3] To confirm the three (3) Pilot lamps are OFF.(to refer Fig.-4)

(4) Take a lines Earthing by using the Earthing Switch of LBS-F3. (to refer Fig.-5)

[1] To confirm the LBS -Position indicator is Erath Position. (to refer Fig.-5)

[2] The Earthling Switch should be continuously closed during the working.

Transmission lines may remain the residual dc voltage after earthing in a few minute. (the decay time is changed by the atmosphere, it is not a constant.) Do not do the next action while discharging of residual voltages.

Fig.-3: Single Line Diagram of Hospital S/S cubicle

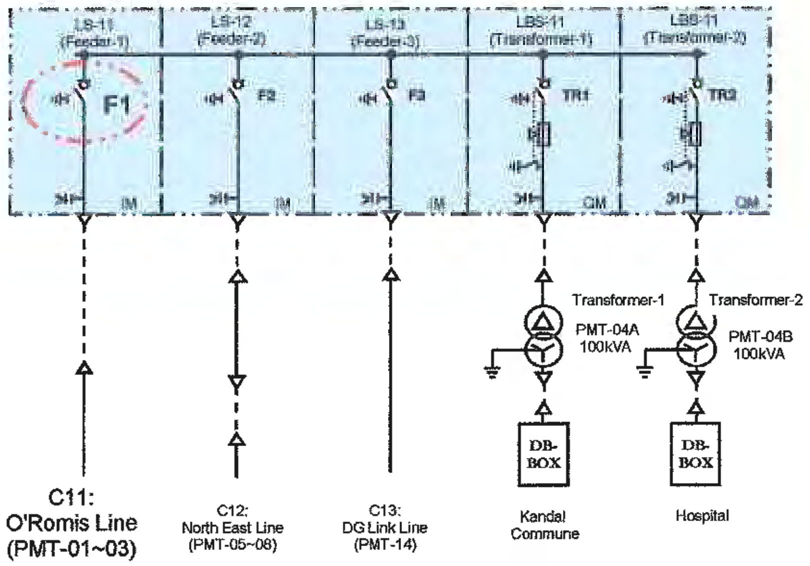


Fig.-4: LBS closed Position

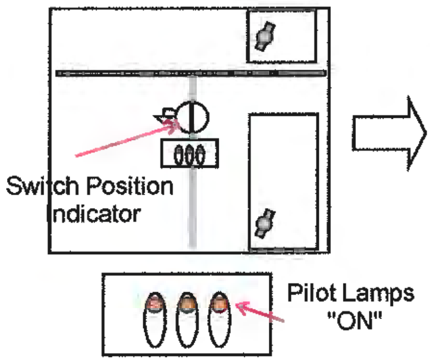


Fig.-5: LBS Opening

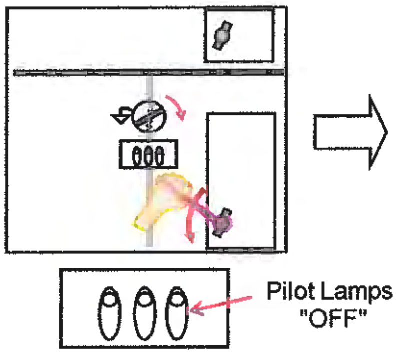
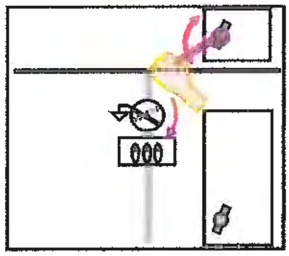


Fig.-6: LBS Earthling



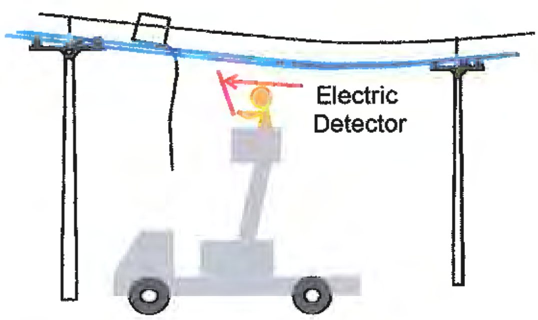
(5) Working at Obstacle

[1] To confirm the No-voltage on the lines by using the Electric-Detector. (This detector can detect the a.c. alternative current only.) (to refer Fig.-7)

Do not forget to wear insulation-gloves and insulation-boots for working.

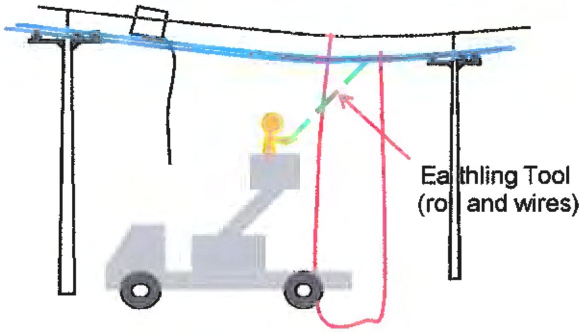
[2] If there is the voltage, to confirm the process from first to now. Do not proceed forward.

Fig.-7: Circuit Voltage Check



[3] To take the Earthing of lines by using Earthing tools. If there is no suitable Earthing conductor, then to take the Earth form the support structures or the overhead earth-wire. (to refer Fig.-8)

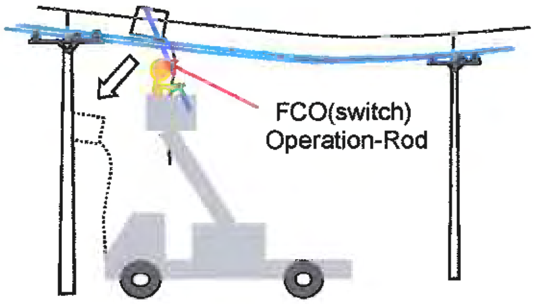
Fig.-8: Circuit Earthling



(6) To remove the obstacle from the lines.

It is preferable to use the insulated tools for removing work as FCO switch operation rod. Do not use conductors without earthing.

Fig.-9: Removing Obstacle



(7) Line restoration

To remove the Earthing tools form the conductors. (to refer Fig.-10)

To open the Earthing Switch of F1 in the Hospital S/S cubicle. (to refer Fig.-11)

To close the LBS:F3. (to refer Fig.-10)

To confirm the pilot lamps.

To inform the finish of work to the Head office and the power stations, and to confirm the power-source condition.

Fig.-10: Removing Obstacle

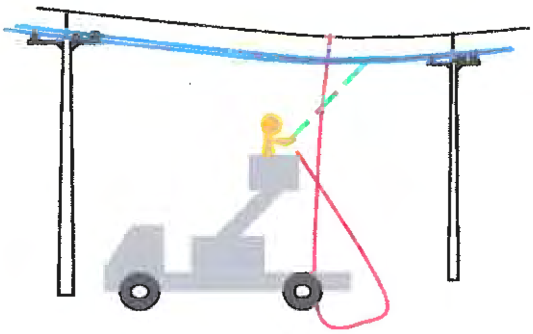


Fig.-11: Opening Earthling Switch

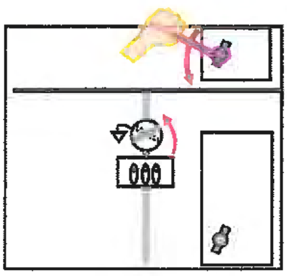
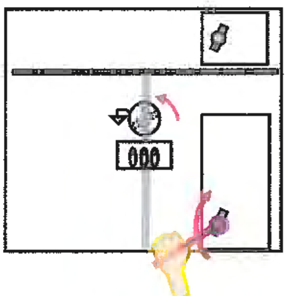


Fig.-12: Closing LBS-F1



R-4-5 Reading of WH (Watt-hour) meter on Transformer Distribution Panel

R-4-5

Reading of WH (Watt-hour) meter on Transformer Distribution Panel

The WH-meters installed in the distribution panels which use the current transformers for measuring. In such case, the real energy consumption is conducted by multiplication of the current transformer ratio and the indicated kilo-watt hour (KWh).

For example, the WH-meter of 50KVA transformer, there are current-transformers with 100/5A ratios. If the indication values is 45KWh, the real value can be conducted as follows:

45 x 100/5 = 45 x 20 = 900 [KWh]

CT ratio (current transformer ratio) is referred as multiplying factor for calculation.

Indication value of Watt-hour meter [kWh]	CT (Current Transformer)Ratio =Multiplying factor	Real Watt hour (energy consumption) [KWh]
45	100/5	45 x 100/5 = 900

Multiplying factor for each Watt hour meter

CTs(Current Transformers) are three types in accord with the transformer capacities. Therefore, the multiplying factor should be chosen for each transformer. The factors are listed in the table below.

Transformer Number	Multiplying factor	Transformer Number	Multiplying factor
PMT-01	x 20	PMT-17	x 10
PMT-02	x 20	PMT-18	x 10
PMT-03	x 10	PMT-19	x 20
PMT-04A	x 50	PMT-20	x 10
PMT-04B	x 1	PMT-21	x 20
PMT-05	x 10	PMT-22	x 10
PMT-06	x 10	PMT-23	x 1
PMT-07	x 1	PMT-24	x 10
PMT-08	x 1	PMT-25	x 1
PMT-09	x 10	PMT-26	x 1
PMT-10	x 10	PMT-27	x 10
PMT-11	x 20	PMT-28	x 1
PMT-12	x 1	PMT-29	x 20
PMT-13	x 1	PMT-30	x 10
PMT-14	x 10	PMT-31	x 10
PMT-15	x 20	PMT-32	x 10
PMT-16A	x 1	PMT-33	x 20
PMT-16B	x 50	PMT-34	x 20
		PMT-35	x 10

R-4-6 Last digit reading manner for Watt-hour meter

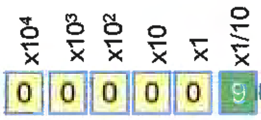
R-4-6

Last digit reading manner for Watt-hour meter

Reading manner of last digit of the Watt hour meter should be kept constantly. The 1/10 digit number should be read to the smaller number as figure-2.

By doing this, the periodical accumulated value which conducted by the subtraction with the previous value and the present value, and this manner can prevent minimally the error by the round figures

Samples of reading value and indication digits are ahown figures below.



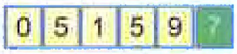
⇨ 0.9 kWh

figure-1

To round-down at reading of 1/10 digit

⇨ 159.7 kWh

figure-2



⇨ 5159.7 kWh

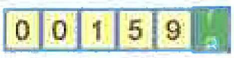
figure-3

Monthly energy consumption is conducted as follows:

372.2 - 159.7 = 212.5 [KWh]

In case of figure-4 and figure-5, the monthly consumption is 212.5 kilo-watt hour [KWh]

Indication value of 2008 October 18



⇨ 159.7 kWh

figure-4

Indication value of 2008 November 18

⇨ 372.2 kWh

figure-5

R-4-7 WH meter Measurement Record

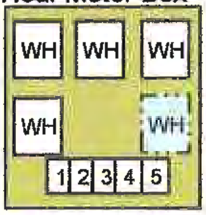
R-4-7

WH meter Measurment Record

1. Transformer WHMeter

Date of Check	PMT-No.	Indication of WH [KWH]	Multiplying factor	Real-WH [KWH]
'08/10/18	PMT-16B		x 50	

Layout of Watt Hour Meter Box



2. House Hold Service WH-meters

Date of Check	Pole No.	Consumers' WH-meter [KWh]				
		WH-1	HH-2	HH-3	HH-4	HH-5
'08/10/18	101 UP.					
	101 DOWN					
	102 UP.					
	102 DOWN					
	103 UP.					
	103 DOWN					
	104 UP.					
	104 DOWN					
	105 UP.					
	105 DOWN					
	106 UP.					
	106 DOWN					
	107 UP.					
	107 DOWN					

2. Mid- and Long-term Plan (Revised)

ANNEX - 2

Japan International Cooperation Agency
Ministry of Industry, Mines and Energy of Kingdom of Cambodia

Project for Operation and Maintenance of the Rural Electrification on Micro-hydropower in Mondul Kiri

Long and Mid-term Strategy

(Maintenance Plan of the Electric Facilities and Prospect of Tariff Rate after Connecting with Vietnam)

February 2011

Electric Power Development Co.,Ltd.

The Chugoku Electric Power Company

Letter of Submittal of Long and Mid-term Strategy
for Micro-hydropower Rural Electrification in Mondul Kiri Province

JICA Project Team for Operation and Maintenance of Micro-hydropower Rural Electrification in Mondul Kiri Province (hereinafter referred to as JICA Team) is pleased to submit a Long and Mid-term Strategy. This strategy is a revised version of the long and mid-term plan that was prepared by JICA Team on April 2009. In this strategy, the maintenance plan for civil structures, generation equipment and transmission and distribution facilities were revised based on their actual performance. And it also includes a prospect of tariff rate after connecting with Vietnam. It is to be noted that the management and administration section was not revised by JICA team because EUMP was merged into EDC in June 2010.

After this project is over in March 2011, EDC Modul Kiri by themselves should update the long and mid-term maintenance plan and take appropriate maintenance to keep their facilities in good conditions. EDC Modul Kiri has also to review its long and mid-term financial plan every year to make budgetary requests to EDC head quarters. It is hoped that this strategy will be useful for such tasks. Finally, JICA Team expresses its hope that the relevant authorities of Cambodia and EDC Mondul Kiri will continue to make the most of the power facilities donated by the Japanese government to respond to the needs for electricity of Mondul Kiri Province.

Koji Mishima
Team Leader, JICA Team

Contents

1. Preface

Long and mid-term plan was made up by JICA Team on April 2009 and approved at the 2nd JCC meeting held on June 2009. In that Plan, basic concept to make up the maintenance plan of facilities was shown and budget allocation from 2009 for 10 years was proposed.

In this strategy, we studied the necessity of revise based on the actual performance from April 2009 regarding the maintenance and financial plan for power facilities such as civil structures, generation equipment and transmission & distribution facilities.

Long and mid-term plan is a rolling plan that should be revised comparing actual performance with future prospect. The Project Team wishes that EDC Mondul Kiri should be able to revise the Plan yearly by itself in the hereafter referring to this strategy.

2. Medium & Long Term Plan (M&L TP) for Electric Power Facilities

2.1 Judgment of Work priority

Regarding to draw up the M&LTP, it is necessary to evaluate the priority of repairing plans in order to optimize the preservation facilities taking keep reliability and reducing maintenance cost into consideration as follows.

As for implementation work plan, it should be ordered the priority of [Compliance] and [Society effectiveness], and then following [Condition of facilities], [Effectiveness of electric power field or owned facilities] and [Most efficiency management plan].

(1) Compliance(Law observance)

The following items are implemented in priority as compliance that,

Measuring equipment (Measurement standards), Dangerous goods (PCB, etc.) and Detailed inspection of Circuit Breaker (Maintenance standards), but, dangerous goods may be considered the disposal period as items 3 and 4 hereinafter in advance.

(2) Society effectiveness (Safety and environmental)

1) Asbestos abatement

In replacement of non-asbestos goods, it is considered items 3 and 4 hereinafter.

2) Safety and environmental

The enterprise must make a countermeasure for oil leakages/noises in safety and social effectiveness, so that it is applied the budget of 5 % in the asset & repairing cost, but the priority may be considered items 3 and 4 hereinafter.

Prevention plan of oil leakages, safety of crane and noises

(3) Facility condition (maintenance, reliability, technical and functional factors)

In the case of heavy trouble, it should be measured in whole power plants based on the instruction of responsible department.

1) Technical factor

Whole facilities

2) Reliability

Aged damage, operation times, repair and fault experiences, decreasing function, remaining life

3) Maintenance ability

Non-production parts, agency and supporting system

4) Function ability

Increasing efficiency, function, reliability and work ability

(4) Effectiveness of Electric power field or owned facilities

1) Economical

Economic effect of replacement or renewable

2) Risk assessments

Evaluation of effectiveness on system fault or out of services
- Black out
- Turbine/generator stop (Non, within 3 days, over 3 days)
- Spilled water (Yes or No) condition: run-off-river type with one unit and required maintenance discharge water

3) Efficiency

Shortage of scheduled stoppage duration in considering parallel work due to reduce maintenance cost and increase operation hours

4) Coordination

Coordination of protective relay setting in the power system

5) Important position

Expectation of supply the power to the power system (such as effectiveness of power system by hot or cold reserves)

(5) Efficiency of management

Evaluation of system analysis and maintenance management

2.2 Civil Facilities

With continuous maintenance works, concrete structures such as intake weir or waterway can be used semi-permanently. Economically speaking, repairing works should be done every when some troubles are found regardless the age of the facilities. Under the ordinal operation except for unexpected disaster, it is rare case that a civil structure suddenly breaks down without some signals. Most cases, some signals can be seen such as crack or strain before breaking down. Structural soundness of civil structures will be kept as far as periodical maintenance works are done and suitable countermeasures are done when some signals on the civil structures are found.

Considering above, it is desirable that actual repairing planning should be drawn up based on the checking results of the maintenance works. In medium- to long-term planning, equivalent price of depreciation cost per year is set for the maintenance cost per year and the disaster recovering cost is not considered since the probability is quite low (design : less than 0.01 /year).

In the view of easiness of operation and maintenance, some upgrading is preferable for some civil facilities because existing facilities have minimum of specification. For example, existing access path of O'Moleng site and O'Romis site have gravel roadbed and mortar-type ditch. After rainy season, they need some repairing such as filling up gravel or for rutting. To make the maintenance work easier, it is desirable to improve the structure, for example, upgrade to asphalt pavement or concrete U-shaped gutter. But the cost for upgrading has much effect on the company management. Aimless upgrading will incur the skyrocket tariff. Cost-benefit performance study should be carefully done. Besides that, there are so many facilities that needs upgrading, those are falling rock protection, slope protection and so on but the cost for upgrading is eliminated in the medium- to long-term planning at this moment. In the future, considering the status of operation, maintenance and management, EUMP should make a decision of upgrading if they need.

2.3 Generating Facilities

The budget for the 3 power stations (O'Romid, O'Moleng and Diesel) are determined by the following estimations,

(1) Operation and maintenance Cost

Annual budget for repairing and replacement of the equipment is calculated based on the operation condition and fault experiences.

(2) Consignment

The consignment of Contractor or Inspectors' (as a supplied manufacturer or domestic inspection company) will be selected for training of advises and execution of the periodic inspection as follows.

1) Periodic inspection: ordinary inspection according to the guidance of manufacturers per year,
2) Detailed inspection : the making the inspection schedule and replacement plan of detail equipment every 5 referring to the maintenance manual,
3) Overhaul Plan

According to the maintenance manual and supplier's standards, the overhauling work will be carried out every 10 years, and parts to be replaced considering of aged and keeping the long life operation.

Therefore, making a budget plan and timing of the inspection may be the most considering matter for the power stations without any trouble and supplied power.

2.4 Transmission & Distribution Facilities

The budget for Transmission & Distribution facilities are determined by the following estimations.

(1) Operation and maintenance Cost

Annual budget for repairing and replacement of the equipment is calculated based on the operation condition and fault experiences.

Spare parts' purchasing for early restoration of facilities' destruction by natural disasters is planned for 10 years. In this case, it is assumed that restoration works are basically conducted by EUMP staff.

Asset-Upgrade budget for improving the system operation is excluded from this plan because experience of system operation is very short, even though such improvement will be necessary for smooth management of EUMP.

(2) Consignment

The consignment of Contractor or Inspectors' (as a supplied manufacturer or domestic inspection company) will be selected for training of advises and execution of the periodic inspection as follows.

1) Bucket Car Inspection: ordinary inspection per year, and detail inspection per 3 years
2) Switch Station Inspection: ordinary inspection per 2 years, and detail inspection per 6 years
3) Insulated Tools Inspection: ordinary inspection per year, and detail inspection per 3 years
4) Tree-Cutting & Trimming Work: a part of tree-cutting & trimming work is planned by consignment.
5) Periodical Training: periodical training per 4 years in order to keep and increase workers' ability especially for rare experienced works

3. Study of the necessity for revise

The way of summing up the yearly budget for long and mid-term plan from 2009 to 2018 that was submitted on April 2009 is as shown in the chapter 2, Medium & Long Term Plan (M&L TP) for Electric Power Facilities. Based on this way, the cost for usual maintenance and periodical inspection from 2009 to 2018 is estimated as table 2 - 4. Because there is no similar hydropower station and no referable data in Cambodia, we set the annual budget equivalent to the depreciation cost that is estimated from the construction cost and durable year. We were planning to revise it after enough actual performance record is prepared.

In most case, we can revise it with enough actual performance record, but there were no referable data during this project because not so long time passed after completion and there are few maintenance records. It is assumed that the cost for replacement of consumable goods or repairing work due to the deterioration will be rising with the passage of time. So it is risky choice to decrease the maintenance cost judging from the maintenance record only two years from 2009 to 2010. Our recommendation is that if EDC Mondul Kiri can estimate the probable data with at least 5 to 10 years actual performance records, the Plan should be revised.

Right now, we did not revise the long and mid-term plan because of the data shortage for revision. As a preparation for revision, EDC Modul Kiri should keep the maintenance records surely and update the basic date such as an average maintenance cost item by item every year. The item with probable data should be revised in series, with that the accuracy should be improved step by step.

Table-1 ‹dgment of Work Priority for Electrical Facility on M & L Term Plan, 2009

Note: N/A: Not applicable A: Applicable

Evaluated Items	Upper: Objective Parts / Lower: Evaluated Points											
Compliance PCB, Dangerous good, Measuring, CB	Not necessary						Necessary					
	0						500					
Safety Asbestos, Crane, etc.	Not necessary						Necessary					
	0						200					
Environment Noises, Clean-up, Oil leakage	Not necessary						Necessary					
	0						100					
Maintenance Order stop, Support system, Spare parts	Out of order				Manufacturer support system				Spare Parts			
	N/A		A		A		N/A		A		N/A	
	0		30		0		30		0		50	
Reliability Past Experience, Repair, Service life, etc.	Run time		Ope. Times		Repaired times		Fault record		Performance		Retired age	
	Less	Over	Less	Over	3>	>3	5>	>5	Good	Not good	>3	3>
	0	50	0	50	0	30	0	30	0	50	0	50
Technical Heavy trouble as same type	Not necessary						Necessary					
	0						80					
Functionary Efficiency, Function, Easiness	Improved efficiency				Improved function & reliability				Improved work ability			
	No		Yes		No		Yes		No		Yes	
			20		0		10		0		10	
Economics Economical effect	Ineffectiveness			Effectiveness (small)			Effectiveness (medium)			Effectiveness (large)		
	0			10			30			50		
Performance Stoppage, Economically	Ineffectiveness			Effectiveness			Ineffectiveness			Effectiveness (large)		
	0			50			0			50		
Valuable Power Source Expectation Pumping P/S, System share)	Expectation (small)				Expectation (medium)				Expectation (large)			
	0				10				20			
Management System CMMS(Analysis, Evaluation)	Unnecessary						Necessary					
	0						100					
System Coordination Protective relays	Coordination				Kind of relays				Applied equipment			
	Unnecessary		Necessary		B & C		A		Tr.	Bus	PSS	Line
	0		30		10		20		20	30	40	50
Risk Assessment Evaluation of effectiveness in faults	Black out		Turbine/generator stoppage						Spilled water			
	No	Yes	No		less 3 days		over 3 days		No		Yes	
	0	50	0		30		50		0		20	

Evaluation-1 (Compliance)
Evaluation-2 (Safety, Environment)
Evaluation 3 to 5 (Maintenance through Risk Assessment)

Table--2 Long and Mid-term Plan

nit: US$

Powerhouse Site	Item	Total	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly
Civil Structures												
(1) O'Moleng		27,800	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780
(2) O'Romis		45,400	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540
(3) Diesel Powerhouse		8,000	800	800	800	800	800	800	800	800	800	800
(4) Administration		11,900	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190
Sub-total		93,100	9,310	9,310	9,310	9,310	9,310	9,310	9,310	9,310	9,310	9,310
Electric Facilities												
(1) O'Moleng		153,014	4,586	4,586	4,586	4,586	22,445	4,586	4,586	22,445	4,586	76,021
(2) O'Romis		143,525	4,302	4,302	4,302	4,302	21,053	4,302	4,302	21,053	4,302	71,307
(3) Diesel Powerhouse		193,088	5,699	5,699	5,699	5,699	31,217	5,699	5,699	31,217	90,760	5,699
(4) Administration		0	0	0	0	0	0	0	0	0	0	0
(5) Common		40,468	3,035	3,035	3,035	3,035	8,094	3,035	3,035	8,094	3,035	3,035
Sub-total		530,095	17,622	17,622	17,622	17,622	82,809	17,622	17,622	82,809	102,683	156,062
Transmission and Distributuion Line												
		277,780	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778
Total		**900,975**	**54,710**	**54,710**	**54,710**	**54,710**	**119,897**	**54,710**	**54,710**	**119,897**	**139,771**	**193,150**

Table-3 Medium & Long Term Plan for Civil Facilities

Unit: US$

Place	Item	Total	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly
O'Moleng PS	Repairment of Acces Path	2,000	200	200	200	200	200	200	200	200	200	200
	Repaorment of Stone Gurad Fence	1,200	120	120	120	120	120	120	120	120	120	120
	Repairment of Slope Protection	1,300	130	130	130	130	130	130	130	130	130	130
	Repairment of Drainage ditch	1,700	170	170	170	170	170	170	170	170	170	170
	Repairment of the Intake Weir	10,800	1,080	1,080	1,080	1,080	1,080	1,080	1,080	1,080	1,080	1,080
	Repairment of Powerhouse Building	3,500	350	350	350	350	350	350	350	350	350	350
	Maintenance of Gate, Trashrack	800	80	80	80	80	80	80	80	80	80	80
	Maintenance of Penstock	2,900	290	290	290	290	290	290	290	290	290	290
	Repairiment of Retaining Wall	400	40	40	40	40	40	40	40	40	40	40
	Repairment of River Protection	1,200	120	120	120	120	120	120	120	120	120	120
	Miscellaneous Work	2,000	200	200	200	200	200	200	200	200	200	200
Total		27,800	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780
O'Romis PS	Repairment of Acces Path	7,000	700	700	700	700	700	700	700	700	700	700
	Repaorment of Stone Gurad Fence	5,300	530	530	530	530	530	530	530	530	530	530
	Repairment of Slope Protection	3,100	310	310	310	310	310	310	310	310	310	310
	Repairment of Drainage ditch	400	40	40	40	40	40	40	40	40	40	40
	Repairment of the Intake Weir	3,500	350	350	350	350	350	350	350	350	350	350
	Repairment of Waterway	3,900	390	390	390	390	390	390	390	390	390	390
	Maintenance of Penstock	12,000	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
	Maintenance of Gate, Trashrack	1,100	110	110	110	110	110	110	110	110	110	110
	Repairiment of Retaining Wall	3,000	300	300	300	300	300	300	300	300	300	300
	Repairment of Powerhouse Building	1,200	120	120	120	120	120	120	120	120	120	120
	Repairment of River Protection	900	90	90	90	90	90	90	90	90	90	90
	Miscellaneous Work	4,000	400	400	400	400	400	400	400	400	400	400
Total		45,400	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540
Administration Office	Repairment of the Building	10,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	Repairment of the Fence	900	90	90	90	90	90	90	90	90	90	90
	Miscellaneous Work	1,000	100	100	100	100	100	100	100	100	100	100
Total		11,900	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190
Diesel PS	Repairment of Powerhouse Building	8,000	800	800	800	800	800	800	800	800	800	800
Total		8,000	800	800	800	800	800	800	800	800	800	800
Grand Total		**93,100**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**

Table-4 Medium & Long Term Plan for Electrical Facilities

Unit : US$

Power Station	Description	Total	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly
(1)O'Moleng												
1. Asset & Repaire Cost	1.1Hydripower generating facility(Turbine/generator)	25,359	2,536	2,536	2,536	2,536	2,536	2,536	2,536	2,536	2,536	2,536
	1.2Control equipment(Control, protection relay)	5,143	514	514	514	514	514	514	514	514	514	514
	1.3Others(Aux. spare parts, etc.)	1,072	107	107	107	107	107	107	107	107	107	107
	total	31,574	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157
2. Consignment Cost	2.1Scheduled ordinary inspection	14,287	1,429	1,429	1,429	1,429	1,429	1,429	1,429	1,429	1,429	1,429
	2.2Scheduled detaile inspection	35,718	0	0	0	0	17,859	0	0	17,859	0	0
	2.3Overhaul Work	71,435	0	0	0	0	0	0	0	0	0	71,435
	total	121,440	1,429	1,429	1,429	1,429	19,287	1,429	1,429	19,287	1,429	72,864
Total		153,014	4,586	4,586	4,586	4,586	22,445	4,586	4,586	22,445	4,586	76,021
(2)O'Romis												
1. Asset & Repaire Cost	1.1Hydripower generating facility(Turbine/generator)	23,787	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379
	1.2Control equipment(Control, protection relay)	4,824	482	482	482	482	482	482	482	482	482	482
	1.3Others(Aux. spare parts, etc.)	1,005	101	101	101	101	101	101	101	101	101	101
	total	29,616	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962
2. Consignment Cost	2.1Scheduled ordinary inspection	13,401	1,340	1,340	1,340	1,340	1,340	1,340	1,340	1,340	1,340	1,340
	2.2Scheduled detaile inspection	33,502	0	0	0	0	16,751	0	0	16,751	0	0
	2.3Overhaul Work	67,005	0	0	0	0	0	0	0	0	0	67,005
	total	113,908	1,340	1,340	1,340	1,340	18,091	1,340	1,340	18,091	1,340	68,345
Total		143,525	4,302	4,302	4,302	4,302	21,053	4,302	4,302	21,053	4,302	71,307
(3)Diesel Plant												
1. Asset & Repaire Cost	1.1Dieselpower generating facility(Diesel/generator)	29,771	2,977	2,977	2,977	2,977	2,977	2,977	2,977	2,977	2,977	2,977
	1.2Control equipment(Control, protection relay)	6,465	646	646	646	646	646	646	646	646	646	646
	1.3Others(Aux. spare parts, etc.)	3,743	374	374	374	374	374	374	374	374	374	374
	total	39,979	400	3,998	3,998	3,998	3,998	3,998	3,998	3,998	3,998	3,998
2. Consignment Cost	2.1Scheduled ordinary inspection	17,012	1,701	1,701	1,701	1,701	1,701	1,701	1,701	1,701	1,701	1,701
	2.2Scheduled detaile inspection	51,037	0	0	0	0	25,518	0	0	25,518	0	0
	2.3Overhaul Work	85,061	0	0	0	0	0	0	0	0	85,061	0
	total	153,110	1,701	1,701	1,701	1,701	27,220	1,701	1,701	27,220	86,762	1,701
Total		193,088	5,699	5,699	5,699	5,699	31,217	5,699	5,699	31,217	90,760	5,699
(4)Common Items	Test equipment and Tools, etc.	10,117	0	0	0	0	5,058	0	0	5,058	0	0
	Contingency	30,351	3,035	3,035	3,035	3,035	3,035	3,035	3,035	3,035	3,035	3,035
Total		40,468	3,035	3,035	3,035	3,035	8,094	3,035	3,035	8,094	3,035	3,035
Total of Asset & Repaire Cost		101,169	10,117	10,117	10,117	10,117	10,117	10,117	10,117	10,117	10,117	10,117
Total of Consignment Cost		388,458	4,470	4,470	4,470	4,470	64,598	4,470	4,470	64,598	89,531	142,910
Grand total		**530,095**	**17,622**	**17,622**	**17,622**	**17,622**	**82,809**	**17,622**	**17,622**	**82,809**	**102,683**	**156,062**

Table-5 Medium & Long Term Plan for Transmission & Distribution Facilities

Unit: US$

Power Station	Description	Total	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly
Transmission & Distribution Facilities												
1. Asset & Repair Cost	1. 22kV Overhead Lines	32,876	3,288	3,288	3,288	3,288	3,288	3,288	3,288	3,288	3,288	3,288
	2. 22kV Underground Cable	1,805	181	181	181	181	181	181	181	181	181	181
	3. Pole-mounted Transformer	9,746	975	975	975	975	975	975	975	975	975	975
	4. Watt-hour Meter & accessory	29,128	2,913	2,913	2,913	2,913	2,913	2,913	2,913	2,913	2,913	2,913
	5. VHF FM Radio Set, etc.	31,894	3,189	3,189	3,189	3,189	3,189	3,189	3,189	3,189	3,189	3,189
	Subtotal	105,450	10,545	10,545	10,545	10,545	10,545	10,545	10,545	10,545	10,545	10,545
2. Consignment Cost	1. Bucket Car Inspection	11,600	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160
	2. Switch Station Inspection	5,900	590	590	590	590	590	590	590	590	590	590
	3. Insulated Tools Inspaction	3,650	365	365	365	365	365	365	365	365	365	365
	4. Tree-Cutting & Trimming Work	4,000	400	400	400	400	400	400	400	400	400	400
	5. Periodical Training	5,000	500	500	500	500	500	500	500	500	500	500
	Subtotal	30,150	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015
Total		135,600	13,560	13,560	13,560	13,560	13,560	13,560	13,560	13,560	13,560	13,560
3. Common Items	Test equipment and tools, etc.	10,545	1,054	1,054	1,054	1,054	1,054	1,054	1,054	1,054	1,054	1,054
	Spare parts for disaster restoration	100,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	Contingency	31,635	3,163	3,163	3,163	3,163	3,163	3,163	3,163	3,163	3,163	3,163
Total		142,180	14,218	14,218	14,218	14,218	14,218	14,218	14,218	14,218	14,218	14,218
Total of Asset & Repair Cost		247,630	24,763	24,763	24,763	24,763	24,763	24,763	24,763	24,763	24,763	24,763
Total of Consignment Cost		30,150	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015
Grand Total		277,780	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778

4. Prospect of Tariff Rate after Connecting with Vietnam

The current tariff rate was set in June 2009. The costs for tariff calculation consisted of two parts: costs of hydropower and those of diesel power including fuel costs. In June 2010, EUMP was transferred to EDC. EDC forthwith embarked on a study on power import from Vietnam with 22 kV transmission line in order to meet future power demand. Electricity from Vietnam is planned to be provided to Sen Monorom city in 2012.

Such a new stage will require a fundamental tariff revision because the cost components for power supply will be changed. A rough estimation of future tariff after connecting with Vietnam is presented here.

(1) Preconditions

1) Hydropower is to make the utmost utilization of river discharge, so that the hydropower plants will be operated for base load.

2) Imported energy will be supplied for middle and peak loads.

3) The diesel power plant will basically be put for standby and used for swing operation in order to maintain stability of the power system when power demand much fluctuates, especially at evening time.

4) The medium-voltage connecting line with Vietnam will be constructed with EDC's own funds and be recovered from tariff collection.

(2) Simulations

Basic case: 1,200MWh of annual energy consumption based on power demand in 2009, (to be covered by hydropower and diesel power)

Year 2012 case: 2,000MWh of annual energy consumption (since connecting with Vietnam)

Year 2014 case: 3,000MWh of annual energy consumption (same condition, as above)

Year 2016 case: 5,000MWh of annual energy consumption (same condition, as above)

(3) Result and Comments

<u>Result</u>

The result of simulation is summarized in the following figure. Initially, the unit cost drastically decreases at the beginning of power import from Vietnam. Thereafter, the unit cost goes down gradually to finally levels off when the annual energy consumption exceeds 5,000MWh.

Indicated in red line is a suggested tariff rate for sustainable electric utility service by Mondul Kiri power system.

Comments

The tariff rate should be revised according to change of the unit cost in such a way to cover the unit cost and the replacement costs of facilities or investment for future expansion.

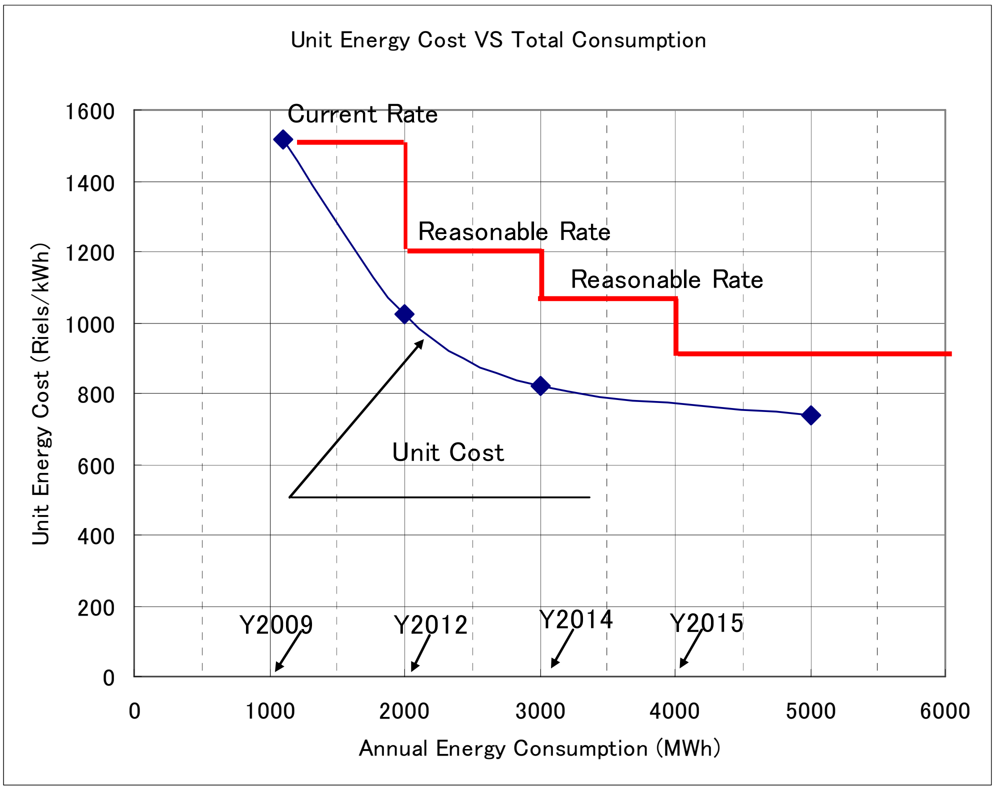


Table-6 Case 2012 Assumed Tariff Rate after connection with Viet Nam (Simplified and Approximate calculation)

: Input data

Item	Unit	Basic Model : Isolated net work using D/G Energy Demand Level : Year 2009		Future Condition : Connected with Vietnam Energy Demand Level : **2,000MWh**	
Ⅰ.O&M Cost (Depreciation of construction is not included)					
1. Total (Annual)					
a Ration supply energy		100%		100%	
b Energy sold	MWh/year	1,200	year 2009 level	2,000	Assumed maximum peak demand is 1000kW
c Salary and overhead cost	US$/year	175,000	nearly actual record	220,000	plus additional T/D cost
d Fuel Cost for D/G	US$/year	96,000	(p*m): coefficient 0.35 kWh/litter	32,000	emergency use only
d' Provision for Overhaul of Grant facility	US$/year	120,000	Instead of depreciation cost of Grant facility	120,000	Instead of depreciation cost of Grant facility
e Import energy cost	US$/year		N.A	76,456	(x*s): from Vietnam to Mondul kiri
f Sub-total	US$/year	391,000	(c+d+e): excluding depreciation cost	448,456	(c+d+e): excluding depreciation cost
2. Hydropower					
h Ration supply energy	%	75%	Conservative side	60%	
i Energy by hydropower	MWh/year	900	(b*h): About 60% of Energy is no used caused by energy demand pattern, Surplus energy	1,200	Base supply operation: surplus energy become to be used. Potential energy may be about 2,000 MWh/ year
j Salary and overhead	US$/year	131,250	(c*h): Cost allocation in line with amount of each energy source	132,000	(c*h): Cost allocation in line with amount of each energy source
k Generation Cost of Hydropower	US$/kWh	**0.15**	(j/i): →	**0.11**	(j/i) :
3. D/G					
l Ration supply energy	%	25%	(a-h):	5%	Use to be stable HZ and Voltage at Peak time
m Energy by D/G	MWh/year	300	(b-i): Auxiliary power source	100	(b*l): Auxiliary power source
n Salary and overhead	US$/year	43,750	(c*l): Cost allocation in line with amount of each energy source	11,000	(c*l): Cost allocation in line with amount of each energy source
o Generation Cost excluding Fuel cost	US$/year	0.15	(n/m): nearly same value of hydropower	0.11	(n/m): nearly same value of hydropower
p Fuel Cost	US$/kWh	0.32	1US$ per litter	0.32	1US$ per litter
q Generation Cost of D/G	US$/kWh	0.47	(o+p):	0.43	(o+p):
4. Import Energy from Viet Num					
r Ration supply energy			N.A.	35%	
s Energy imported from Viet Num	MWh/year		N.A.	805	(b-i): Auxiliary power source
t Salary and overhead	US$/year		N.A.	88,000	(c*r): Cost allocation in line with amount of each energy
u O&M cost for T/D	US$/kWh		N.A.	0.11	(t/s): O&M cost for additional T/D
Construction Cost of T/D	US$			650,000.00	
Annual Depreciation Cost	US$/year			32,500.00	20 Year
Depreciation Cost per kWh	US$/kWh			0.006	
v Electric price at the border	US$/kWh	0.069	FOB price from Vietnam in 2008 base	0.069	FOB price from Vietnam in 2008 base
v2 Import tax and VAT		0.012	7% of import, 10% of VAT	0.012	7% of import, 10% of VAT
w Transmission loss	%		N.A.	15%	Loss ratio: shall be analyzed in detail
x Electric Cost including T/D loss	US$/kWh		N.A.	0.095	(v2*1/(1-w)):
y Energy Cost of imported at demand point	US$/kWh		N.A.	0.21	(u+x):
5. Combined Energy Generation Unit Cost					
g Energy Generation Cost	US$/kWh	0.33	(f/b): including **Provision(d')**	0.22	(f/b): including **Provision(d')**
Ⅱ. Revenue					
z Income (considering commercial loss and including provision and profit)	US$/kWh	0.37	3% revenue loss and 10% of profit	0.25	3% revenue loss and 10% of profit
	Riel/kWh	**1,510**		**1,039**	

Remind !

1. Unit Cost of Energy is **not Constant**. It's depend on amount of energy sold.
2. This sheet shows that **unit cost of hydropower will decrees after connection with Vietnam**

Table-7 Case 2014 Assumed Tariff Rate after connection with Viet Nam (Simplified and Approximate calculation)

Item	Unit	Basic Model : Isolated net work using D/G Energy Demand Level : Year 2009		Future Condition : Connected with Vietnam Energy Demand Level : 3,000MWh	
Ⅰ.O&M Cost (Depreciation of construction is not included)					
1. Total (Annual)					
a Ration supply energy		100%		100%	
b Energy sold	MWh/year	1,200	year 2009 level	3,000	Assumed maximum peak demand is 1000kW
c Salary and overhead cost	US$/year	175,000	nearly actual record	220,000	plus additional T/D cost
d Fuel Cost for D/G	US$/year	96,000	(p*m): coefficient 0.35 kWh/litter	48,000	emergency use only
d' Provision for Overhaul of Grant facility	US$/year	120,000	Instead of depreciation cost of Grant facility	120,000	Instead of depreciation cost of Grant facility
e Import energy cost	US$/year		N.A	147,451	(x*s): from Vietnam to Mondul kiri
f Sub-total	US$/year	391,000	(c+d+e): excluding depreciation cost	535,451	(c+d+e): excluding depreciation cost
2. Hydropower					
h Ration supply energy	%	75%	Conservative side	50%	
i Energy by hydropower	MWh/year	900	(b*h): About 60% of Energy is no used caused by energy demand pattern, Surplus energy	1,500	Base supply operation: surplus energy become to be used. Potential energy may be about 2,000 MWh/ year
j Salary and overhead	US$/year	131,250	(c*h): Cost allocation in line with amount of each energy source	110,000	(c*h): Cost allocation in line with amount of each energy source
k Generation Cost of Hydropower	US$/kWh	**0.15**	(j/i): ⟶	**0.07**	(j/i) :
3. D/G					
l Ration supply energy	%	25%	(a-h):	5%	Use to be stable HZ and Voltage at Peak time
m Energy by D/G	MWh/year	300	(b-i): Auxiliary power source	150	(b*l): Auxiliary power source
n Salary and overhead	US$/year	43,750	(c*l): Cost allocation in line with amount of each energy source	11,000	(c*l): Cost allocation in line with amount of each energy source
o Generation Cost excluding Fuel cost	US$/year	0.15	(n/m): nearly same value of hydropower	0.07	(n/m): nearly same value of hydropower
p Fuel Cost	US$/kWh	0.32	1US$ per litter	0.32	1US$ per litter
q Generation Cost of D/G	US$/kWh	0.47	(o+p):	0.39	(o+p):
4. Import Energy from Viet Num					
r Ration supply energy			N.A.	45%	
s Energy imported from Viet Num	MWh/year		N.A.	1,553	(b-i): Auxiliary power source
t Salary and overhead	US$/year		N.A.	110,000	(c*r): Cost allocation in line with amount of each energy source
u O&M cost for T/D	US$/kWh		N.A.	0.07	(t/s): O&M cost for additional T/D
Construction Cost of T/D	US$			650,000.00	
Annual Depreciation Cost	US$/year			32,500.00	20 Year
Depreciation Cost per kWh	US$/kWh			0.005	
v Electric price at the border	US$/kWh	0.069	FOB price from Vietnam in 2008 base	0.069	FOB price from Vietnam in 2008 base
v2 Import tax and VAT		0.012	7% of import, 10% of VAT	0.012	7% of import, 10% of VAT
w Transmission loss	%		N.A.	15%	Loss ratio: shall be analyzed in detail
x Electric Cost including T/D loss	US$/kWh		N.A.	0.095	(v2*1/(1-w)):
y Energy Cost of imported at demand point	US$/kWh		N.A.	0.17	(u+x):
5. Combined Energy Generation Unit Cost					
g Energy Generation Cost	US$/kWh	0.33	(f/b): including **Provision(d')**	0.18	(f/b): including **Provision(d')**
Ⅱ. Revenue					
z Income (considering commercial loss and including provision and profit)	US$/kWh	0.37	3% revenue loss and 10% of profit	0.20	3% revenue loss and 10% of profit
	Riel/kWh	**1,510**		**827**	

Table-8 Case 2016 Assumed Tariff Rate after connection with Viet Nam (Simplified and Approximate calculation)

Item	Unit	Basic Model : Isolated net work using D/G Energy Demand Level : Year 2009		Future Condition : Connected with Vietnam Energy Demand Level : **5,000MWh**	
Ⅰ.O&M Cost (Depreciation of construction is not included)					
1. Total (Annual)					
a Ration supply energy		100%		100%	
b Energy sold	MWh/year	1,200	year 2009 level	5,000	Assumed maximum peak demand is 1000kW
c Salary and overhead cost	US$/year	175,000	nearly actual record	220,000	plus additional T/D cost
d Fuel Cost for D/G	US$/year	96,000	(p*m): coefficient 0.35 kWh/litter	80,000	emergency use only
d' Provision for Overhaul of Grant facility	US$/year	120,000	Instead of depreciation cost of Grant facility	120,000	Instead of depreciation cost of Grant facility
e Import energy cost	US$/year		N.A	354,975	(x*s): from Vietnam to Mondul kiri
f Sub-total	US$/year	391,000	(c+d+e): excluding depreciation cost	774,975	(c+d+e): excluding depreciation cost
2. Hydropower					
h Ration supply energy	%	75%	Conservative side	30%	
i Energy by hydropower	MWh/year	900	(b*h): About 60% of Energy is no used caused by energy demand pattern, Surplus energy	1,500	Base supply operation: surplus energy become to be used. Potential energy may be about 2,000 MWh/ year
j Salary and overhead	US$/year	131,250	(c*h): Cost allocation in line with amount of each energy source	66,000	(c*h): Cost allocation in line with amount of each energy source
k Generation Cost of Hydropower	US$/kWh	**0.15**	(j/i): ——→	**0.04**	(j/i) :
3. D/G					
l Ration supply energy	%	25%	(a−h):	5%	Use to be stable HZ and Voltage at Peak time
m Energy by D/G	MWh/year	300	(b−i): Auxiliary power source	250	(b*l): Auxiliary power source
n Salary and overhead	US$/year	43,750	(c*l): Cost allocation in line with amount of each energy source	11,000	(c*l): Cost allocation in line with amount of each energy source
o Generation Cost excluding Fuel cost	US$/year	0.15	(n/m): nearly same value of hydropower	0.04	(n/m): nearly same value of hydropower
p Fuel Cost	US$/kWh	0.32	1US$ per litter	0.32	1US$ per litter
q Generation Cost of D/G	US$/kWh	0.47	(o+p):	0.36	(o+p):
4. Import Energy from Viet Num					
r Ration supply energy			N.A.	65%	
s Energy imported from Viet Num	MWh/year		N.A.	3,738	(b−i): Auxiliary power source
t Salary and overhead	US$/year		N.A.	154,000	(c*r): Cost allocation in line with amount of each energy source
u O&M cost for T/D	US$/kWh		N.A.	0.04	(t/s): O&M cost for additional T/D
Construction Cost of T/D	US$			650,000.00	
Annual Depreciation Cost	US$/year			32,500.00	20 Year
Depreciation Cost per kWh	US$/kWh			0.004	
v Electric price at the border	US$/kWh	0.069	FOB price from Vietnam in 2008 base	0.069	FOB price from Vietnam in 2008 base
v2 Import tax and VAT		0.012	7% of import, 10% of VAT	0.012	7% of import, 10% of VAT
w Transmission loss	%		N.A.	15%	Loss ratio: shall be analyzed in detail
x Electric Cost including T/D loss	US$/kWh		N.A.	0.095	(v2*1/(1−w)):
y Energy Cost of imported at demand point	US$/kWh		N.A.	0.14	(u+x):
5. Combined Energy Generation Unit Cost					
g Energy Generation Cost	US$/kWh	0.33	(f/b): including **Provision(d')**	0.15	(f/b): including **Provision(d')**
Ⅱ. Revenue					
z Income (considering commercial loss and including provision and profit)	US$/kWh	0.37	3% revenue loss and 10% of profit	0.18	3% revenue loss and 10% of profit
	Riel/kWh	**1,510**		**718**	

Remind !

1. Unit Cost of Energy is **not Constant**. It's depend on amount of energy sold.
2. This sheet shows that **unit cost of hydropower will decrees after connection with Vietnam**

3. Suggested Power Tariff (First version)

March 2009
JICA Advisory Team

Proposed Power Rate for Mondol Kiri Hydropower Project

1． Introduction

Electric power facilities constructed in Senmonorom town with a Japanese government donation was started to supply electricity by EUMP in November 2008. To set a power rate properly, it is necessary to accumulate past records of demand and supply and customers; and so, currently a provisional rate is being applied and a regular rate will be proposed in March 2009 toward application in June 2009 based on the data collected till then as determined in the first JCC meeting.

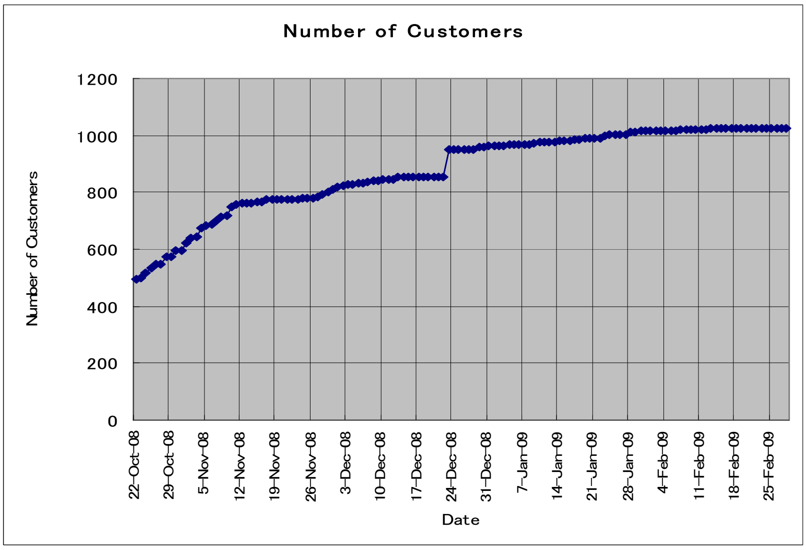
The provisional rate was initially set at 1,800 riel/kWh for residential use and 2,000 riel/kWh for business use such as hotel and guesthouse, which were calculated in August 2008 with an assumed price of diesel fuel at US$ 1.5. The price of diesel fuel dropped abruptly from October 2008 to reach more or less US$ 0.7. This fuel price drop was reflected in the power rate from January 2009 to be 1,600 riel/kWh for residential use and 1,800 riel/kWh for business, that is current price.

The power rate proposed here is the regular one to be approved by EAC based on the past records of demand and supply and customers for 4 months from November 2008, starting month of commercial operation through February 2009. Also proposed is a power tariff in case of price fluctuation of diesel fuel.

2. Current situation of Demand

2.1 Number of Customers

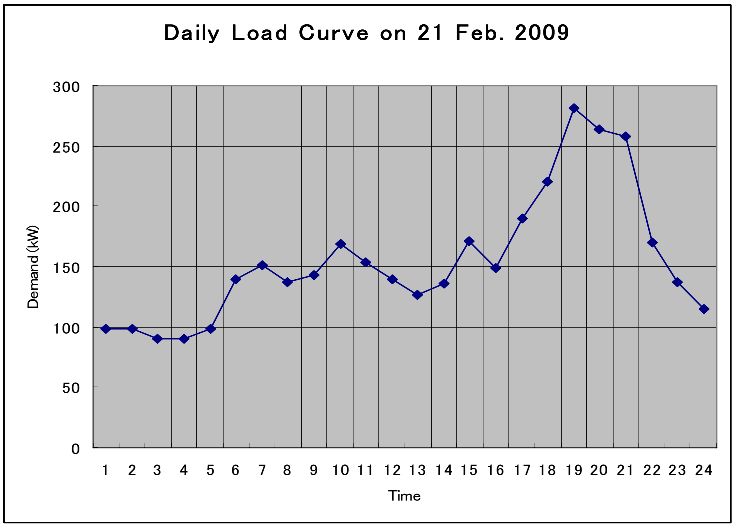
Number of customers on 20th February 2009 is 1,032 households.



March 2009
JICA Advisory Team

2.2 Daily Load Curve

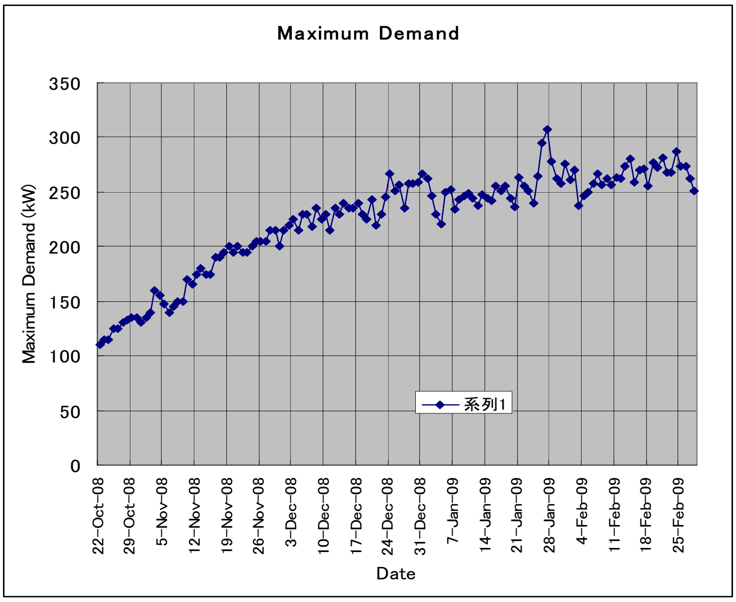
Typical Daily Load Curve, 21st February 2009, is shown bellow:



This value includes transmission loss, that is, total value of all power output.
Daily load factor is to be 50% approximately.

2.2 Maximum Demand

Maximum demand is occurred around 7 P.M.
Recent maximum demand record from 270 to 280 in February, only once over 300kW was recorded on 27th January.



March 2009
JICA Advisory Team

3. Energy Consumption

3.1 Current power rate (as of 20 February 2009)

Table-1 Current rate (provisional) (to be applied from February 2009)

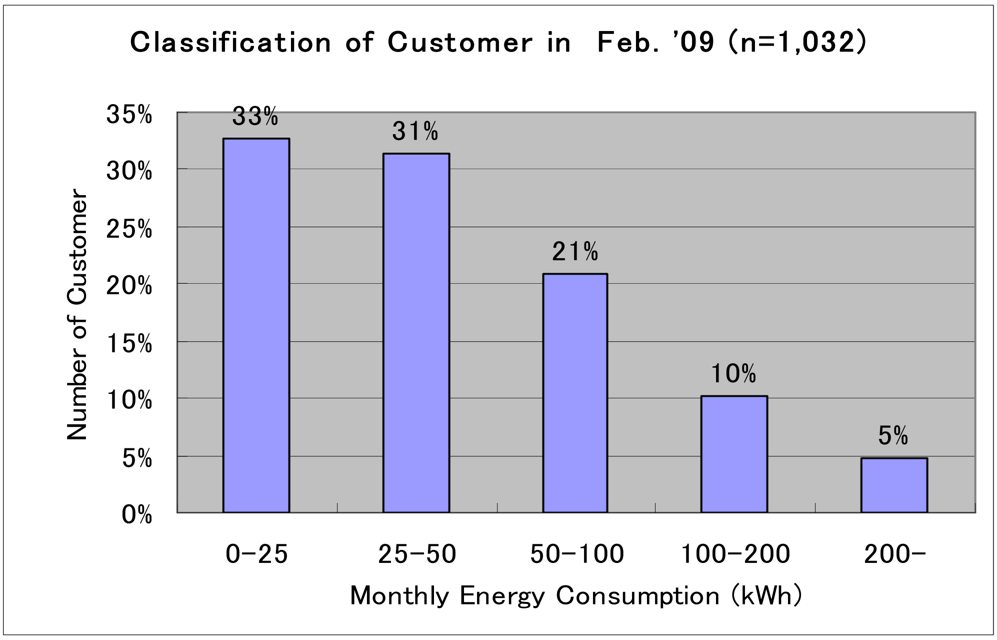
	Category	Power rate (Riel/kWh)	remark
1	Residence and others	1,600	All except the category 2 below
2	Guesthouses, hotels, restaurants and karaoke bars	1,800	Definition of business categories (size) is ambiguous

3.2 Energy Consumption

Conditions for analysis: Analysis was made of 1,032 customers, the number of users as of 20 February 2009. Data were taken for 1 month from20 January 2009 to 20 February 2009. Total power consumption for that one month was 81.7 MWh – excluding that of EUMP – which is translated into 79kWh/month/household.

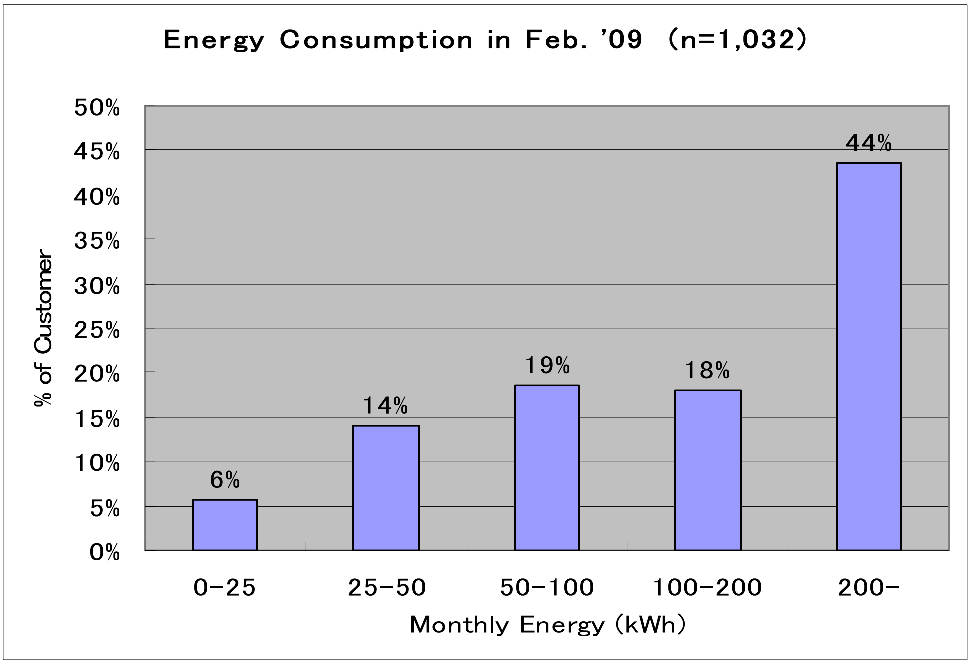
3.3 Customer classification by power consumption

Fig.-1 Classification of Customers by Power Consumption



The above graph shows that 338 customers occupying some 33% of all the customers use electricity less than 25kWh monthly. This customer group is categorized as low-income customer. Future increase of electrification coefficient is targeted at this category of customers.

2.4 Power consumption by customer categories



The customer category of 25kWh and under (33%) occupies only 6% of the total power consumption. In the meantime, the category of 200kWh and over, 5% in the number of customers, use electricity of 44% of the total power consumption. Most of this category is business use such as guesthouses, hotels, restaurants and karaoke bars.

4. Power rate setting

4.1 Basic policy (unchanged as before)

1) All the consumers shall bear the power rates without exception and EUMP shall be operated with the income from them;
2) Priority shall be given to maintaining the financial balance of the corporate operation for stable management;
3) The recovery cost of the power facilities, being donated by Japanese aid, shall not be included in the operation cost and, however, the expenses for inspection, maintenance and repair shall be secured in order to maintain the functions of the power facilities;
4) Capital accumulation shall be made in preparation for future demand

increase; and,

5) Promotion of electrification of low-income group shall be made to the extent to satisfy the above conditions.

4.2 Proposed power tariff

Different power rates are proposed for a range of fuel costs because the generating cost, which is a basis for power rate, is governed by diesel fuel costs.

１） Standard rate

Conditions: Diesel fuel price per liter is between 2,501 riel and 3,000 riel

	Category	Power rate (Riel/kWh)	Applied to
1	Residence	1,450	All except the Category 2 below
2	Business	1,650	Guesthouses, hotels, restaurants and karaoke bars

２） Power rate reflecting fuel price fluctuation

Fuel price (Riel/Litter)	Residence	Business	Remark
2,000 Riel and under	1,290	1,460	-11%
2,001 ～2,500	1,370	1,560	-6%
2,501 ～3,000	1,450	1,650	standard
3,001 ～3,500	1,540	1,750	+6%
3,501 ～4,000	1,620	1,840	+11%
4,001 ～4,500	1,700	1,940	+17%
4,501 ～5,000	1,780	2,030	+23%

It is advisable to take the 3-month average fuel price prior to the power rate revision considering the period of storage and procurement.

4.3 Simulation results of the standard power rate

Conditions:

1) Profit rate should be secured at 10%.
2) The total loss should include the station service and street lamps (some 300 pieces) of EUMP. (to be taken from the actual performance)
3) Diesel fuel price: 0.75 US$/Litter
4) Diesel fuel efficiency is taken from the actual performance.

March 2009
JICA Advisory Team

Table - Summary of operation simulation results（with demand of 2009）

Item	Unit	Value	Remark
I. Energy calculation			
1 Annual energy produced	MWh	1,295	At the transmitting end
2 By hydropower	MWh	927	72% Estimated by past records
3 By diesel power	MWh	369	28% Estimated by past records
4 Fuel consumption	Litter	114,100	0.31 Litter/kWh :fuel consumption rate
5 Annual energy sales	MWh	971	25% :total loss ratio (past record)
II. Financial costs			
1 Personnel	US$	75,250	30 persons: 14 months of monthly payroll
2 Fuel	US$	85,570	0.75 US$/Litter
3 Operating expenses of EUMP	US$	51,600	80 %: proportional to personnel costs (past records)
4 Maintenance and repairs	US$	78,500	Incl. Reserves for overhaul
5 Drought reserves	US$	21,550	10 %: proportional to hydropower energy production
6 Total	US$	312,470	
7 Cost of generation and transmission Cost/kWh	US$/kWh Riel/kWh	0.322 1,287	4,000 Riel/US$
8 As per Effective energy consumption Cost/kWh	US$/kWh Riel/kWh	0.335 1,336	5% Commercial loss considered
9 Weighted average rate 加	US$/kWh Riel/kWh	0.376 1,505	(value entered)
10 Income from power rate	US$	347,160	
11 profit	US$ %	34,690 10%	