付属図書 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.)

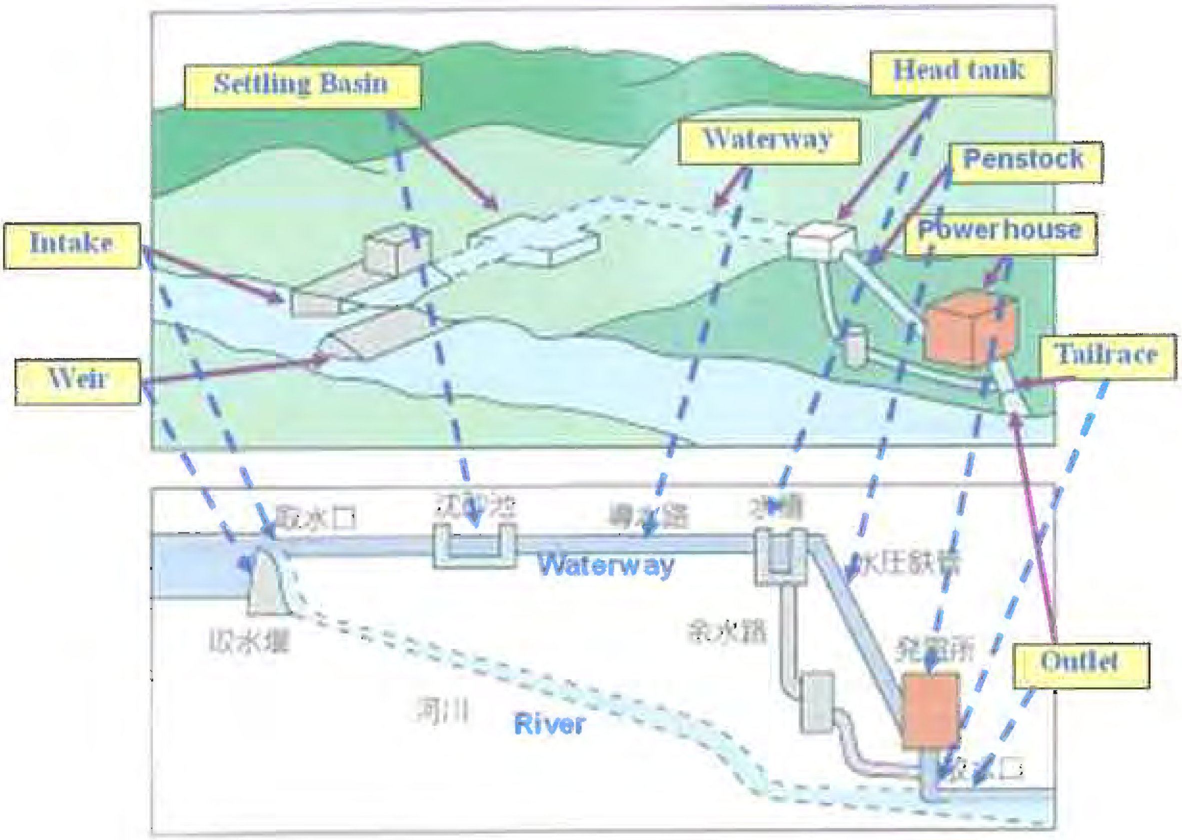
Reference 2: Civil Structure

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

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

1. Components of civil structures for hydropower

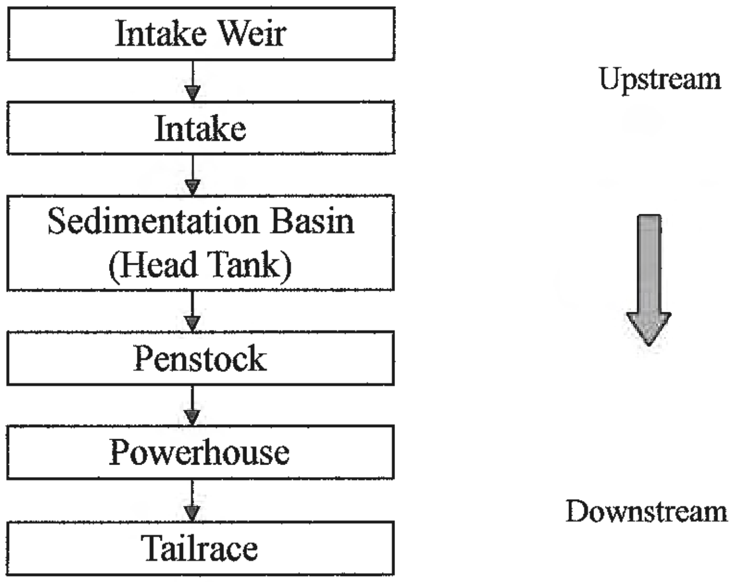
In most case of small hydropower station, when civil structures are arranged from the upstream by its function, it is consisted of intake weir, intake, sedimentation basin, waterway, head tank, penstock, powerhouse, tailrace and outlet (See the figure bellow). Some structures can be curtailed by economical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



2. Components of each hydropower station

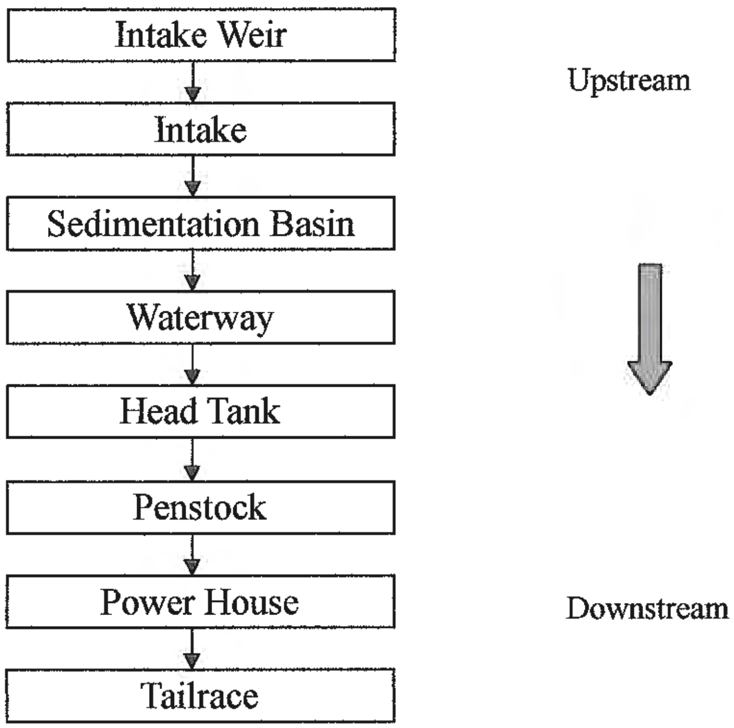
(1) O'Moleng Hydropower Station

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.

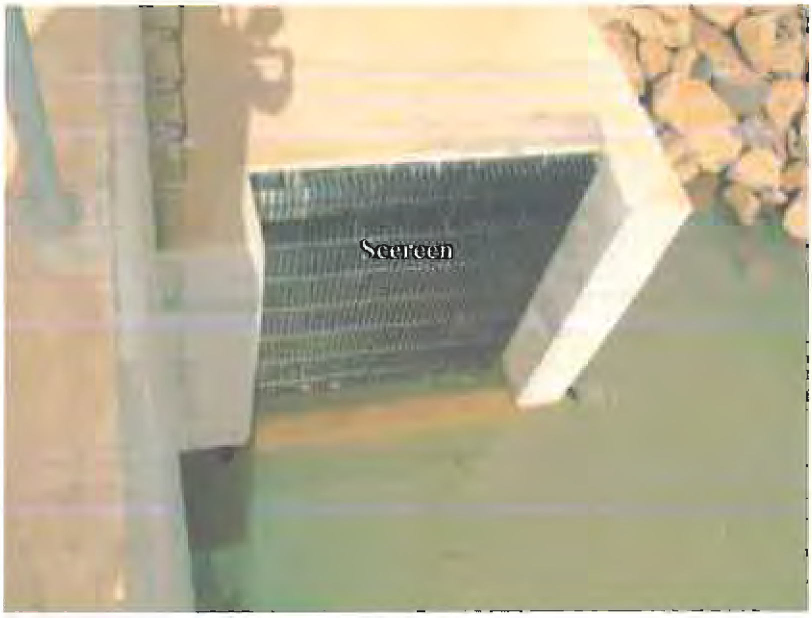
(2) Intake

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

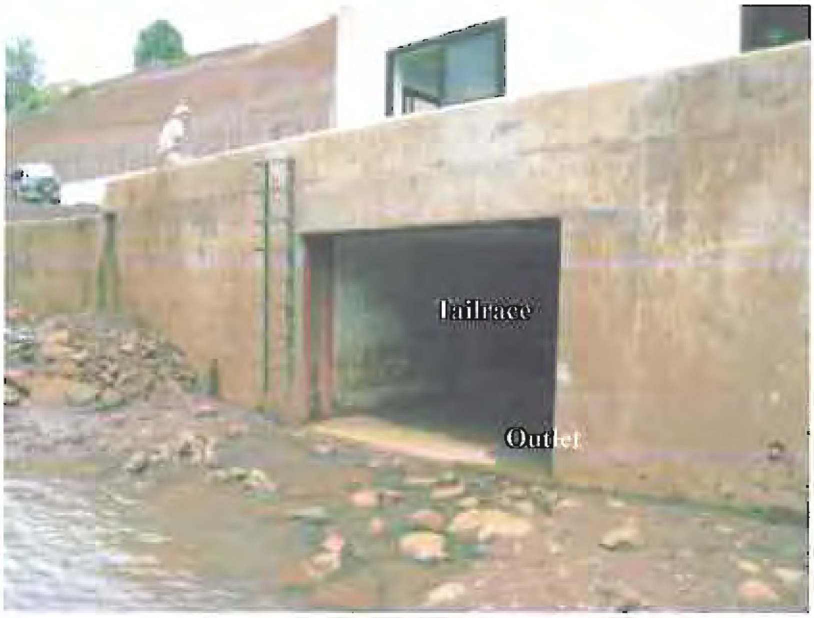
Explanation

- 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

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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.

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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,

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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.

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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,

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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.

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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.

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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,

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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.

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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.

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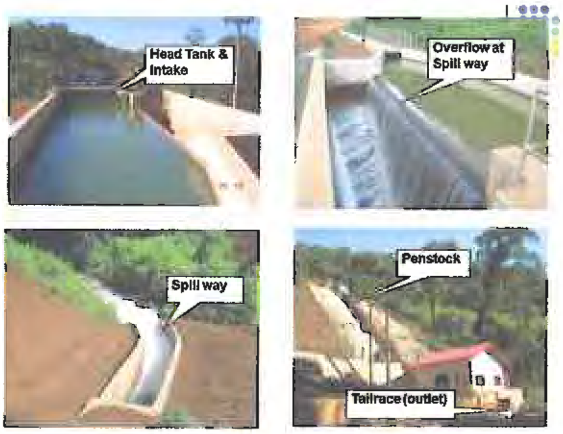

2. O&M for Civil Facilities, Mondul Kiri (4)

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.

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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,

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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.

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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

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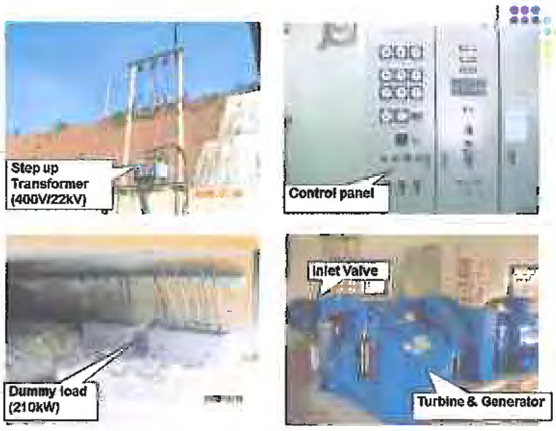

2. Maintenance of Generating Facilities, Mondul Kiri (2)

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

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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

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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.

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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

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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

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Project Summary

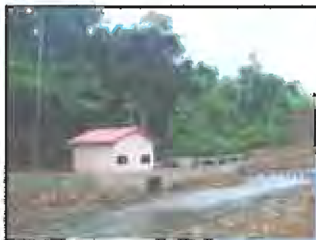
- 1) Hydropower Plant :
- Turbine Type: Cross-flow (Tanaka Suiryoku)
- Turbine out put : O'Moleng 185kW
- O'Romis 185kW
- Generator Type : Synchronous 3-phases generator (Yawata Electric)
- Generator out put : 250kVA, 1,000rpm

2

Project Summary

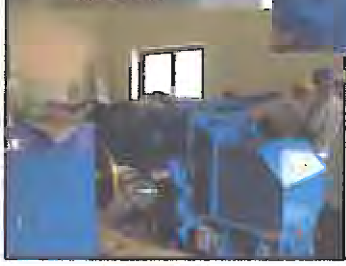
- 2) Diesel Generating Plant :
- Diesel Engine Type: 6DL-16 4cycle (Daihatsu)
- Diesel out put : 322kW, 1,000 rpm
- Generator Type : Synchronous 3-phases generator (Taiyo Electric)
- Generator out put : 375kVA, 1,000rpm
- 3) Transmission Line
- 22kV Transmission lines : 28km
- 400V Distribution lines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

3



O'Moleng P.S

O'Romis P.S



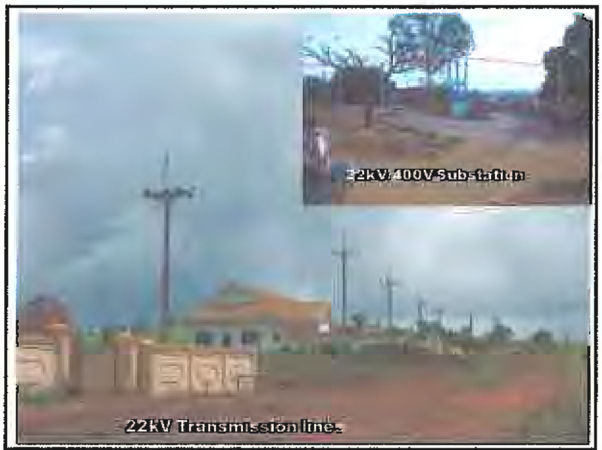
O'Romis Turbine (above)

O'Moleng Turbine (left)

5

Inlet valve

Shop test (Guide vanes)



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.

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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.

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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.

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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.

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1. Five (5) Senses

- Five Senses Technique

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

Finding	Judging
➢Procedures	➢Criteria & Standards
➢Skilled & Senses (check sheets)	➢Statistical Data (inspection records)

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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

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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.

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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.

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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>

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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.

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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

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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

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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

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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.

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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

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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.

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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.

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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

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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

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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-

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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.)

Temp. / Volt (kV)	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

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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

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9. Resistance

1) Conversion of Measured Resistance

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

$R20\ (\Omega) = (234.5 + 20/234.5 + t1) \times Rt1$

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.)

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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.

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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.

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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.

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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.

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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.Inflow 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.

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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.

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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.

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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.Inflow 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.

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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.

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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

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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

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12. International Standards

10) ANSI: American National Standards Institute
11)ASTM: American Society for testing and Materials
12)AWS: American Welding Society
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17)VDE: Verbard Deutscher Elektrotechniker
18)BS: British Standard
19)NF: Norme Francaise
20)API: American Petroleum Institute

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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,

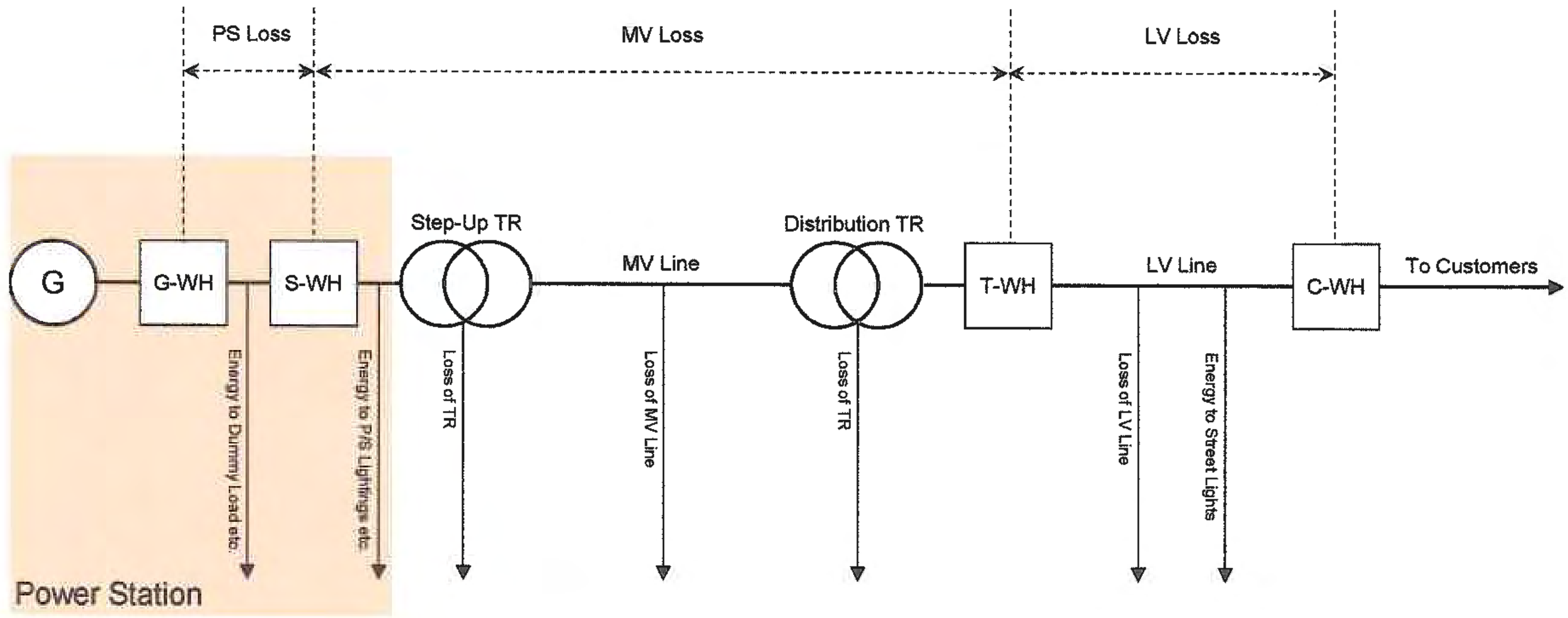
"PS Loss" includes Energy to Dummy Load etc.
"MV Loss" includes Energy to P/S Lightings, Loss of TR, Loss of MV Line etc.
"LV Loss" includes Loss of LV Line, Energy to Street Lights.

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.)

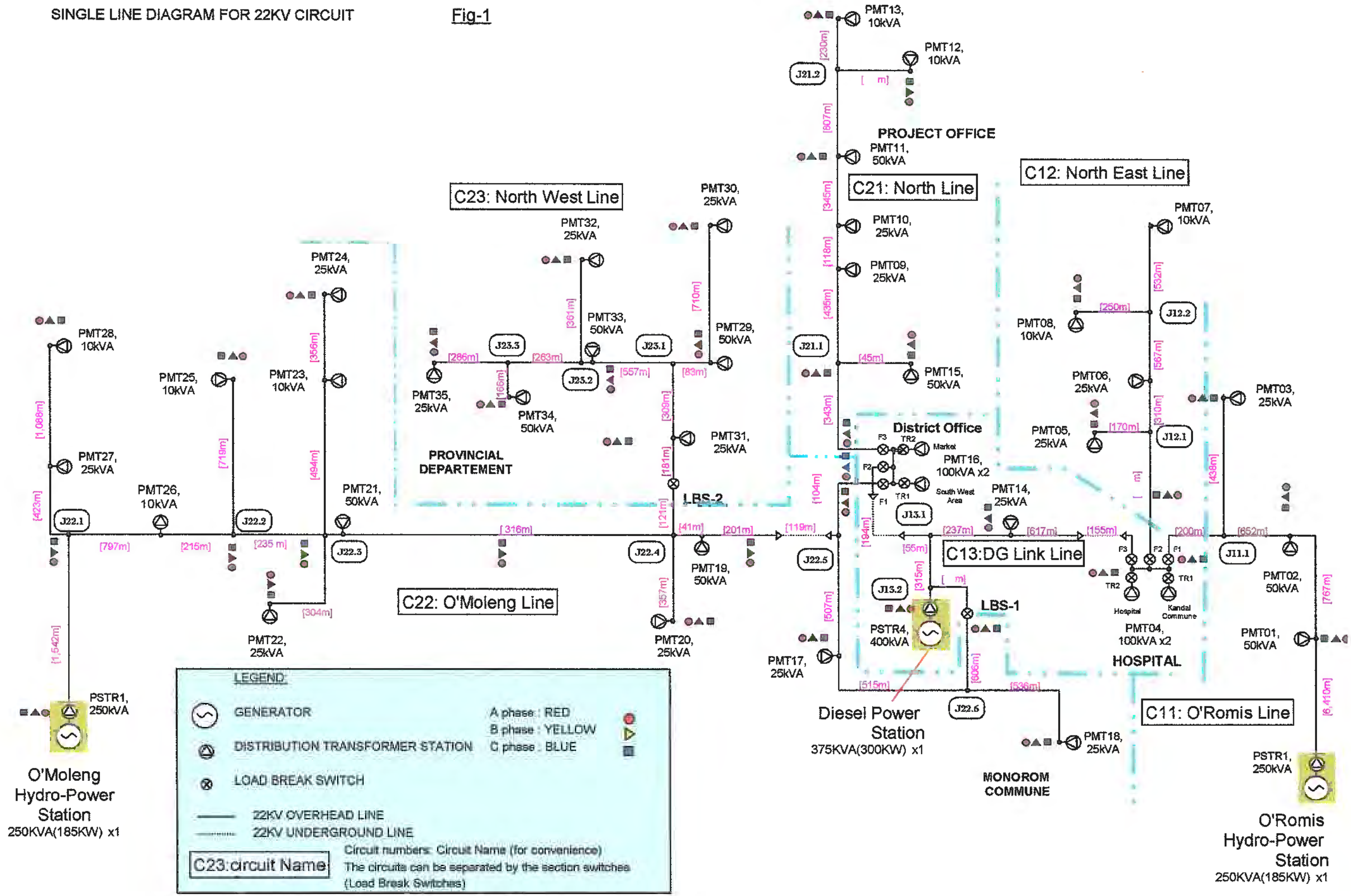
** Loading order may be prioritized from the needs of demand. It will be considered from the experience of operations.

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

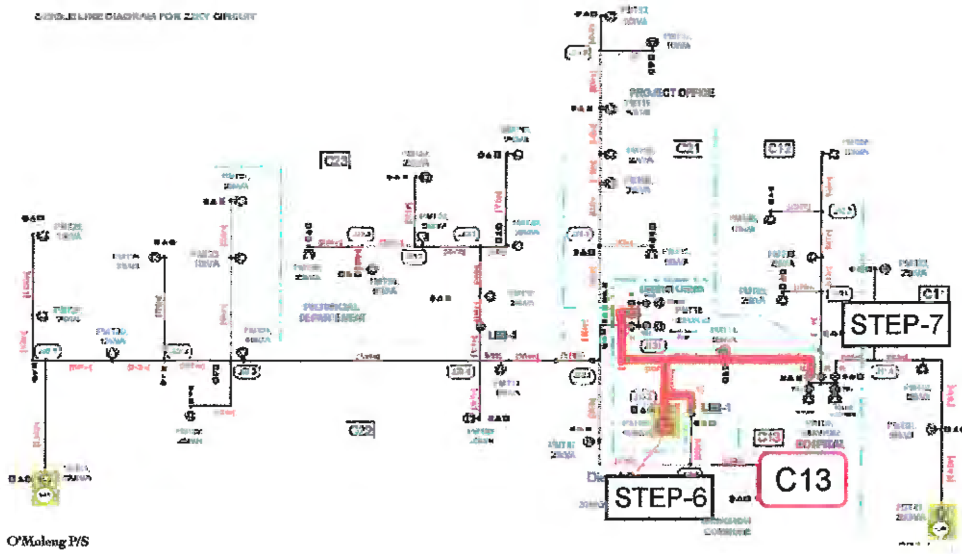


Fig-2

Step-8: C11 Charging

Step-9: O'Romis Start

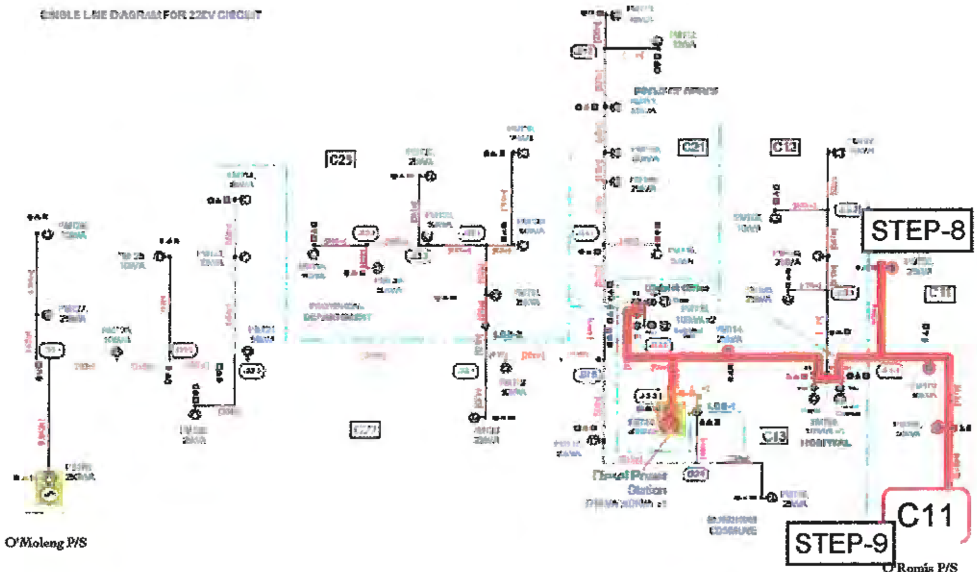


Fig-3

Step-10: C22 Charging

Step-11: O'Moleng Start

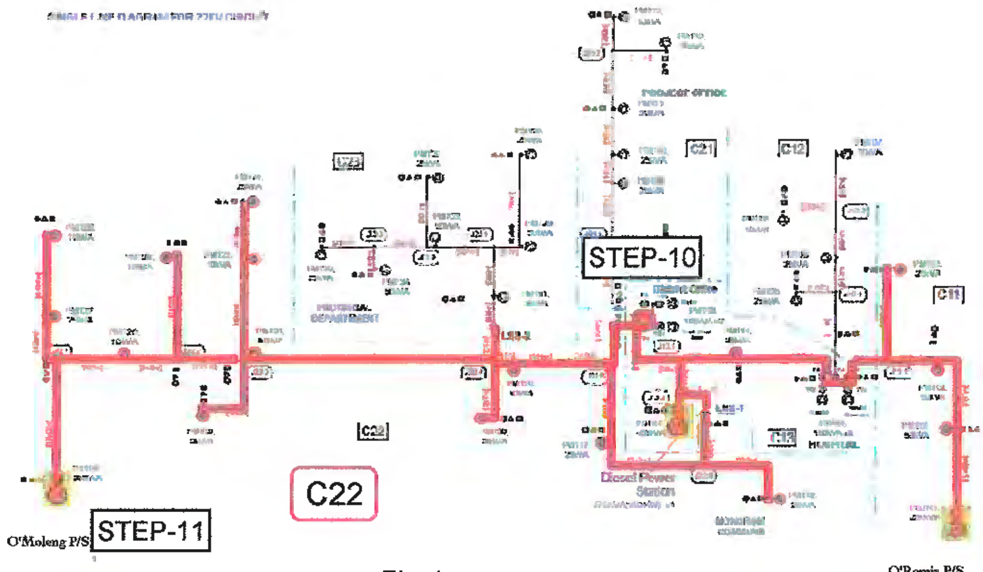


Fig-4

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

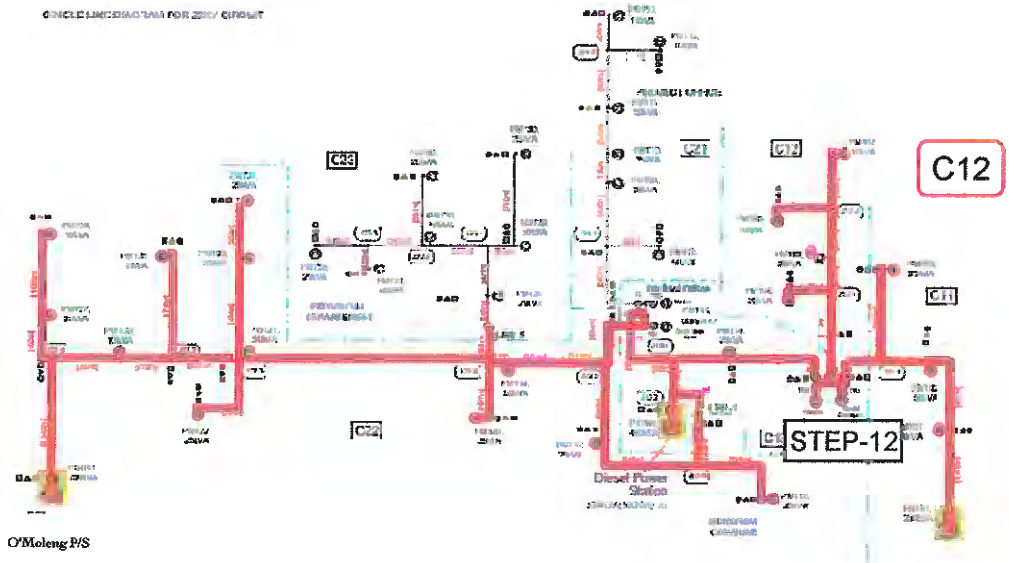


Fig-5

Step-13: C21 Charging

Market Service Transformer

South West Area from Market

C21:North Area

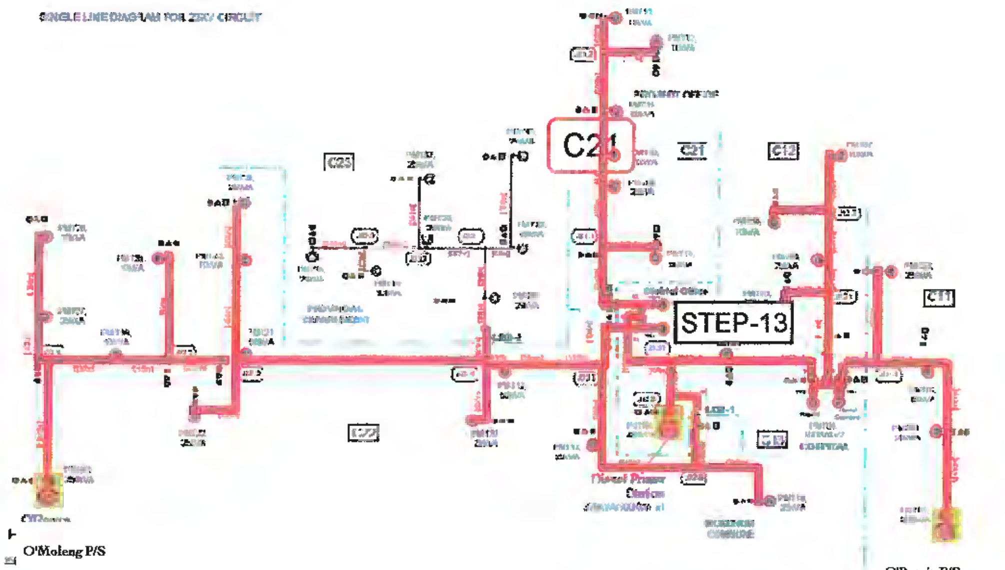


Fig-6

Step-14: C23 Charging

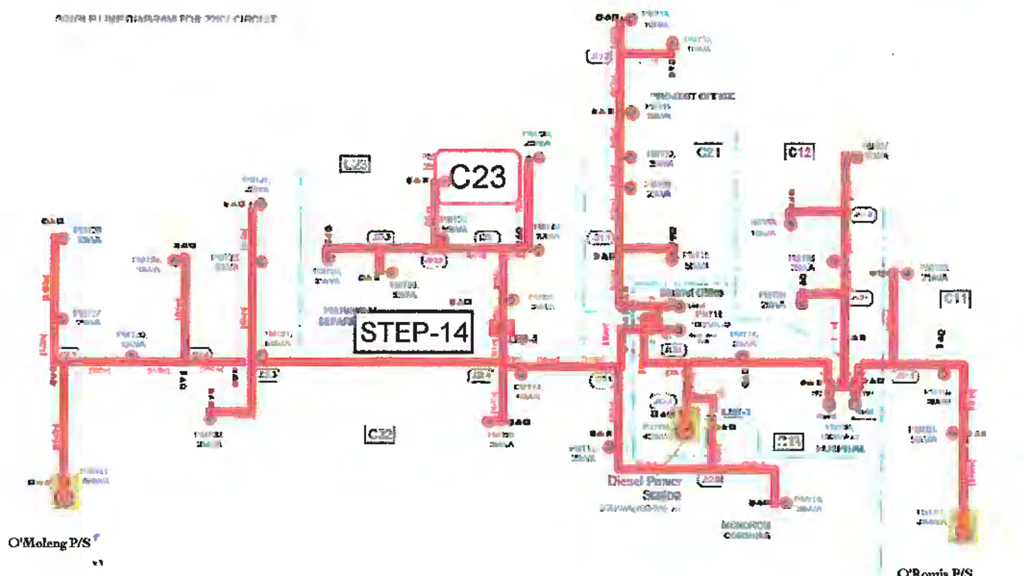


Fig-7

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

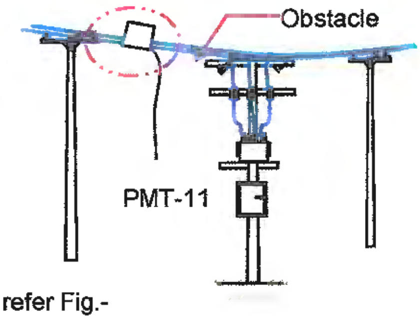
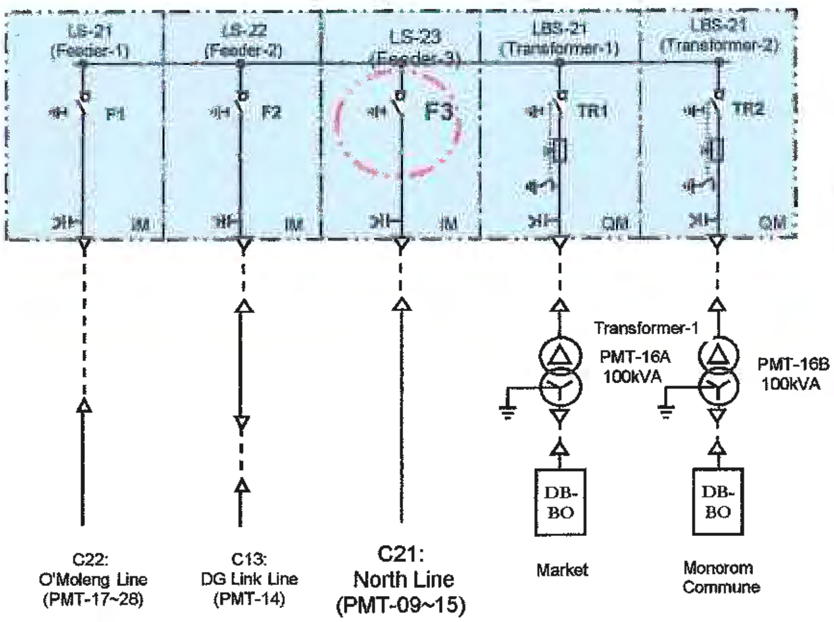


Fig.-2: Single Line Diargram of District Office S/S cubicle



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

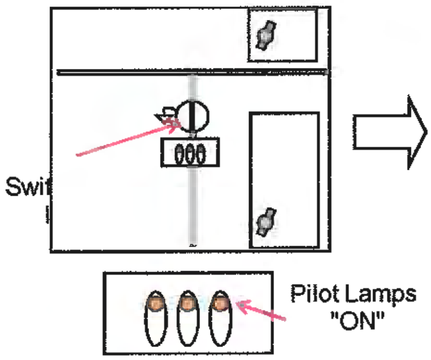


Fig.-4: LBS Opening

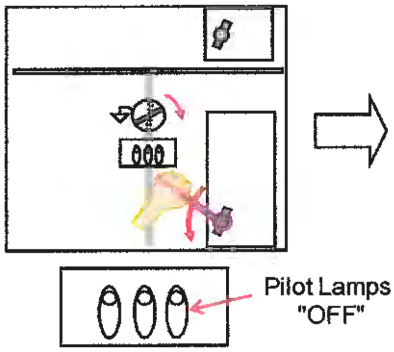
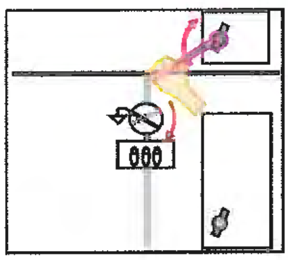


Fig.-5: LBS Earthing



(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.

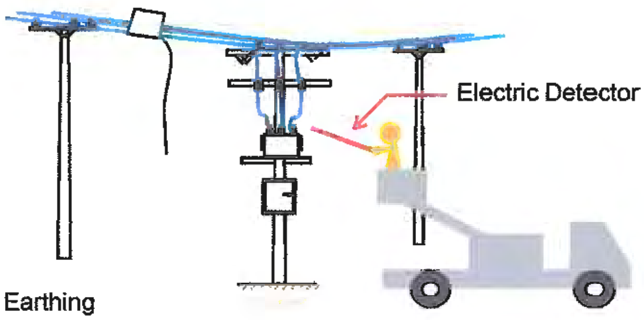


Fig.-6: Circuit Voltage Check

[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)

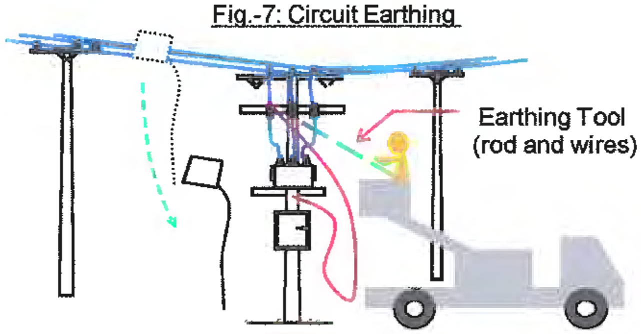


Fig.-7: Circuit Earthing

(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.

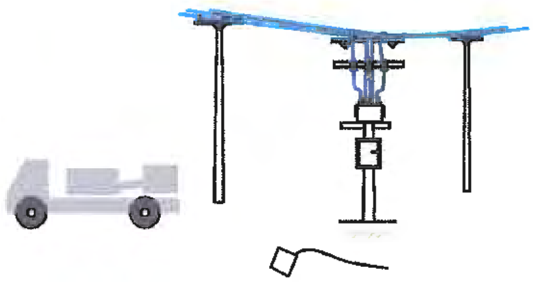


Fig.-8: Removing Earthing tools

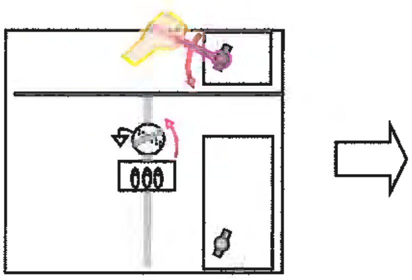


Fig.-9: Opening Earthing Switch

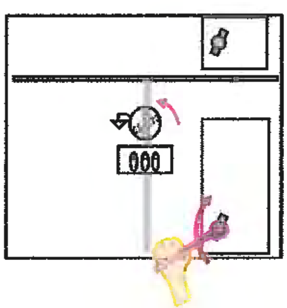


Fig.-10: Closing LBS:F3

R-4-4 Removing an Obstacle from 22kV Overhead line

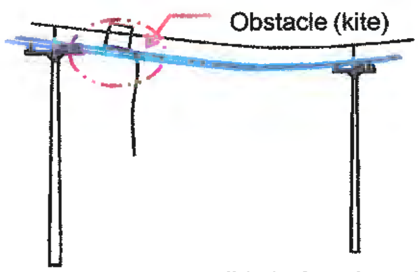
(Example: The obstacle is on the 22kV line from O'Romis Power Sta tion)

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:

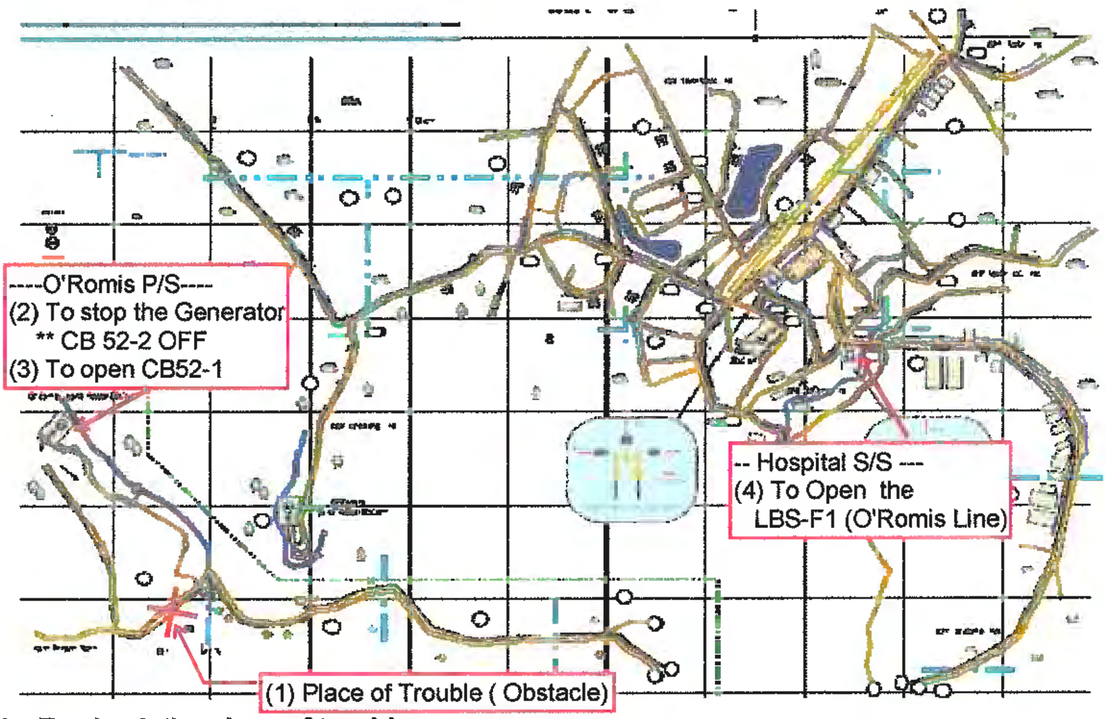
A kite is hanging on the overhead earth-wire. (Fig.-1) It seems not so big trouble. But, when the strong rain will come, this kite make a water rout form the earth-wire to the live conductors. (The kite will conduct the water-drop from the earth-wire to the live conductors. It has potential to bring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

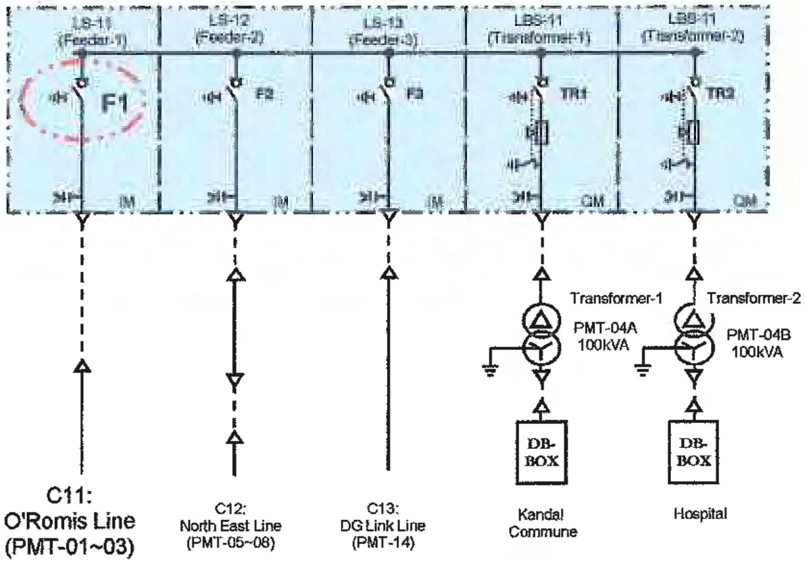


Fig.-4: LBS closed Position

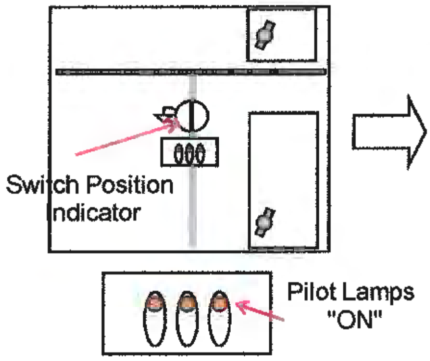


Fig.-5: LBS Opening

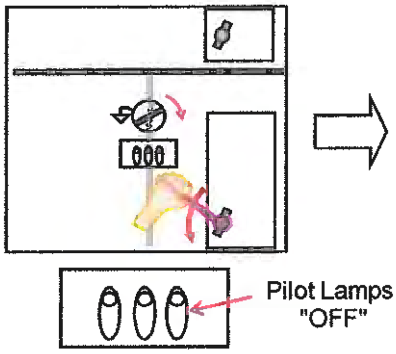
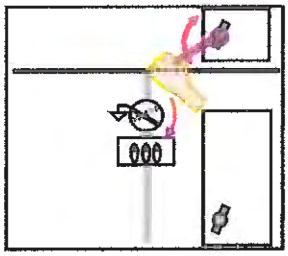


Fig.-6: LBS Earthling



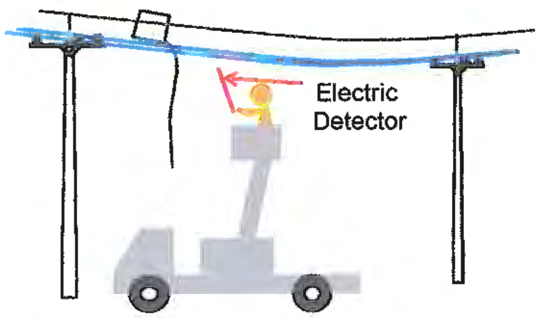
(5) Working at Obstacle

[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.

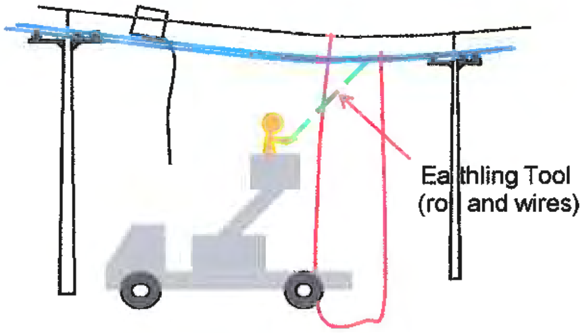
[2] If there is the voltage, to confirm the process from first to now. Do not proceed forward.

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)

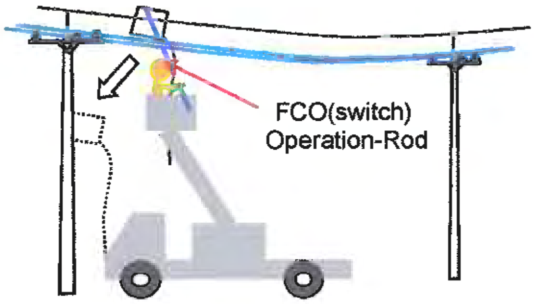
Fig.-8: Circuit Earthling



(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

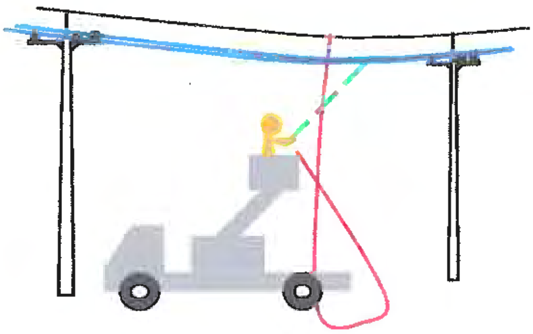


Fig.-11: Opening Earthling Switch

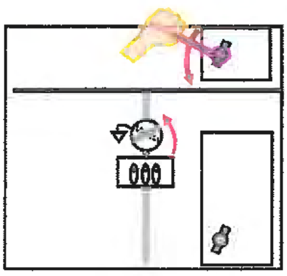
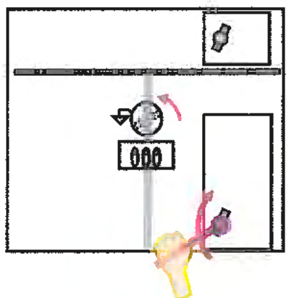


Fig.-12: Closing LBS-F1



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:

$$45 \times 100/5 = 45 \times 20 = 900 \text{ [KWh]}$$

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
PMT-01	x 20
PMT-02	x 20
PMT-03	x 10
PMT-04A	x 50
PMT-04B	x 1
PMT-05	x 10
PMT-06	x 10
PMT-07	x 1
PMT-08	x 1
PMT-09	x 10
PMT-10	x 10
PMT-11	x 20
PMT-12	x 1
PMT-13	x 1
PMT-14	x 10
PMT-15	x 20
PMT-16A	x 1
PMT-16B	x 50

Transformer Number	Multiplying factor
PMT-17	x 10
PMT-18	x 10
PMT-19	x 20
PMT-20	x 10
PMT-21	x 20
PMT-22	x 10
PMT-23	x 1
PMT-24	x 10
PMT-25	x 1
PMT-26	x 1
PMT-27	x 10
PMT-28	x 1
PMT-29	x 20
PMT-30	x 10
PMT-31	x 10
PMT-32	x 10
PMT-33	x 20
PMT-34	x 20
PMT-35	x 10

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

R-4-6

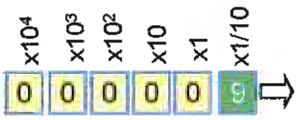
Last digit reading manner for Watt-hour meter

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.

To round-down at reading of 1/10 digit



0.9 kWh

figure-1

159.7 kWh

figure-2

5159.7 kWh

figure-3

Monthly energy consumption is conducted as follows:

372.2 - 159.7 = 212.5 [KWh]

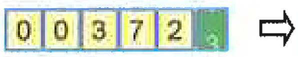
In case of figure-4 and figure-5, the monthly consumption is 212.5 kilo-watt hour [KWh]

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

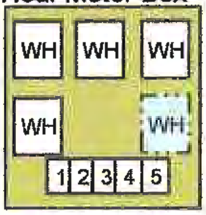
R-4-7

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．中長期計画書（改訂版）

独立行政法人 国際協力機構
カンボジア国鉱工業エネルギー省

モンドルキリ州小水力地方電化計画の運営・維持管理プロジェクト

モンドルキリ州電力公社 中長期事業戦略

（土木構造物・発電施設・送配電設備のメンテナンスおよび電気料金改定の見通し）

2011 年 2 月

電源開発株式会社
中国電力株式会社

モンドルキリ州小水力地方電化中長期事業戦略提出状

モンドルキリ州小水力地方電化維持運営 JICA スタディチームとして同地方電化のための中長期事業戦略を提出いたしますので、ご査収方よろしくお願い申し上げます。
この中長期事業戦略は、同チームが 2009 年 4 月に作成・提出した中長期計画のうち、設備メンテナンス計画（土木構造物、発電施設および送配電設備）について、その後の維持管理実績を踏まえた上での見直しならびにベトナム連系後の電気料金の見通しについて報告するものです。なお、経営および事務管理部門については、2010 年 6 月に EUMP が EDC に統合されたため、EDC において作成されるものとして本書には含まれません。

本プロジェクトは 2011 年 3 月に終了いたしますが、これ以降は、EDC モンドルキリが自らの力で発電設備を健全な状態に保つための中長期メンテナンス計画他を適切に策定し、維持管理を確実に行う必要があります。EDC モンドルキリは、メンテナンスに必要な中長期資金計画を毎年見直し、EDC 本社に対して予算要求しなければなりませんが、本書がその際の参考になればと考えています。JICA チームとしては、カンボジア関係当局と EDC モンドルキリが、日本政府より贈与された電力設備を引き続き最大限に活用して、モンドルキリ州の電力需要に応えていくことを期待しております。

モンドルキリ州小水力地方電化維持運営 JICA スタディチーム
チームリーダー　　　三島　耕二

目　次

1. はじめに

中長期計画については、2009 年 4 月にモンドルキリ州小水力地方電化維持運営プロジェクトチームが作成し、第 2 回 JCC で承認を得ている。同計画では、2009 年から 10 年間の設備保守に関する基本的な考え方を示し、各年度への必要な予算配分を提案している。

本書では、既に提出済みの中長期計画のうち、保守・資金計画（土木構造物メンテナンス、発電施設メンテナンスおよび送配電メンテナンス）について、2009 年 4 月以降の実績を踏まえ、改訂の必要性について検討した結果を示している。

中長期計画は、実績と将来の見通しを踏まえて改訂していくローリングプランとして位置づけられ、今後は、EDC モンドルキリの手で毎年更新し、EDC 本社に対して予算請求を行っていくべきものであると考えるが、その際に本書が参考になると思われる。

2. 設備保守計画

2.1 保守計画優先順位基準

長期保守計画策定を行うにあたり、発電所の信頼度維持と保守費用削減を考慮した設備保全最適化を図るため、下記のとおり設備・修繕件名の優先順位評価を行う。

尚、優先順位としては、「コンプライアンス」及び「社会的影響」のあるものを優先した上で、「設備状態」「電力及び自社への影響」「業務効率化」を評価した優先順位付けとする。

順位 1.コンプライアンス（法令遵守）

コンプライアンス（法令遵守）の観点から以下の項目については、最優先実施とする。

計量設備（計量法）、危険物（ＰＣＢ等）、遮断器細密点検（保安規程）

但し、危険物対応については対応期間もあり３、４項を考慮した長期優先順位とする。

順位 2.社会的影響（安全・環境面）

1) アスベスト対応

関連のカンボジア法に則る事とする。

2) 安全・環境対応

安全及び社会的影響が大きい油流出・騒音等についての対策については、企業として行わなければならない課題であることから年度設備費用枠の５％を引き当て確実に実施し、優先順位については３項「(1) 技術面」４項「(3) 効率面」を考慮したものとする。

油流出防止対策、クレーン等安全対策、騒音対策

順位 3. 設備状態（保守性・設備信頼度・技術面・機能面）

1) 技術面

重大事故水平展開設備

2) 設備信頼度

経年劣化、動作回数、補修及び障害履歴、性能及び機能低下、余寿命

3) 保守性

廃型及び製造中止設備、保守サポート体制及び部品供給中止設備

4) 機能面

効率向上、機能及び信頼性向上、作業性向上

順位 4. 電力及び自社への影響

(1) 経済面

設備更新及び補修による経済効果

(2) リスクアセスメント

当該設備が事故に至った場合の発電所影響度合いについて評価する。

・発電所全停

・主機停止（なし・３日未満・３日以上）

・溢水電力（有・無）　条件：流れ込み式で主機１台、下流維持流量

(3) 効率面

同調工事とすることによる停止の効率化と運転可能時間アップ及び費用削減

(4) 協調面

相手端が電力会社の場合に協調が必要となる系統保護継電器

(1) 地点重要面

電力会社からの期待度（揚水発電所や電力系統への影響度）

順位 5.　業務効率化

分析・解析の効率化（系統等)、発電所の保守作業効率化を考慮した件名について評価する。

2.2 土木設備関連

取水堰、水路等のコンクリート構造物他土木設備については、適切なメンテナンスを実施することで、半永久的に使用できるものである。土木設備関連の維持・補修については、時期がきたら一律交換・全面補修ではなく、不具合が発生するたびに補修するのが合理的である。土木設備については、想定を越えた天災等により、大きなダメージを受けることを除けば、通常の運用で、突然、使用不能になることは稀である。使用不能に至る前に小さなクラックの発生、ひずみの増大等の前兆現象が起こることが多いため、定期的な点検により、この前兆現象を見逃さず、適切な予防措置を取れば、土木構造物の健全性は維持できるものと考える。

上記に鑑み、具体的な補修計画については、点検結果を踏まえ上で、適宜立案することとし、中長期計画上は、減価償却費相当分を各年の維持管理コストとして計上している。ただし、先にも述べたが、想定を越えた降雨や出水等により、大きなダメージを受けることもあるが、これらについては、確率論的にはかなり低いため（設計上は 1/100 年以下）、中長期計画上は、災害復旧工事費用については考慮していない。

また、現状の設備は必要最低限の設備であるが、維持・管理サイドからすれば、アップグレードされることが望ましいものもある。例えば、オモレン、オロミス地点の既設アクセスパスについては、路盤は砂利敷き、側溝はモルタル張りと必要最低限の構造となっており、雨季終了時には、砕石の補充や轍掘れの補修が必要である。維持管理を容易にするためには、アスファルト舗装およびコンクリート製の U 字溝へのアップグレードが望ましいが、改造工事費用の発生に伴う経営面への影響（電気料金への反映）等を考えると、その費用対効果を十分に検討する必要がある。その他にも、落石防護対策や法面防護対策等アップグレードが望まれるものも多いが、中長期計画上は、この費用を考慮していない。今後の状況を良く見た上で、道路条件あるいは法面状況の悪化に伴う維持管理業務への支障の程度および経営状況等（予算的な余裕）を総合的に判断した上で、必要性が高ければアップグレードを計画・実施すべきであると考える。

2.3 発電設備関連

電気部門での中長期計画は基本方針に則り、以下の項目について取り組むこととする。

2.3.1 基本方針

長期保守計画策定にあたっては、「経済性と信頼性を両立する設備保全」を目指すこととし、「保守手法（仕様、数量、頻度）の最適化」と「キャッシュアウトの最少化」を基本に取り組むこととする。現状の設備信頼度維持を前提とし、保守に必要な案件を適正な順位づけのもと、修繕による延命化を図り、今後、老朽化が進む設備については、定期点検などのデータを基に更新の計画立案を行う。

2.3.2 計画策定にあたって

(1) 策定対象

①対象費目：設備、修繕および委託

②対象期間：2009 年度～2018 年度までの 10 ヵ年（想定し得る件名を計上）

(2) 諸元

①物　　価：将来計画における物価変動は加味しない。

②契約諸元：一括保守契約における直接人件費単価・経費率等は 2008 年度契約諸元とする。

(3) 前提条件

①現状の信頼性維持を前提とし、保守に必要な件名を計上。

②適切な時期に適切な件名を必要最小限の金額で計上する。

③ライフサイクルコストの最少化を前提に設備の生涯年運転継続を原則とする。

④発電所別重要度評価は行わない。

⑤機能毎にリスク分析に基づく優先順位を付す（原則同順位は認めない）

2.3.3 発電部門予算策定方針

(1) 支出内容の再点検

a)適正な外注費算出

b)件名，内容の妥当性確認

・現状の設備状況（不具合状況、補修・更新の必要性、経過年数等）を確実に記入し、妥当性および必要性を再点検すること。

c) 計上予算の妥当性確認

・適正なコスト削減方策が施されているか（競争入札、同一仕様品の一括購入等）再点検すること。

d)オーバーホール関連補修項目確認

・メーカー推奨事項をそのまま計画へ盛り込まず、再検討し、必要性を含め精査すること（不確定なものは計画に盛り込まない）。

・経験豊富な数名を招集し、資金３ヵ年に計画している案件についてチェックの作業会を行うこととする。

(2) 優先順位評価

別紙の優先順位評価基準に従い、長計システムへ評価項目に入力を行う。

2.3.4 具体的な予算策定案

全３発電所（オモレン、オロミスおよびディーゼル）を対象に、下記の計画案で予算を計上した。

（１）設備・修繕費

各発電所の運転状況に応じて、毎年の設備修繕、補修などの予算を計上した。

（２）委託費

外部発注（供給メーカーあるいは、国内の点検保守業者など）可能な業者を選定し、点検の実施とアドバイスを受ける。

１）定期一般点検：年１回の定期点検を実施する。

２）定期詳細点検：5年毎に詳細点検を実施する。

３）オーバーホール作業（OH）: 10年毎に必要な項目について実施する。

2.4 送配電設備関連

送配電部門での中長期計画は基本方針に則り、以下の項目について取り組むこととする。

2.4.1 基本方針

※発電部門と同一

2.4.2 計画策定にあたって

※発電部門と同一

2.4.3 送配電部門予算策定方針

※発電部門と同一

2.4.4 具体的な予算策定案

全送配電設備を対象に、下記の計画案で予算を計上した。

（1）設備・修繕費

各設備の運転状況に応じて、毎年の設備修繕、補修などの予算を計上した。

天災等による設備損壊時に必要となる復旧用機材を 10 年間で順次配備していくよう計画した。なお、復旧にかかる工事は原則として直営工事により実施するよう想定した。（直営施工が困難な復旧工事が発生した場合は各設備毎に計上した設備修繕予算を引き当てる前提とした。）

今後、系統運用の効率化のための設備改良工事が必要となることも想定されるが、運用実績が乏しいことから今回計画には計上しなかった。

（2）委託費

外部発注（供給メーカーあるいは、国内の点検保守業者など）可能な業者を選定し、点検の実施とアドバイスを受ける。

1）高所作業車点検：年１回の一般点検、３年毎の詳細点検を実施する。

2）Switch Station 点検：２年毎の一般点検、６年毎の詳細点検を実施する。

3）絶縁用防具・保護具点検：年１回の一般点検、３年毎の詳細点検を実施する。

4）樹木定期伐採： 送配電線接近樹木伐採の一部を委託により実施する。

5）技能教育：稀頻度作業の技能維持・技術力向上のため４年毎に周期教育を実施する。

3. 中長期設備計画の改訂の必要性検討結果

2009 年 4 月に提出した 2009～2018 年度の中長期計画の年度予算算出の考え方は「2. 設備保守計画」に示した通りである。この考え方に基づいて、通常のメンテナンスで必要とされる補修費用や外注により実施する定期点検費用他を算出し、2009 年～2018 年の年度毎に配分したのが、表 2～4 である。カンボジア国内では類似の水力地点がなく、引用できるデータがないことから、最初の中長期資金計画としては、建設価格を基礎データに、減価償却費分を毎年の維持管理費用として計上※、実績に応じて修正することとしていた。

通常は、ある程度の実績が蓄積されれば、それをベースに年度費用の見直しをかけるが、本地点については、完成後間もないこともあってか、2009～2010 年度の補修実績はほとんどなく、参考となるデータが得られなかった。消耗部品の交換や経年劣化に伴う補修等は年を重ねるに従って増えてくると考えられ、2009～2010 年に補修実績がなかったからといって、予算を減額するのは危険である。最低でも 5～10 年程度の実績を蓄積し、年あたりの平均的な補修費用に関して精度の高いデータが得られた後に見直しをかけるのが良いと思われる。

現時点では、十分な実績データが揃わなかったことから、中長期計画の見直しは行わないが、今後の中長期計画の改定に向けた準備として、補修・交換履歴、費用実績を確実に記録し、それを元に項目毎（構造物単位あるいは部品単位）の年度あたりの平均補修費用等の基礎データの整備を行い、十分なデータが揃った項目から見直しをかけることで、計画精度を順次高めていくべきと考える。

※　（基礎価格）／（設備毎の耐用年数）×（補正値（0.5～1））で年度費用を算出

表-1　中長期保守計画　電気部門優先順位評価基準

評価項目	上段：評価対象等 / 下段：評価ポイント												
コンプライアンス（法令遵守）	必要なし						必要有						評価1
PCB、危険物、計量設備、遮断器	0						500						
安全面	必要なし						必要有						評価2
アスベスト、クレーン安全対策等	0						200						
環境面	必要なし						必要有						
騒音、環境美化、油流出防止	0						100						
保守性	廃型・製造中止				製作者保守サポート体制				部品供給				評価3～5
廃型・製造中止、保守サポート体制、部品供給	対象外		対象		サポート可		サポート不可		有		なし		
	0		30		0		30		0		50		
設備信頼度	経年		動作回数		補修回数		障害履歴		性能		余寿命		
経年、動作回数、補修・障害履歴、性能、余寿命	指定年未満	指定年以上	指定回数未満	指定回数以上	3回未満	3回以上	5回未満	5回以上	満足	満足していない	3年以上	3年未満	
	0	50	0	50	0	30	0	30	0	50	0	50	
技術面	必要なし						必要有						
重大事故水平展開	0						80						
機能面	効率向上				機能・信頼性向上				作業性向上				
効率、機能・信頼性、作業性向上	なし		有		なし		有		なし		有		
	0		20		0		10		0		10		
経済面	経済効果なし			経済効果有（小）			経済効果有（中）			経済効果有（大）			
経済効果	0			10			30			50			
効率面（紐付けの必要性）	同時実施による停止効率向上なし			同時実施による停止効率向上有			同時実施による経済効果なし			同時実施による経済効果有			
停止効率、経済性	0			50			0			50			
地点重要面	期待度（小）				期待度（中）				期待度（大）				
電力よりの期待度（揚水P/S、電力系統への影響）	0				10				20				
業務効率化	効率化考慮の必要なし						効率化考慮の必要有						
分析・解析（系統等）および保守作業効率化等	0						100						
協調面	協調の必要性				種別				要素				
系統保護継電器（電力相手端との協調	なし		有		丙・乙		甲		トランス	ブス	安定化	ライン	
	0		30		10		20		20	30	40	50	
リスクアセスメント	電気所全停		主機停止						溢水				
事故時の影響度合い評価	なし	有	なし		有（3日未満）		有（3日以上）		なし		有		
	0	50	0		30		50		0		20		

表-2　中長期保守計画 年度別所要資金

単位: US$

発電所	項　目	合計	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			計	計	計	計	計	計	計	計	計	計
土木設備関連												
(1)オモレン発電所		27,800	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780
(2)オロミス発電所		45,400	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540
(3)ディーゼル発電所		8,000	800	800	800	800	800	800	800	800	800	800
(4)管理棟		11,900	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190
計		93,100	9,310	9,310	9,310	9,310	9,310	9,310	9,310	9,310	9,310	9,310
電気関連												
(1)オモレン発電所		153,014	4,586	4,586	4,586	4,586	22,445	4,586	4,586	22,445	4,586	76,021
(2)オロミス発電所		143,525	4,302	4,302	4,302	4,302	21,053	4,302	4,302	21,053	4,302	71,307
(3)ディーゼル発電所		193,088	5,699	5,699	5,699	5,699	31,217	5,699	5,699	31,217	90,760	5,699
(4)管理棟		0	0	0	0	0	0	0	0	0	0	0
(5) 共通		40,468	3,035	3,035	3,035	3,035	8,094	3,035	3,035	8,094	3,035	3,035
計		530,095	17,622	17,622	17,622	17,622	82,809	17,622	17,622	82,809	102,683	156,062
送配電設備												
		277,780	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778	27,778
総計		**900,975**	**54,710**	**54,710**	**54,710**	**54,710**	**119,897**	**54,710**	**54,710**	**119,897**	**139,771**	**193,150**

表-3　土木関係　中長期保守・資金計画

単位: US$

発電所	項　目	合計	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			計	計	計	計	計	計	計	計	計	計
オモレン発電所	アクセスパス補修	2,000	200	200	200	200	200	200	200	200	200	200
	落石防護柵補修	1,200	120	120	120	120	120	120	120	120	120	120
	法面保護工	1,300	130	130	130	130	130	130	130	130	130	130
	取水堰補修	1,700	170	170	170	170	170	170	170	170	170	170
	ゲート、スクリーン補修	10,800	1,080	1,080	1,080	1,080	1,080	1,080	1,080	1,080	1,080	1,080
	水圧鉄管補修	3,500	350	350	350	350	350	350	350	350	350	350
	発電所擁壁補修	800	80	80	80	80	80	80	80	80	80	80
	発電所建物補修	2,900	290	290	290	290	290	290	290	290	290	290
	発電所側溝補修	400	40	40	40	40	40	40	40	40	40	40
	護岸工補修	1,200	120	120	120	120	120	120	120	120	120	120
	雑工事	2,000	200	200	200	200	200	200	200	200	200	200
小計		27,800	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780
オロミス発電所	アクセスパス補修	7,000	700	700	700	700	700	700	700	700	700	700
	落石防護柵補修	5,300	530	530	530	530	530	530	530	530	530	530
	法面保護工	3,100	310	310	310	310	310	310	310	310	310	310
	発電所側溝補修	400	40	40	40	40	40	40	40	40	40	40
	水路補修	3,500	350	350	350	350	350	350	350	350	350	350
	水圧鉄管補修	3,900	390	390	390	390	390	390	390	390	390	390
	ゲート、スクリーン補修	12,000	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
	発電所擁壁補修	1,100	110	110	110	110	110	110	110	110	110	110
	発電所建物補修	3,000	300	300	300	300	300	300	300	300	300	300
	取水堰補修	1,200	120	120	120	120	120	120	120	120	120	120
	護岸工補修	900	90	90	90	90	90	90	90	90	90	90
	雑工事	4,000	400	400	400	400	400	400	400	400	400	400
小計		45,400	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540	4,540
管理棟	建物補修	10,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	フェンス補修	900	90	90	90	90	90	90	90	90	90	90
	雑工事	1,000	100	100	100	100	100	100	100	100	100	100
小計		11,900	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190
ディーゼル発電所	建物補修	8,000	800	800	800	800	800	800	800	800	800	800
小計		8,000	800	800	800	800	800	800	800	800	800	800
合計		**93,100**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**	**9,310**

表-4　電気関係　中長期保守・資金計画

単位: US$

発電所	項　目	合計	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			計	計	計	計	計	計	計	計	計	計
(1)オモレン発電所												
1. 設備・修繕費	1.1水車発電機装置本体（水車、発電機）71%	25,359	2,536	2,536	2,536	2,536	2,536	2,536	2,536	2,536	2,536	2,536
	1.2制御盤（制御回路、保護リレー）24%	5,143	514	514	514	514	514	514	514	514	514	514
	1.3その他・補機装置（予備品1式含む）5%	1,072	107	107	107	107	107	107	107	107	107	107
	小計	31,574	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157	3,157
2. 委託費	2.1定期一般点検	14,287	1,429	1,429	1,429	1,429	1,429	1,429	1,429	1,429	1,429	1,429
	2.2定期詳細点検	35,718	0	0	0	0	17,859	0	0	17,859	0	0
	2.3OH作業	71,435	0	0	0	0	0	0	0	0	0	71,435
	小計	121,440	1,429	1,429	1,429	1,429	19,287	1,429	1,429	19,287	1,429	72,864
合計		153,014	4,586	4,586	4,586	4,586	22,445	4,586	4,586	22,445	4,586	76,021
(2)オロミス発電所												
1. 設備・修繕費	1.1水車発電機装置本体（水車、発電機）71%	23,787	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379
	1.2制御盤（制御回路、保護リレー）24%	4,824	482	482	482	482	482	482	482	482	482	482
	1.3その他・補機装置（予備品1式含む）5%	1,005	101	101	101	101	101	101	101	101	101	101
	小計	29,616	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962	2,962
2. 委託費	2.1定期一般点検	13,401	1,340	1,340	1,340	1,340	1,340	1,340	1,340	1,340	1,340	1,340
	2.2定期詳細点検	33,502	0	0	0	0	16,751	0	0	16,751	0	0
	2.3OH作業	67,005	0	0	0	0	0	0	0	0	0	67,005
	小計	113,908	1,340	1,340	1,340	1,340	18,091	1,340	1,340	18,091	1,340	68,345
合計		143,525	4,302	4,302	4,302	4,302	21,053	4,302	4,302	21,053	4,302	71,307
(3)ディーゼル発電所												
1. 設備・修繕費	1.1ディーゼル発電機装置本体（DG、発電機）70%	29,771	2,977	2,977	2,977	2,977	2,977	2,977	2,977	2,977	2,977	2,977
	1.2制御盤（制御回路、保護リレー）19%	6,465	646	646	646	646	646	646	646	646	646	646
	1.3その他・補機装置（予備品1式含む）11%	3,743	374	374	374	374	374	374	374	374	374	374
	小計	39,979	400	3,998	3,998	3,998	3,998	3,998	3,998	3,998	3,998	3,998
2. 委託費	2.1定期一般点検	17,012	1,701	1,701	1,701	1,701	1,701	1,701	1,701	1,701	1,701	1,701
	2.2定期詳細点検	51,037	0	0	0	0	25,518	0	0	25,518	0	0
	2.3OH作業	85,061	0	0	0	0	0	0	0	0	85,061	0
	小計	153,110	1,701	1,701	1,701	1,701	27,220	1,701	1,701	27,220	86,762	1,701
合計		193,088	5,699	5,699	5,699	5,699	31,217	5,699	5,699	31,217	90,760	5,699
(4)共通項目	試験用機器、点検用ツールなど	10,117	0	0	0	0	5,058	0	0	5,058	0	0
	予備費	30,351	3,035	3,035	3,035	3,035	3,035	3,035	3,035	3,035	3,035	3,035
合計		40,468	3,035	3,035	3,035	3,035	8,094	3,035	3,035	8,094	3,035	3,035
	設備・修繕費合計	101,169	10,117	10,117	10,117	10,117	10,117	10,117	10,117	10,117	10,117	10,117
	委託費合計	388,458	4,470	4,470	4,470	4,470	64,598	4,470	4,470	64,598	89,531	142,910
総計		**530,095**	**17,622**	**17,622**	**17,622**	**17,622**	**82,809**	**17,622**	**17,622**	**82,809**	**102,683**	**156,062**

表-5　送配電関係　中長期保守・資金計画

単位: US$

発電所	項　目	合計	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
			計	計	計	計	計	計	計	計	計	計
送配電設備												
1. 設備・修繕費	1. 22kV架空電線路	32,876	3,288	3,288	3,288	3,288	3,288	3,288	3,288	3,288	3,288	3,288
	2. 22kV地中ケーブル	1,805	181	181	181	181	181	181	181	181	181	181
	3. 配電用柱上変圧器	9,746	975	975	975	975	975	975	975	975	975	975
	4. 積算電力量計器	29,128	2,913	2,913	2,913	2,913	2,913	2,913	2,913	2,913	2,913	2,913
	5. 無線その他	31,894	3,189	3,189	3,189	3,189	3,189	3,189	3,189	3,189	3,189	3,189
	小計	105,450	10,545	10,545	10,545	10,545	10,545	10,545	10,545	10,545	10,545	10,545
2. 委託費	1. 高所作業車点検	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点検	5,900	590	590	590	590	590	590	590	590	590	590
	3. 絶縁用防具・保護具点検	3,650	365	365	365	365	365	365	365	365	365	365
	4. 樹木定期伐採	4,000	400	400	400	400	400	400	400	400	400	400
	5. 技能教育	5,000	500	500	500	500	500	500	500	500	500	500
	小計	30,150	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015
合計		135,600	13,560	13,560	13,560	13,560	13,560	13,560	13,560	13,560	13,560	13,560
3. 共通項目	試験用計器類	10,545	1,054	1,054	1,054	1,054	1,054	1,054	1,054	1,054	1,054	1,054
	災害復旧用機材	100,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	予備費	31,635	3,163	3,163	3,163	3,163	3,163	3,163	3,163	3,163	3,163	3,163
合計		142,180	14,218	14,218	14,218	14,218	14,218	14,218	14,218	14,218	14,218	14,218
設備・修繕費合計		247,630	24,763	24,763	24,763	24,763	24,763	24,763	24,763	24,763	24,763	24,763
委託費合計		30,150	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015	3,015
総計		**277,780**	**27,778**	**27,778**	**27,778**	**27,778**	**27,778**	**27,778**	**27,778**	**27,778**	**27,778**	**27,778**

4. ベトナム連係後の電気料金の見通し

現行の電気料金は 2009 年 6 月に設定された。料金算定の元となる費用は主電源である水力発電に掛かる費用と補完電源であるディーゼル発電の費用からなっていた。2010 年 6 月に EUMP が EDC に移管された。EDC は直ちに将来の需要増に応えるべくベトナムから 22kV による電力輸入計画に着手し、2012 年までには運用が開始される予定である。これにより、費用の構成が従来と異なることから、料金の改定が必要となってくる。

ここでは、ベトナムからの電力輸入開始後の電気料金について概算する。実際の適用に当っては、EAC と協議の上、設定されたい。

(1)計算の前提条件

1)水力発電は河川流量を最大限有効利用するため、ベース電源として運用する。

2)ピークおよび増分需要の電源として、ベトナムからの輸入する電力を充てる。

3)ディーゼル発電は基本的には待機電源とするが、ピーク時など需要の変動が激しい時間帯において、系統の安定化を維持するために部分的な運転を行う。

4)ベトナムとの中圧連系線は EDC の自己資本により建設し、モンドルキリでの料金収入で回収する。

(2)計算ケース

2009 年ベース：年間消費電力量を 1,200MWh と設定(水力とディーゼルで供給)
2012 年ベース：年間消費電力量を 2,000MWh と設定(ベトナムより電力輸入開始)
2014 年ベース：年間消費電力量を 3,000MWh と設定
2016 年ベース：年間消費電力量を 5,000MWh と設定

(3) 試算結果

結果を下図に示す。ベトナムよりの電力輸入開始当初はまだ需要が小さいため、単価は急激に下がるが、その後は緩やかとなり、年間の電力需要量が 5,000MWh を超えると、費用もほぼ横ばいとなる。モンドルキリ系統での安定供給と健全な経営を維持するための、料金案を赤線で示す。電気料金の設定に当っては、その後の需要の伸びに応じて、段階的に値下げする方法が望ましい。

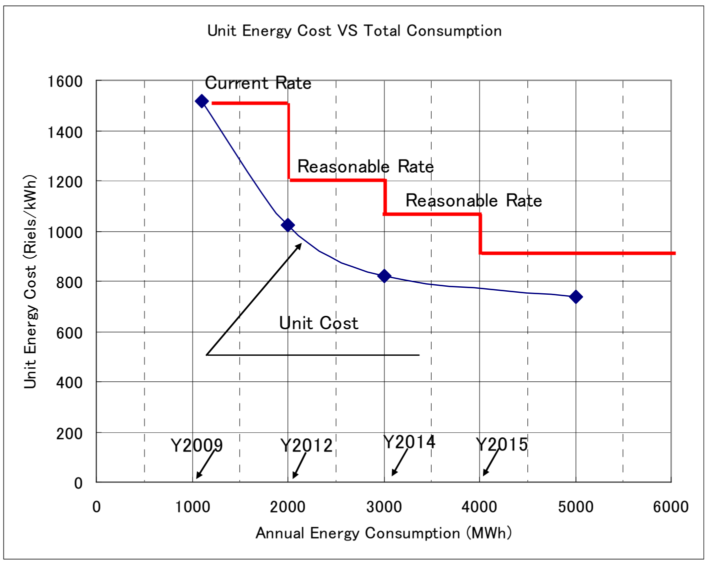


表-6 Case 2012 Assumed Tariff Rate after connection with Viet Nam (Simplified and Approximate calculation)

: 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**

表-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
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**	

表-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
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．電気料金提案書（初版）

2009年3月
JICA Team

モンドルキリ州小水力電化計画
電気料金案について

１．概要

日本の無償資金協力によって設置されたセンモノロム市への電力設備は 2008 年 11 月よりモンドルキリ州電力公社（EUMP）によって電気の供給が開始されている。適正料金を定めるためには、需要・供給および顧客の実績データーが必修となるため、現在は暫定料金が適用されているが、先の第一回 JCC 会議で本年３月にそれまでのデーターを元に料金案を提案し、本年６月頃を目処に適用を目指すこととなった。

暫定料金については、当初、一般 1,800 ﾘｴﾙ/kWh、ホテル・ゲストハウスなどビジネス 2,000 ﾘｴﾙ/kWh が適用されていたが、これは昨年８月頃に算定されたもので、ディーゼル発電用の燃料単価を１リッター当り 1.5 ﾄﾞﾙを想定したものであった。その後、１０月頃より急落し、１月では 0.7 ドル前後となった。そのため、１月使用分（２月徴収分）より、燃料価格変動分の調整を行って,一般 1,600 ﾘｴﾙ/kWh、ホテルおよびゲストハウスなどのビジネス 1,800 ﾘｴﾙ/kWh が現在適用されている。

今回、提案する料金は EAC より承認を得る正式料金であり、EUMP が２００８年 11 月より営業を開始して本年 2 月までの 4 ヶ月間の需要・供給および顧客の実績データーに基づいて算定されたものである。また、併せてディーゼル発電の燃料単価が変動した場合の電気料金表も準備した。

２．現在の利用状態

２．１　現在の適用料金　（２００９年２月２０日時点）

顧客数：1032 戸

Table-1 現在の暫定料金（2009 年 2 月徴収分より適用）

	区分	電気料金 (Riel/kWh)	備考
1	一般世帯他	1,600	下記２以外の全て
2	ｹﾞｽﾄﾊｳｽ・ﾎﾃﾙ・ﾚｽﾄﾗﾝおよびｶﾗｵｹ	1,800	業種区分（規模）の規定が曖昧

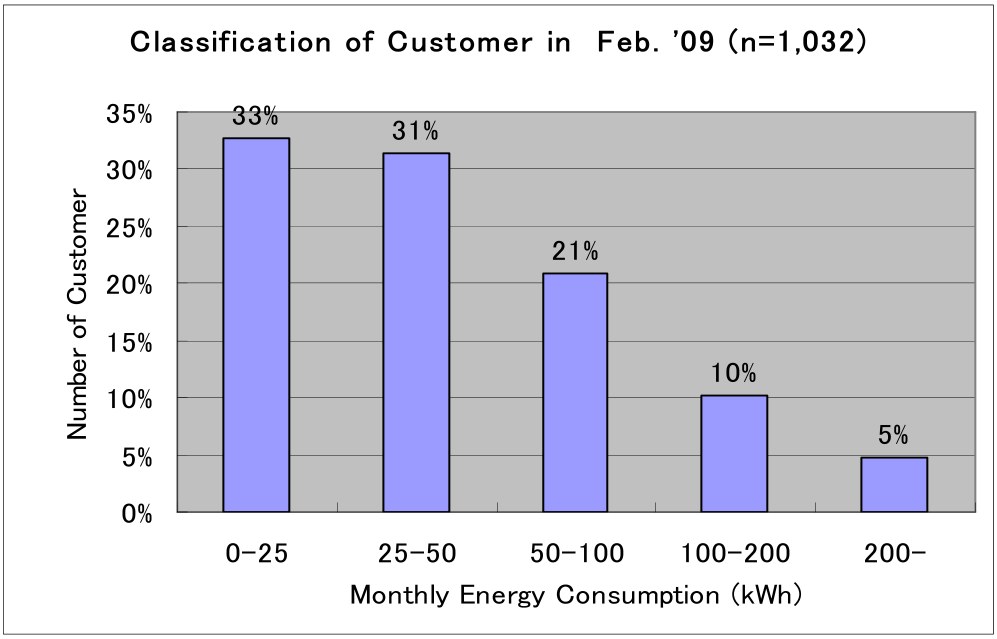
２．２利用状況

２００９年２月２０日締めの契約利用者は１，０３２件となっている。集計は２００９年１月２０日から２月２０日間の１ヶ月間の利用状況を対象とした。

１ヶ月間の総電力消費量（EUMP 分を除く）は 81.7MWh で一戸当り 79kWh/月となる。

２． ３　電力使用量別顧客分布

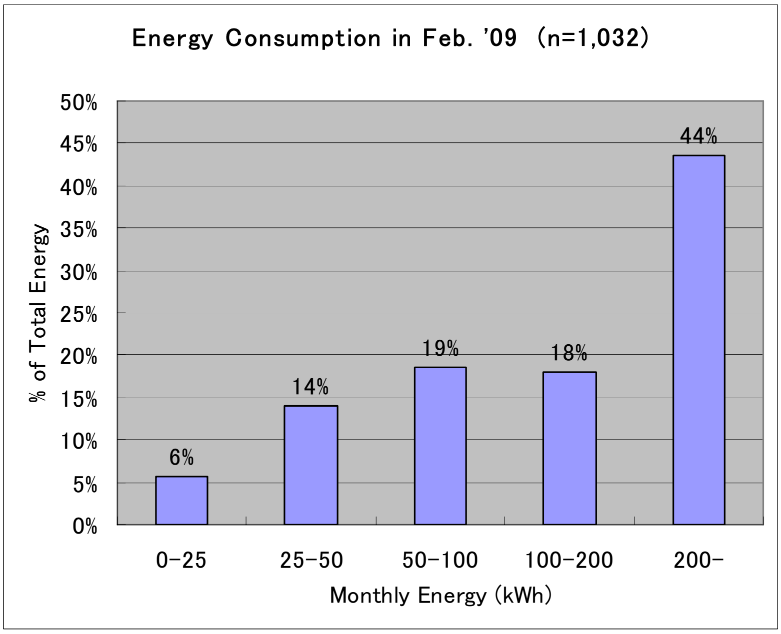
Fig.-1 電力使用量別顧客分布



上図より全体の約３３％を占める 338 戸の加入者は月当たり 25kWh 以下の使用であることが分かる。このカテゴリーを低額所得者と見做す。将来の電化率向上はこのカテゴリーがターゲットとなる。

２． ４　電気使用量別の顧客分布

Fig.-2 顧客別の電気使用割合



月当たり 25kWh 以下の顧客（33%）は全体の僅か６％の電力消費量に過ぎない。一方、200kWh 以上は顧客比率では５％に過ぎないが、電力消費量は全体の４４％を使用している。その顧客のほとんどがゲストハウス・ホテル・レストランおよびカラオケなどのビジネスを営んでいる。

３．電気料金設定について

３．１基本方針（従来より堅持）

1) 例外なく全ての利用者が電気料金を負担し、その収入で電力公社が運営される。
2) 安定経営を維持させるため、運営上の財務収支バランスの安定を最優先とする。
3) 設備は日本の援助によって設けられたため、それの回収に掛かる費用は含めないが、機械の性能を維持して行くための点検・修理・補修に掛かる経費を確保する。
4) 将来の需要増に備え資本の蓄積を図る。
5) 上記条件を満足させた上で可能な範囲で低所得者向けの電化を促進する。

３．２電気料金案

電気料金の元となる発電コストはディーゼル発電に用いる燃料費によって大きく変動するため、燃料費単価のレンジ毎に電気料金を提案する。

１）標準案

（条件）: ディーゼル燃料単価が１リッター当たり 2501Riel から 3000Riel

	区分	電気料金 (Riel/kWh)	適用
1	一般世帯	1,450	下記２以外の全て
2	ビジネス	1,650	ｹﾞｽﾄﾊｳｽ・ﾎﾃﾙ・ﾚｽﾄﾗﾝ・ｶﾗｵｹなどﾋﾞｼﾞﾈｽ業

２）燃料費変動による電気料金

燃料単価（Riel/Litter）	一般世帯	ビジネス	備考
2,000 Riel 以下	1,290	1,460	-11%
2,001 ～2,500	1,370	1,560	-6%
2,501 ～3,000	1,450	1,650	標準案
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%

燃料単価は貯蔵および調達期間を考慮して、改定前の３ヶ月平均値を採用するのが望ま

しい。

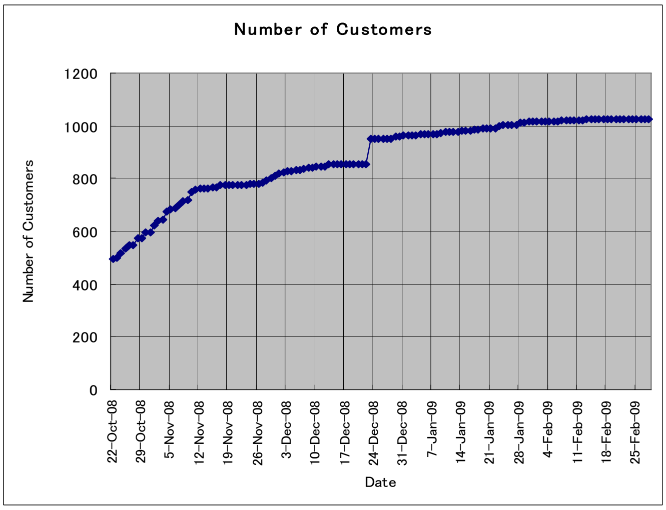
４．標準案のシュミレーション結果

条件

1) 利益率 10%を確保する
2) 総合ロスには EUMP 所内消費および EUMP 街燈（約 350 個）消費を含む（実績値より設定）
3) ディーゼル燃料単価：0.75 US$/Litter
4) ディーゼル燃料効率は実績値を採用

Table - 運用シュミレーション結果の概要（2009 年需要値）

項目	単位	年値	備考
I. 電力量計算			
1 年間発電量	MWh	1,295	送電端
2 水力発電分	MWh	927	72% 実績値より推定
3 ディーゼル発電分	MWh	369	28% 実績値より推定
4 燃料消費量	Litter	114,100	0.31 Litter/kWh :燃料消費率
5 年間販売電力量	MWh	971	25% :総合ロス率(実績値)
II. 財務計算			
1 人件費	US$	75,250	30 名、月例 14 ヶ月分
2 燃料費	US$	85,570	0.75 US$/Litter
3 公社運営諸経費	US$	51,600	80 % :人件費比率(実績)
4 保守・営繕費	US$	78,500	オーバーホール準備金を含む
5 渇水対策準備費	US$	21,550	10 % :水力発電量比率
6 計	US$	312,470	
7 発送電原価 Cost/kWh	US$/kWh	0.322	
	Riel/kWh	1,287	4,000 Riel/US$
8 有効消費電力量あたり Cost/kWh	US$/kWh	0.339	5% コマーシャルロスを考慮
	Riel/kWh	1,336	
9 加重平均料金	US$/kWh	0.376	(入力値)
	Riel/kWh	1,505	
10 料金収入	US$	347,160	
11 利益	US$	34,690	
	%	10%	


Number of Customers
Number of Customers
1200
1000
800
600
400
200
0
22-Oct-08
29-Oct-08
5-Nov-08
12-Nov-08
19-Nov-08
26-Nov-08
3-Dec-08
10-Dec-08
17-Dec-08
24-Dec-08
31-Dec-08
7-Jan-09
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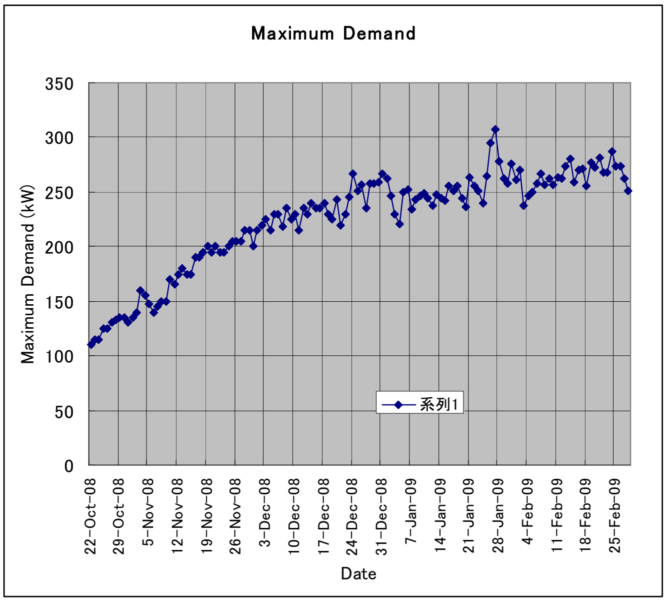
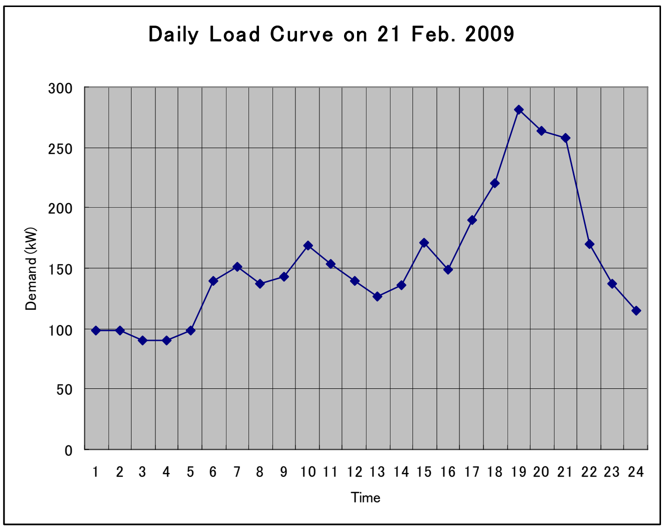
21-Jan-09
28-Jan-09
4-Feb-09
11-Feb-09
18-Feb-09
25-Feb-09
Date


Maximum Demand
Maximum Demand (kW)
350
300
250
200
150
100
50
0
系列1
22-Oct-08
29-Oct-08
5-Nov-08
12-Nov-08
19-Nov-08
26-Nov-08
3-Dec-08
10-Dec-08
17-Dec-08
24-Dec-08
31-Dec-08
7-Jan-09
14-Jan-09
21-Jan-09
28-Jan-09
4-Feb-09
11-Feb-09
18-Feb-09
25-Feb-09
Date


Daily Load Curve on 21 Feb. 2009
Demand (kW)
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time