# REHABILITATION OF A RURAL ELECTRICITY SYSTEM

## Smau Khney Village
## Trapeang Sab commune
## Bati District
## Takeo Province
## CAMBODIA

### Project funded by Energy Assistance
### Implemented by GRET and Kosan Engineering

### General Report

*Children looking at TV, Smau Khney, August 2005*

***Ky Chanthan,***
*KOSAN Engineering, Hotel Cambodiana, Phnom Penh. Cambodia. Tel: 855 (0)23 212 891,(0)12 801 966*
*Kosan@online.com.kh,*

***Jean-Pierre Mahé,***
*GRET, No 64, street 111, Phnom Penh. Cambodia. Tel: 855(0)12 891 156, mahe@gret.org*

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# SUMMARY


The electricity system of Smau Khney is located along the national road NR 2 in the commune Trapeang Sab in the Bati district of Takeo province, at 40 km south of Phnom Penh, capital of Cambodia. This project responded to the demand of Mr. Srey Sokhom, the REE (Rural Electricity Entrepreneur) of Smau Khney, the commune of Trapeang Sab and the National regulator (Electricity Authority of Cambodia) to improve the electricity service in the Smau Khney area.

*The REE, Mr. Srey Sokhom, 2nd from right, and Mr. Urima (EA), 1st from right*

The rehabilitation of the electricity system of Smau Khney is the first pilot project implemented by GRET (French NGO) in partnership with KOSAN Engineering (a Cambodian engineering company specialized in infrastructure) with the support of Energy Assistance. (In this document, Gret-Kosan refers to the partnership between GRET and KOSAN Engineering)

On the technical point of view, the rehabilitation of the electricity system of Smau Khney (Trapeang Sab) began in July 2004 and was completed in July 2005. The genset was repaired, a new power-house was built, the poles and the cables were all re-sized, replaced and extended. The improvement of the system allowed a better service; the current is stable and the voltage drop at the end of the lines is below 10%. It also permitted about 33% energy saving, most of it due to the improvement of cables, genset and the installations of capacitors on the fluorescent lamps.

Thank to Energy Assistance which provided incentives that were delivered according to the OBA financing model (Output Based Aid), 220 poor and remote household were connected, bringing the total number of connections to 500, and the connection rate in the project area at 99%.

Recently, EAC, the electricity regulator of Cambodia, did a complete check up of the system of Smau Khney, issued a 7 years license (one of the longest for a REE), however, this license is still not sufficient to cover the 9 year ROI (Return on Investment) period of the new system.

*Major changes occurred in the system of Smau Khney before an after the rehabilitation:*

| **Management** | Before (April 2004) | After (July 2005) | Changes |
|---|---|---|---|
| Number of HH connected | 280 | 500 | + 78% |
| Rate of connection in the project area | 56% | 99% | + 43% |
| Sales: kWh sold / day | 81.5 kWh/day | 140 kWh/day | + 72% |
| Tariff | 0.50$ ( 2000 riels) | $0.56 (2300 riels) | + 12% |
| Cost price | 0.40 (1633 riels) | 0.44 (1806 riels) | +10% |
| **Efficiency** | | | |
| Fuel / kWh produced | 0.42 l/kWh | 0.35 l/kWh | -17% |
| Fuel / kWh billed | 0.70 l/kWh | 0. 47 l/kWh | -33% |
| Losses on grid | 40% | 25% | -15% |
| Voltage drop at end of lines | 33 % | 9.5% | -23.5% |
| **Investment** | | | |
| Total investment capital | $ 23 100 | $ 51,200 | + 121% |
| Investment capital / HH connected (without connection costs) | $ 82.5 /HH | $ 102.5/HH | + 24% |

All the steps developed in the course of this project are exposed hereinafter, in the two sections, the institutional aspects and the technical aspects.

# I CONTEXT

## I.1 General context

Cambodia, country enclosed between Vietnam and Thailand. It is essentially a rural country where 85% of the population (12 millions of inhabitants) live of agriculture. The country comes out of thirty years of civil war during which the infrastructures (water and electricity) have been destroyed or neglected.

### I.1.1 The level of electrification is very low in rural Cambodia

Currently, only 12% of the Cambodian people have access to grid electricity supply. To fill this gap, the most important in South-East Asia is, Cambodia has initiated a national program of production, transmission and rural electrification, with the support of the World Bank.

### I.1.2 The actors of the rural electrification

The numerous Cambodian REEs[1] (Rural Electricity Entrepreneur) are currently the main producers and distributors of alternative current in rural areas of Cambodia. However, because of technical and financial constraints, their selling price is very expensive (0.5 to 0.7 US$/kWh), their service is poor (low electricity quality, limited service duration), their profitability is very low and the safety of their systems is inexistent. But, their proximity and their capacity of local management are usually good.

Between 50 and 75% of the Cambodian in rural area have access to electricity by batteries. They buy the batteries and have them recharged by a local entrepreneur in the village. The price of recharge varies from 500 R (1,25 US$) to 1000 R (0,25 US$) for a battery of 70 Ah. Each battery charger station contains more than hundred batteries. The average family budget varies between 0,5 US$/month for the poorest to 2 US$/month for the richest families. The profitability of the battery chargers is generally low. Their equipment is reduced to the strict minimum; in general, a Chinese motor of 10 Hp mated with a dynamo of 3,5 KVA and a redresser. The pollution generated by their genset is high and battery disposal is erratic.

The public sector, notably EDC (the national company; Electricité du Cambodge) essentially concentrates its activity in the cities, and in the transport of electricity that will be distributed in rural areas through partnership with private sector.

### I.1.3 Regulation of the sector

A regulator (Electricity Authority of Cambodia, EAC) has been created in 2001 to monitor the sector and attribute licenses of production, transmission, and distribution. The licenses issued by EAC are to date quite short term (from 2 to 7 years) for small and medium REE like Smau Khney, but they may be longer for bigger systems.

[1] According to EAC, there are about 250 REE in Cambodia, 600 according to a study done in 2001 by SME Cambodia

## I.2 Plan of rural electrification of the Royal Government of Cambodia

In 2001, Cambodia has initiated an ambitious rural electrification plan to electrify 70% of the rural population from now to 2030, either through independent networks, or by individual solutions such as the solar panels.

A website, developed by the WindRock firm, was created. This website gives some general information on the rural electrification in Cambodia: www.recambodia.org.

### I.2.1 The R.E.F (Rural Electrification Funds)

The rural electrification funds is a device supported by the World Bank aiming to help the private sector to put in place the solutions of decentralized rural electrification. This REF will provide incentives on an OBA basis for:

- Installation of mini-hydro: 400 $/ kWh installed
- Installation of micro-hydro: 400 $/ kWh installed
- Solar home System: 100 US$/set of 40 Wp
- Independent rural mini-grid: 45 US$/ connected rural household.

The REF will also finance technical support for:

- Co-financing of feasibility study
- Marketing assistance

It is foreseen that the REF will be operational by mid 2006.

# II THE PROJECT: INSTITUTIONAL ASPECTS

*Project area*

Smau Khney is a village located at 40 km south of Phnom Penh, in Trapeang Sab Commune, Takeo province. The village is made of a dense market area, with about 500 households of local sellers and farmers. The village was equipped of a very inefficient electricity grid, invested and put in place by a local entrepreneur, Mr. Srey Sokhom.

The Smau Khney project was initiated by the wish of the commune of Trapeang Sab and the local entrepreneur to improve the quality of the electricity service in the Smau Khney area, as well as the demand for the regulator (Electricity Authority of Cambodia) to comply with national technical requirements.

In parallel with the technical improvement of the system, a commune electrification committee, was created to contract, on behalf of the commune, the electricity service to the entrepreneur and to manage the incentive funds provided by Energy Assistance for the connection of the poor and remote households.

## II.1 The Commune Electrification Committee (CEC)

With the support of GRET-KOSAN, the commune of Trapeang Sab formed a commune electrification committee, composed of men and women, which main role is to supervise the electricity sector in the commune. This CEC committee (picture) was created under the commune/Sangkat law stating that commune councils are entitled to create committees to take in charge public services. The CEC is composed 4 commune council members including the commune chief as the chief of the committee, the deputy commune chief, two women of the commune council, the chiefs of the 4 concerned villages and the clerk of the commune council.

Before the starting the rehabilitation of the system, all the members of the committee were trained by the engineers of Gret-Kosan about the security related to electricity and possible electrocution risks due to bad electricity uses, in order to provide information and advice to the users.

## II.2 Training of users

The CEC committee distributed leaflets to all households in the area, with indications and pictures describing the possible dangers due to bad electricity uses. The committee preferred direct contact rather than large meeting in which a few people usually come because they are too busy with their professional activities. It was noticed that many people had a good knowledge about the risks linked to electricity, because there had been already given information by M. Srey Sokhom, the rural electricity entrepreneur of Smau Khney.

## II.3 The Commune Electrification Funds (CEF)

A Commune Electrification Funds was created in a local bank to receive and administer the incentives of Energy Assistance. The signing parties of this account included the chief of commune, as chief of the CEC and the treasurer of the CEC. All the disbursement went smoothly according to the conditions of the incentive contract exposed hereinafter.

## II.4 Contracts

2 contracts were designed for the purpose of the project, the electricity supply contract that sets the conditions of service between the commune and the REE, and the incentive contract that contains the rules of incentive delivery. The preparation of these contracts has been made by Gret-Kosan with the support of EAC (Electricity Authority of Cambodia). During the preparation, several discussions were hold between the CEC, the provincial authority, EAC (Electricity authority of Cambodia) and Gret-Kosan in order to ensure that all parties involved in the contract fully participate and agree on the terms of the contract.

### II.4.1 The incentive contract

The incentive contract (see in annexes) was made between the commune council of Trapeang Sab, represented by the commune electrification committee and Gret-Kosan, with the validation of the provincial authority. The objective of this contract is that Gret-Kosan and CEC joined together to help the poor or remote households to get connected. By this contract the REE would receive 45 $ for the 220 poor and remote households connected.

Before the beginning of the project, the commune electrification committee (CEC) and the REE had listed and collected all 'willingness to connect' of the poor or remote people in the area. Households interested to be connected would sign in 'the willingness to connect' form with the validation of the CEC and the REE (see form in annexes). Two types of connection were offered:

- The minimum level of service (MLS), which consisted in a free connection but access to only one or two lamps, with a fixed amount to pay every month (1 $/month for a 10W lamp)
- The metered service, with a connection fee of 15US$

The total number of interested households was 220, most of them chose the Minimum level of service. To date, these households have all been connected by the REE.

In the incentive contract, the CEC had the following roles:

- To identify the number of poor or remote households that are interested to be connected, and
- To create and manage the commune electrification fund (CEF) that is used to receive the incentives.

Whereas Gret-Kosan had to:

- Provide technical support to the private entrepreneur to improve end extend his own system in accordance with the specification of EAC,
- Provide financial support for subsidizing 220 poor and remote households and administrative support to the CEC.

The amount of incentive was set at $45 for each household. The REE could get 50% at the beginning, and the rest according to the connection of the poor and remote households (6 disbursement were actually made).

The incentive contract also included a special fund to the CEC to perform his activities. Once one listed household were connected, the CEC committee got 2 US$ from the CEF. This fund was used to for administration and logistic expenses of the members of the CEC to collect the 'Willingness to Connect' among the 220 poor families and ensure that they were properly connected.

## II.4.2 The power supply contract

The power supply contract (see in annexes) was made between the commune, represented by the commune electrification committee (CEC) and the REE to set the conditions of electricity service in the area as well as specify the rules of connection of the 220 HH poor households. This contract did not include the tariffs and other regulations already supervised by the regulator, EAC. This contract will last 15 years.

In the power supply contract, the role of the CEC is to control and supervise the work done by the private entrepreneur, support him in educational and awareness-raising activities related to the service provided, disburse the incentive to the entrepreneur once he has made connection of the listed poor and remote households and mediate between the investor and the users especially concerning the installation of electric poles in private land.

The role of the REE is to supply the electricity in accordance with technical specifications of EAC, to finance the rehabilitation and extension of the existing electricity system and then to connect at least 500 HH in which 220 households are to be connected by MLS and 280 HH by meter.

### II.4.2.1 Tariff and connection fee

The tariff and connection fees were not included in the power supply contract as they are directly regulated from Phnom Penh by the regulator (EAC). Concerning tariffs, EAC has issued a tariff grid that is used to check if the REE applies correct tariff. The tariff is Smau Khney is presently quite high, 2300 riels/kWh and 4000 riels/month per lamp of 10W, this being due to the small scale of the system and the high cost of fuel.

The connection fees are also regulated by EAC. For the present time, the REE set the connection fee at $ 15 for the metered service and free for the Minimum level of service. EAC consider that the REE should take in charge a part of the connection costs and charge it through the tariff. However, the MLS of service proposed in this project is another way to provide electricity to the poorest without the obstacle of the connection fee.

## II.4.3 Licensing

As mentioned earlier, EAC is in charge of regulating the REEs all over Cambodia. The EAC issues licenses to REE with related obligations of service. REE license are usually short term because EAC considers that they need to improve their systems before getting long-term licenses.

Before the project, Mr. Srey Sokhom had a license of 2 years. After the rehabilitation of his facilities, he has obtained a license of 7 years from EAC. Even though this license is too short to ensure a proper return on investment (estimated at 9 years), it was one of the first time that EAC had issued such a long license. In addition EAC promised that they would automatically renew the license if the service remains satisfactory over the coming years.

## II.5 Support to the REE

### II.5.1 Access to credit

Gret-Kosan helped the REE, Mr. Srey Sokhom, to obtain a credit of 2000 US$ from the commercial Peng Heng SME Bank in Phnom Penh with the interest rate of 14% per year for a period of 3 years. The credit was made in the frame of a credit and guarantee scheme put in place by Gret-Kosan. This credit and guarantee scheme provides to Peng Heng:

- Long term refinancing to allow the bank to lend money on longer term than the usual one-year credit, with lower rates than the usual market, (about 20%/year)
- A 30% financial guarantee to allow the bank to decrease the size of collateral which is is usually more than 3 times higher than the loan itself.

### II.5.2 Training of REE

During the whole duration of the project, the REE, Mr. Srey Sokhom received regular support from the project team, Mr. Ky Chantan and Mr. JP Mahé. At the end of the construction of the system, Mr. Jean-Louis Urima, EA, and Mr. Ky Chantan conducted a training session (picture) at the electricity station of Smau Knhey. Other REEs nearby the station were also invited. The training mainly focused on the electric installations, daily checking of the generator functioning, safety and environment. Considering the high cost of fuel in Cambodia, most of the concerns of the REES related to fuel saving, especially production issues and cable sizing.

# III TECHNICAL ASPECTS

## III.1 Analysis of the existing system

The mini-grid of Smau Khney is based in the Trapeang Sab commune, Bati district of Takeo province. Mr. Srey Sokhom, private investor, has created and invested this electricity system since 1994 to respond the needs of villagers in the area and on his side, in order to secure revenues within a long period. This system served 280 households in single phase. The equipment of the REE included:

- A generator of 100 KVA (Origin: Czechoslovakia)
- 2.5 km of electric network (single phase: 110V), copper cables, metal poles of 5m high.

### III.1.1 Legal Aspects

This electric enterprise and installations are the property of Mr. Srey Sokhom, who is a civil servant of the Ministry of Agriculture. He is also the owner of the piped water system of Smau Khney.

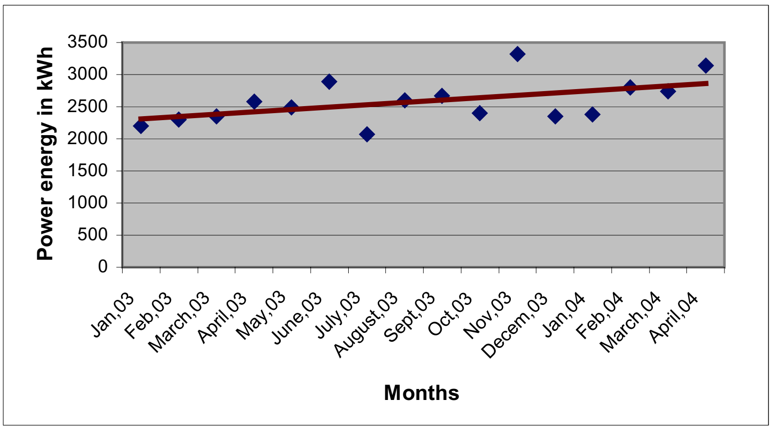
Including the land of the power station, the total amount of investment was about **23000 US$** (value given by the investor).

This electric enterprise had received a license from the EAC (Electricity Authority of Cambodia) in November 2002. This license was valid for 2 years. After rehabilitating the system, Mr. Srey Sokhom expected to get a license of at least 10 years.

### III.1.2 Clientele

The number of households in the area was about 500 of which 280HH were already connected (so to say about 56%) and 220HH were to be connected (44%). These connected households were essentially domestic clients.

The average consumption per household was about **9, 5 kWh/month**. All connected households had a metered connection. The commercial clients such as the battery chargers, welding systems, restaurants, photo shops…etc, had their own gensets. The following graph shows the electric consumption in 2003 and beginning of 2004.




*Graph I.1: Electric consumption by users in 2003 and beginning 2004*

According to the above graph, the needs of electricity from year to year are increasing. Indeed, the average increase of monthly consumption of the last 4 months in 2004 compared to that in 2003 was about 400 kWh, so to say about 30%.

#### III.1.2.1 Time of operation

The electricity system functioned from 17h00 to 22h30 (Monday-Friday) and from 11h00 to 22h30 (Saturday-Sunday). Operational time should be extended according to the recommendations of EAC when the system is rehabilitated.

#### III.1.2.2 Connection

The household paid for a meter installed in a box on the nearest pole to the household. The investor is in charge of making connection. All meters to be installed are calibrated by EDC (Electricity du Cambodge).

### III.1.3 Management

Mr. Srey Sokhom, investor supervised the operation and maintenance of the system.

The functioning of enterprise includes two other people:

- Mr. Vesna, staff being in charge of station operation; and
- Mr. Chea Long, staff ensuring the distribution system.

Mr. Srey Sokhom pays a salary of about US$ 50/month for both.

The wife of Mr. Srey Sokhom is in charge of collecting the bills at the end of the months. There are few of non-payment per month. Mr. Srey Sokhom pays taxes, patent as well as the licensing fee (10 Riels/kWh sold).

### III.1.4 Analysis of cables

Incorrect choice of the cable section was causing energy losses on the distribution system. The conductors used in the existing distribution system were essentially made of aluminum (non isolated) of 16mm² to 35mm². These conductors covered about 30% of the total existing distribution lines. Others were isolated copper of 4mm² to 10mm². The power distribution was made through split phase (110V single phase, so to say 220V between phases, without neutral).

This system needed to be changed to three phase 380V in order to (1) increase the capacity of power supply, (2) minimize power losses and voltage drops, (3) avoid power possibly stolen by users because if the users drove energy from one of two phases and used the ground conductor installed at their homes as the neutral conductor, the meter typed Liuzhou, fabricated in China would not work (experienced directly by Mr. Srey Sokhom).

According to the EAC's estimation, the power losses on the existing distribution system were about 40%. The voltage value measured at the end of the longest distribution line (1.1km) was 156V (33%)

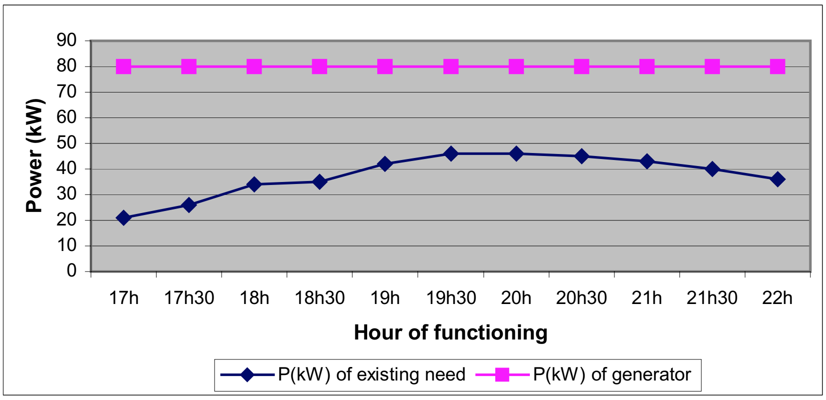
### III.1.5 Power station

The existing generator had been installed in 2001. It was made of a diesel engine mated with a dynamo with belt. This generator was easy to repair (spare parts and expertise available in

Cambodia), however, it created a negative environmental pollution, noise, bad disposal of spent oil and greenhouse gas emission.

The motor was 120 HP (about 88 kW). The dynamo was 100 KVA, so to say 80 kW. The capacity of the engine was not so sufficient to rotate the dynamo, it should have been at least 118 kW so to say 160 HP.

The generator functioned 5 hours and half a day from Monday to Friday. The graph below shows that the peak consumption of the system was about 46 kW, so to say 2 times less than the maximum power of the generator.




*Graph I.2: Total power demand on the existing system*

### III.1.5.1 Fuel consumed by the generator

A control on the fuel consumed by the generator and kWh produced and sold shows a very bad efficiency rate. The following table shows the efficiency of the present generator in the two months before the rehabilitation.

| Month | Total fuel consumed by Generator | Total number of Kwh produced | Total number of kWh billed | Efficiency of Generator per Kwh produced | Efficiency of generator per kWh billed |
|---|---|---|---|---|---|
| March 2004 | 1705 L | 4060kWh | 2234 kWh | 0.42 L/kWh | 0.7 L/kWh |
| April 2004 | 1743 L | 4120 kWh | 2526 kWh | 0.42 L/Kwh | 0.69 L/Kwh |

The present generator consumed fuel about two times more than a normal generator should do (consumption: 0.25L/kWh).

### III.1.5.2 Estimation of capital

| Type of investment | Year of buying | Cost in (US$) |
|---|---|---|
| Motor 120 HP and generator 100KVA | 1994 | 8000 |
| Distribution lines (2.5km) | 1994 | 3000 |
| Poles and other accessories | 2001 | 3500 |
| Land to install the powerhouse | 1994 | 8600 |
| Total | | 23100 |

### III.1.5.3 Result of exploitation

An analysis on the result of exploitation was made in April 2004 with participation of Mr. Srey Sokhom:

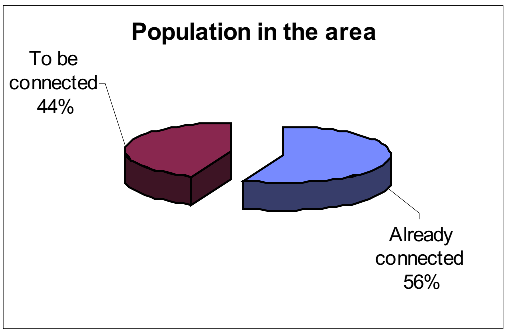
| | |
|---|---|
| Revenues | • 2526 kWh x 0.5 $/ kWh =**1263 US$** |
| Expenses | • Fuel: 739 US$<br>• Oil: 42 US$<br>• Reparation and maintenance: 50 US$<br>• Staff salary: 100 US$<br>• License: 2.5 US$<br>• Taxes and Patent: 5.5 US$<br>• **Total expenses: 939 US$** |
| Net result | • 324 US$ without depreciation |
| Actual depreciation | • Poles: 10%/year, or 10US$/month<br>• Genset: 60 US$/month<br>• Conductors: 10 US$/month<br>• **Total: 80 US$** |
| Result of exploitation / month | • **244 US$** |
| Cost price | • $(939 + 80) / 2526 kWh<br>• **$ 0.40 so to say 1633 riels/kWh** |

## III.2 Demand assessment

A survey was conducted in 180 households of the Smau Khney area (April 2004), taken randomly among connected and non-connected households. This survey provided interesting information to prepare the rehabilitation of the system.

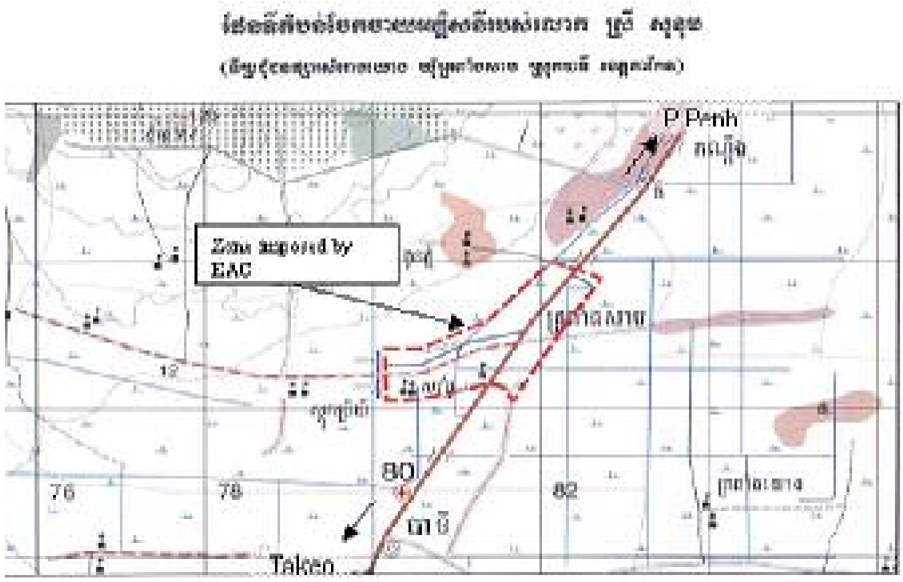
### III.2.1 Configuration of the village

The habitat of Smau Khney area is densely arranged along the national road NR2. The households counted in this zone were 500HH in which 280HH were already connected and 220HH others were yet to be connected, so to say 44%. Mr. Srey Sokhom rehabilitated his electric system in order to supply electric power to all those 500 households, so that the electrification rate at the end of the rehabilitation phase would reach 100%.



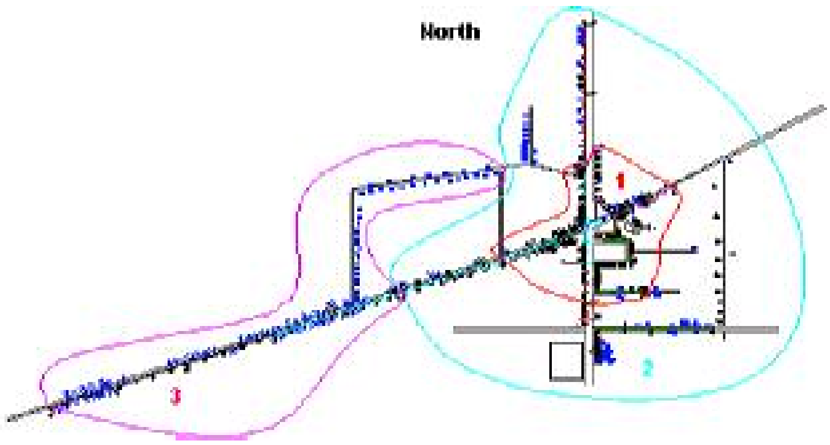

*Graph II.1: Situation of the population/network*

The following map of the village indicate the zone imposed by EAC for the grid of Smau Khney:



### III.2.2 Existing domestic clientele

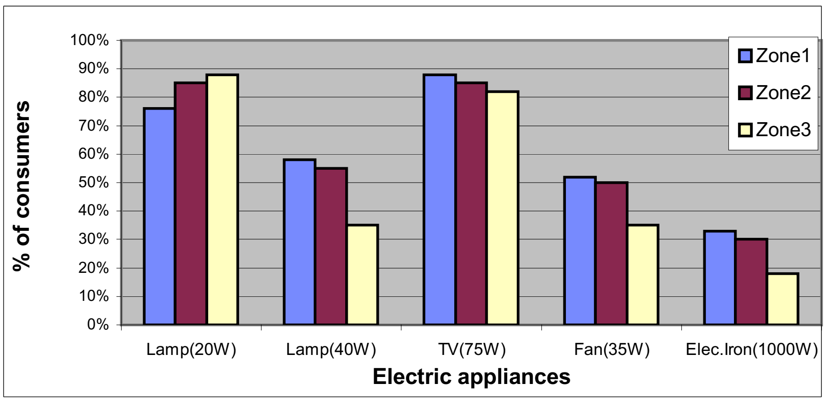
A survey on the existing electric appliances and consumption had been done among already connected HH. For that, the area was divided into three categories: very densely area located around the market (called Zone 1), quite densely area (called Zone 2) and scattered area or zone of extension (called Zone 3).




In each zone mentioned above, the number of electric appliances as well as their power (in Watt) equipped by the households is different. According to the survey, each household had at least one lamp and a color television. On average, household had 3 lamps for those in the zone 1 and 2, and 2 lamps for those in the zone 3 (see table below).

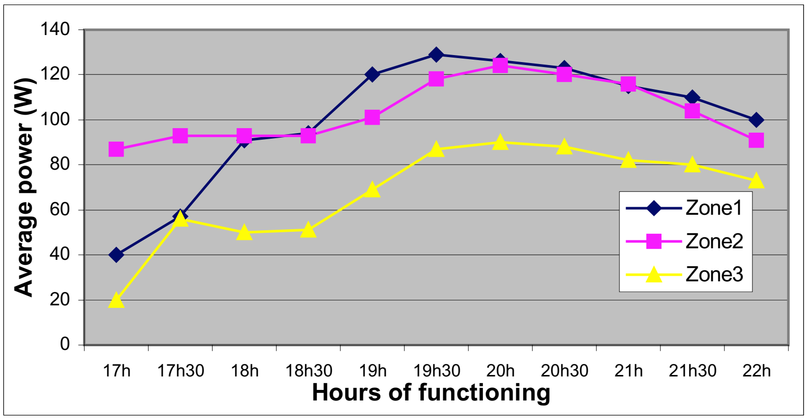
| Nb. lamps | 1 | 2 | 3 | 4 | 5 | 6 | 8 |
|---|---|---|---|---|---|---|---|
| % of people in Zone 1 | 12% | 42% | 18% | 12% | 9% | 3% | 3% |
| % of people in Zone 2 | 5% | 30% | 30% | 15% | 5% | 5% | 10% |
| % of people in Zone 3 | 30% | 25% | 20% | 0% | 5% | 5% | 0% |

The graph below clearly shows the level of electric appliances used of the households in corresponding zone:




*Graph II.2: Level of appliances of the population in the area*

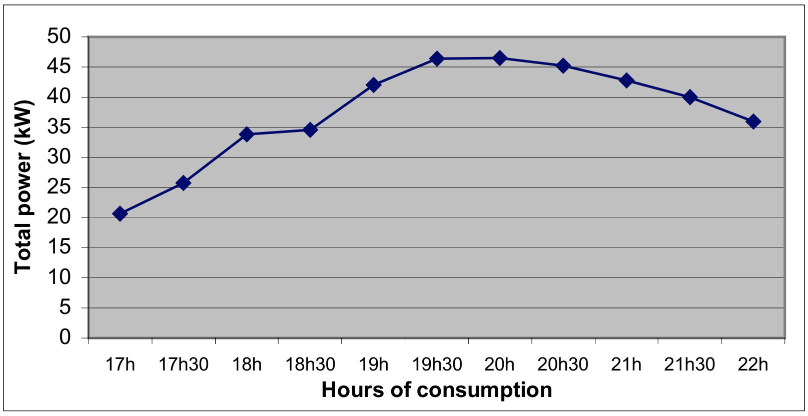
People use these appliances only during the evening from 6 to 10 (opening hours). The survey showed that the average power consumption during the peak hour of functioning of the system was about **116 W/HH**. The graph below shows the detail of the average consumed power per connected household during the functioning hours of the system in each zone:




*Graph II.3: Average HH consumption*

| | Maximum verage power consumption (W) |
|---|---|
| Zone1 | **129** |
| Zone2 | **124** |
| Zone3 | **90** |

The total power demand of the existing households during the peak hours of operation of the generator was about 46 kW (see the curb of power demand of the existing domestic clientele in the graph below).




*Graph II.4: Curb of power demand on the existing system*

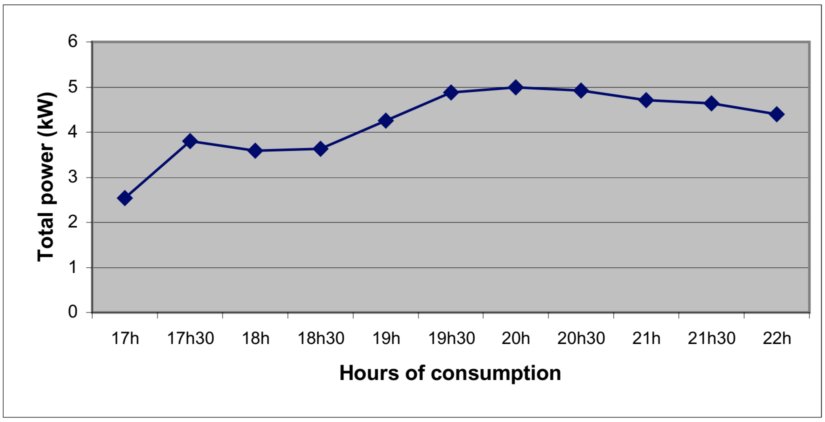
### III.2.3 New domestic clientele

It was foreseen that 220 new domestic clients would connect to the electricity system thanks to the incentive provided by the project to the investor. According to the survey, only 35 of those were willing to connect by meter and 185 at fixed rate (MLS). The 35 HH who wanted a meter were located in the zone 3, their power consumption was considered as already connected HH, so to say about 90W/HH.

For the ones who would connect by fixed rate (Minimum Level of Service: 1 or 2 lamps of 10W), the maximum consumption would therefore be about 20W.

| | |
|---|---|
| Connection by meter | 90W |
| Connection by MLS | 20W |

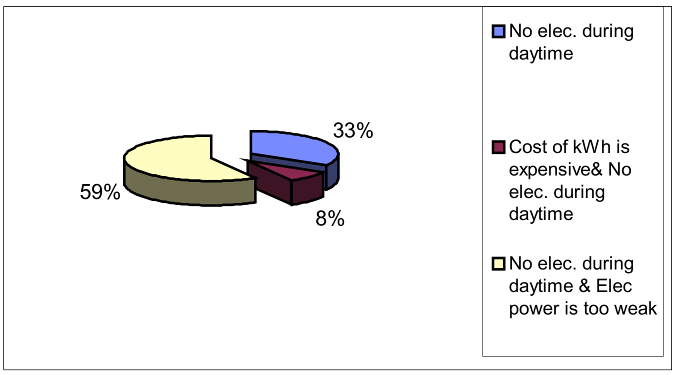
The total power demand of the new clientele during the peak hours of operation of the generator was estimated at about 5 kW (see curb in the graph below).




*Graph II.5: Curb of power demand of the new domestic clients*

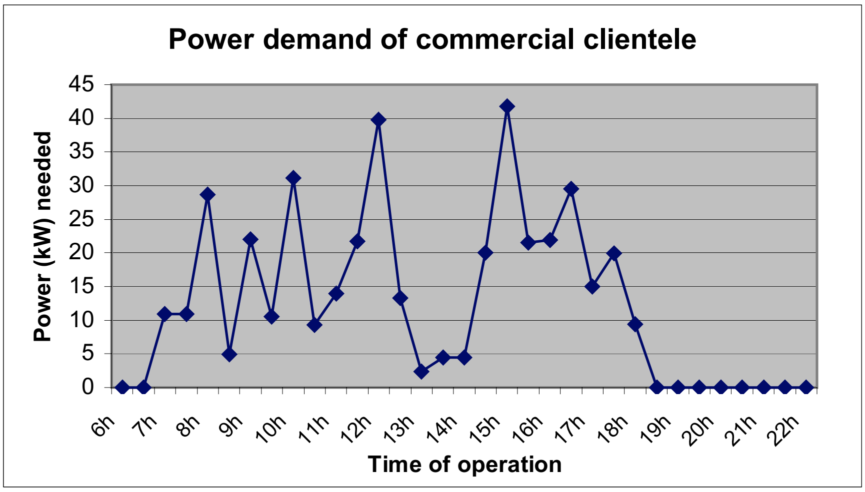
### III.2.4 New commercial clientele

There are 12 commercial clients existing in the area. They are battery chargers, welders, and mechanics, etc. These clients are located close to the main road. Nowadays, they rely on their own gensets because there is no electricity supplied during the daytime and the present system is too weak. The graph below showed the reasons of the commercial business for not being connected.




*Graph II.6: Reasons for non-connection of the commercial clients*

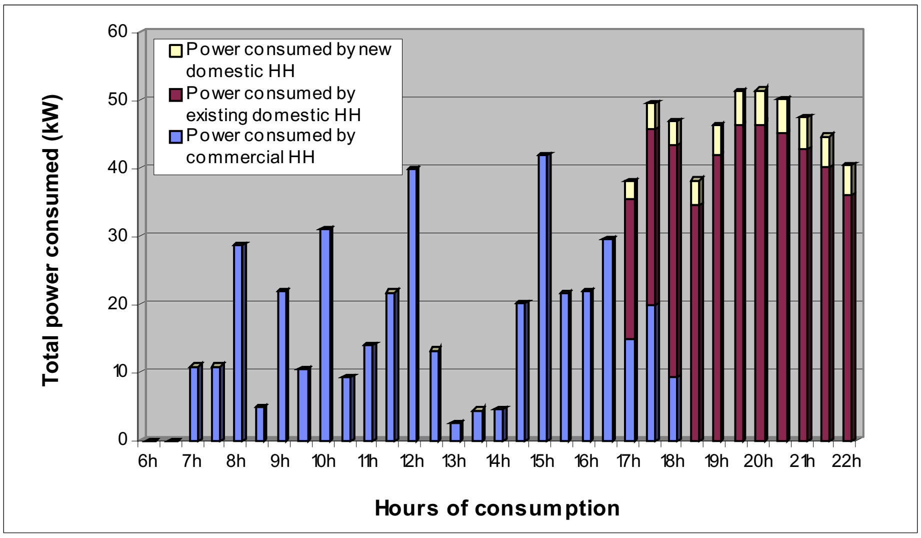
According to the survey, 6 out of 12 (so to say 50%) were interested to connect to the electricity system. Their energy demand is only during the daytime. The peak energy demand of these people was about 42 kW (see graph below).




*Graph II.7: Estimation of the power demand of commercial clients*

## III.2.5 Present total power demand

The superposing of the total power demands of the existing domestic clientele, the new domestic clientele and the new commercial clientele, is shown below.




*Graph II.8: Estimation of the overall present power demand*

The peak power demand is during the nightime from 19h00 to 20h30. The overall power peak demand during this period equaled to 51 kW. The selection of the generator to put in place should therefore be based on this configuration.

### III.2.6 Anticipation of the power development

When the electricity system is improved and functions 24 hours a day, 10% of connected households, so to say 28 HH, said they would buy more electric appliances. According to the survey, the total power for this new equipment would be about 25% more than the present consumption. Two other factors were to be taken into consideration to evaluate the future demand:

- The anticipated increase of households based on the census, so to say about 2%/year, or about 30%/15 years.
- The estimated general increase of consumption, so to say about 2%/year, or 30%/15 years (this was an estimation).

*Therefore, the cable design would be based on:*

| | Power consumption per HH (W) | Total coefficient of increase | Total power consumption per HH (W) |
|---|---|---|---|
| **Zone 1** | 129 | +85% | **238** |
| **Zone 2** | 124 | +85% | **229** |
| **Zone 3** | 90 | +85% | **166** |

In order to simplify the design of the conductors, we have considered that the future average power consumption per household in the zone 1 and 2 equaled to **235W, so to say about 300 VA.** As for people in the Zone 3, their future average power consumption was equal to **166W, so to say about 210 VA.**

### III.2.7 Conclusion

The generator shall be based on the estimated present consumption, but the cable should be sized and installed to cover the needs of the 15 coming years:

| Size | Now | Within 15 years |
|---|---|---|
| Generator | 60 kW/75 KVA | 95 kW/118 KVA |
| Cable | 95kW<br>Designed for voltage drop less than 10% | 95 kW<br>Designed for voltage drop less than 10% |

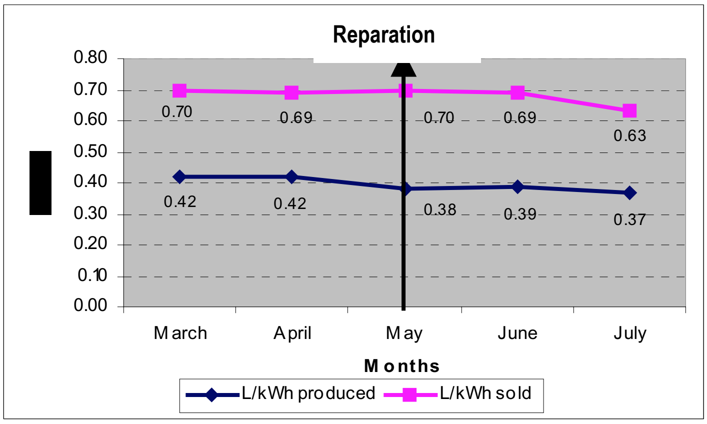
## III.3 Improvement of the power generation

### III.3.1 Reparation of the engine

As indicated in point 1.5, the existing dynamo was activated by an engine that was under dimensioned. Due to this, it was found that it broke down frequently. In May 2004, it broke again. The interruption of the power supply lasted about 5 days. The motor was sent for repair in order to be in better condition and save fuel.

After reparation, it consumed less fuel than before. The detail of the fuel consumption during several months after its reparation is shown in the table below:

| Month | Total fuel consumed by Generator | Total number of Kwh produced | Total number of kWh billed | Efficiency of Generator per Kwh produced | Efficiency of generator per kWh billed |
|---|---|---|---|---|---|
| May | 1795 L | 4680 kWh | 2564 kWh | 0.38/kWh | 0.7 L/kWh |
| June | 1952.5 L | 4940 kWh | 2773 kWh | 0.39/kWh | 0.69 L/kWh |
| July | 1774 L | 4760 kWh | 2805 kWh | 0.37/kWh | 0.63 L/kWh |

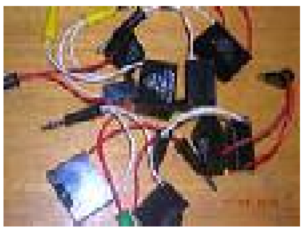



*Graph III1: Fuel consumed by generator after reparation*

As shown in the graph above, the fuel consumed by the generator (after its reparation) has decreased about 12% of fuel compared to the previous situation.

### III.3.2 Improvement of the fuel consumed by installing capacitors on fluorescent lamps

Even though there has been saving after the reparation of the engine, the level of fuel consumption by kWh produced was still quite high compared to what a normal generator does. One of the reasons was because there was loss of reactive power on the lightings due to the bad power factor of the magnetic ballasts installed. This made the generator have a high speed of rotation and consumes more fuel (the existing regenerator operated at 55 Hz during peak hour). Therefore, in order to correct the power factor of the magnetic ballast, we recommended to install capacitors on all lamps installed in domestic households.



The value of capacitor chosen to install was calculated and tested by the training center called CKN (Center Krom Nguy) of Phnom Penh.

The calculation was determined by the following equation:

$$C = \frac{I \times Sin\phi}{6.3 \times U \times f}$$

Where

C = Value of capacitor required (farads)

U = normal operating voltage (V)

$f$ = Power frequency, usually 50 or 60 Hz

$\phi$ = Power factor angle (= cos $^{-1}$)

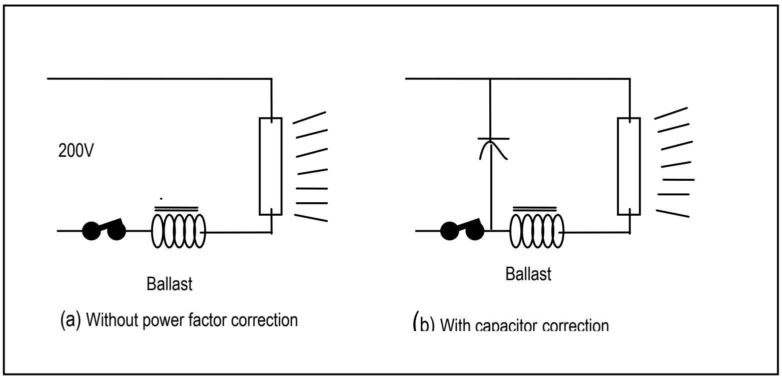
Capacitors exist in the local market

The value of *I*, the current in ampere drawn by each unit was indicated in the nameplate of the unit.

The table below shows the results of the calculation of capacitors chosen to increase the power factor value from 0.3 to 0.9.

| Ballasts | Lamp (W) | Operating voltage (V) | Initial power factor (μF) | Calculated capacitor (μF) | Power factor corrected (μF) | Capacitor installed in the market (μF) | Price of capacitor (Riels)[2] |
|---|---|---|---|---|---|---|---|
| 10/20W OCTANE* | 20W | 200V | 0.37 | 4.59 | 0.88 | **4.75** | **1300** |
| 36/40W OCTANE* | 20W | 200V | 0.35 | 6.57 | 0.9 | **6.5** | **700** |

Two capacitors 4.75 μF and 6.5 μF are chosen to install with lightings in the households of the users.




(a) Without power factor correction

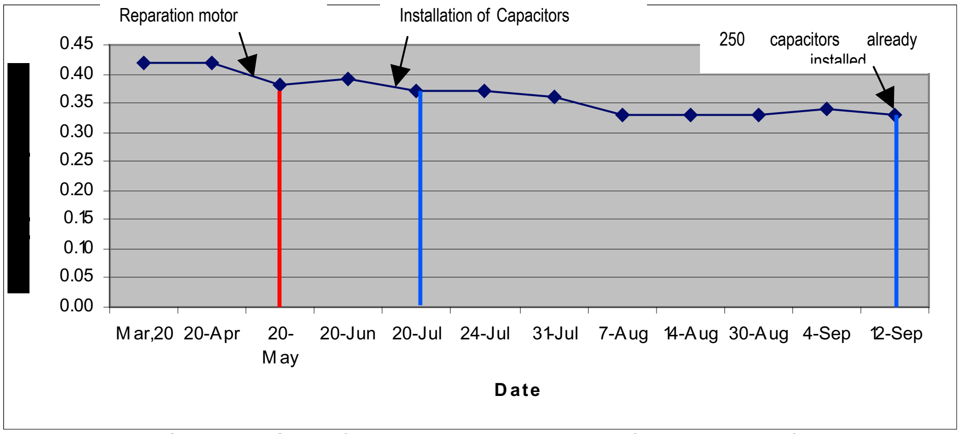
(b) With capacitor correction

The installation has been made by the son of the entrepreneur with the assistance of an trainee of ITC (Institute of Technology of Cambodia). Most of the lamps were 20W assembled with a ballast of 40W. There were more than 100 households having been equipped with these capacitors. The figure above shows the details of its installation.

According to Mr. Srey Sokhom, owner of the system, the existing generator operated with significant better changes after the installation of capacitors. He said that his generator was before operating at 55 Hz and smoked black during the peak consumption as well as produced a big noise. After installation, it operated at 51 Hz without smoke during the peak consumption, and it was more silent than before.

The installation of 250 capacitors installed in more than 100 connected households (a few capacitors installed per each household) create a significant fuel saving The following graph showed the curb of fuel consumed by the existing generator after the installation of capacitors.

[2] 4000 riels = 1 US$




*Graph III2: Saved fuel consumed by generator after installation of capacitors*

The investor had saved about 11% of fuel from the installation of 250 capacitors. So to say, with the reparation of the motor and 250 capacitors, the investor has saved about 23% of fuel usually consumed by the existing generator. The return of investment regarding the installation of capacitors is about 2 months. The detail of the calculation was shown as the following:

| Nº | Designation | Quantity | Total price (USD) |
|---|---|---|---|
| 1 | Capacitors installed | 250 | 66 |
| 2 | Fuel saved per month | 76 | 32 |
| **The return of the investment: 66/32 = 2 months** | | | |

## III.3.3 Improving the generator

The sizing of the generator was based on the present overall energy demand during the peak hour of consumption multiplied by a coefficient of 20%. According to the evaluation of the energy demand, the overall demand of energy of Smau Knhey electricity system including the 220 new households was 51 kW. Therefore, the generator selected to put in place would be about **60 kW, so to say 75 kVA.**

This selected generator would function 6 hours during the evening hours (from 17h00 to 23h00) and 5 hours during the daytime for commercial consumer's needs.

Since the investor, Mr. Srey Sokhom, could not afford buying this generator it was proposed to recondition the generator by changing the coupling from split phase to three phase 380V with neutral, and reinstalling it in series with the motor with a transmission shaft.

### III.3.3.1 Changing coupling

The coupling was split phase 220V (without neutral), so to say 110V on each phase. This coupling was changed into three-phase (4 wires), 380/400V between phases and 230V between phase and neutral. By doing this, the power stolen on the distribution lines due to the users that drive energy from one of two phases and use the ground as neutral was minimized The figure below shows how was made the coupling of three-phase 380V:

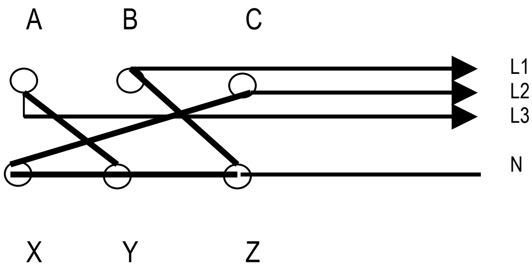



Figure 1

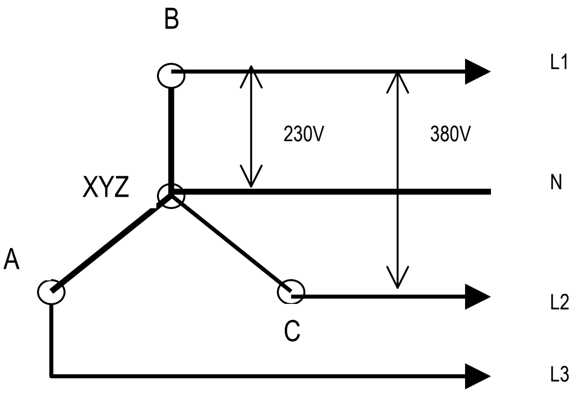
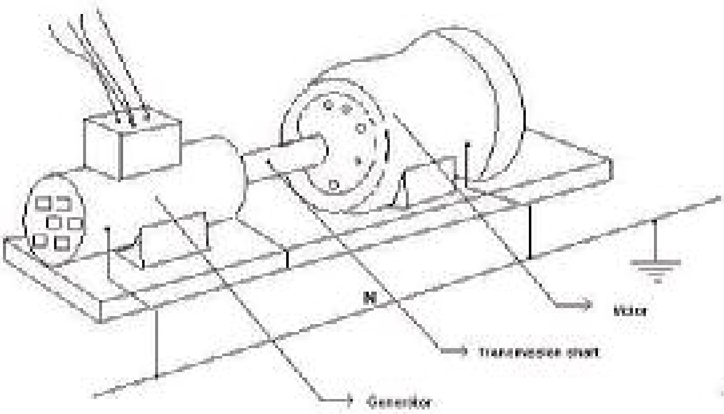



Figure 2

#### III.3.3.2 Changing the belt system to a transmission shaft

In addition, the generator was reinstalled in line with the motor through a transmission shaft. Once it is put in place, the problem of vibration created by the belt disappeared. The figure below shows the general lay out of the installation.




### III.3.4 Improving the control system

Electric devices have been installed to measure the following electric parameters:

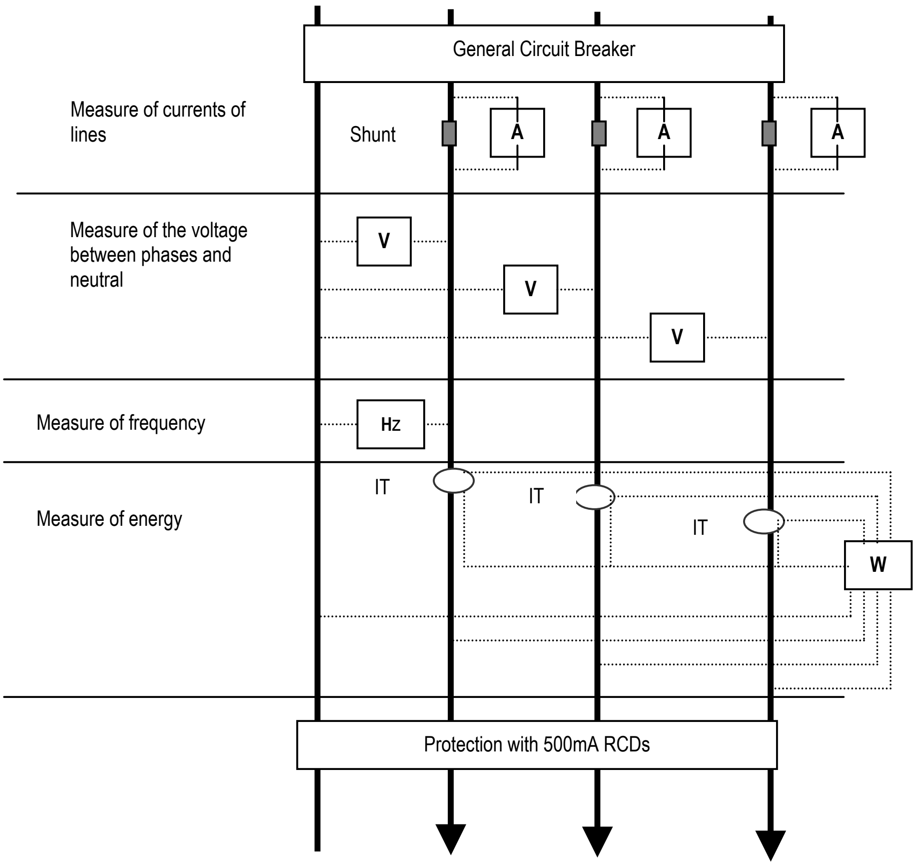
- *Current on each phase*: this measurement is realized by an Ammeter (ampere-meter). The currents along the lines are generally too high to be controlled on lines. The measurement is made on a shunt.
- *Voltage between each phase and neutral*: this measurement is realized by a voltmeter installed between neutral and phase.
- *Frequency of generator:* as the frequency is linked with speed of rotation of the generator, it is the same on the three phases. Only one frequency-meter is therefore necessary and shall be placed between neutral and one of these three phases.
- *Energy supplied by the generator through the network:* this measurement is realized by a wattmeter hooked up through intensity transformers (IT).

Two possible solutions of measurement can be done:

(1) Hook up the measuring devices on each phase. This solution is very simple to be implemented, but it needs 3 Ammeters and 3 Voltmeters. This solution permits a simultaneous reading of all measures.

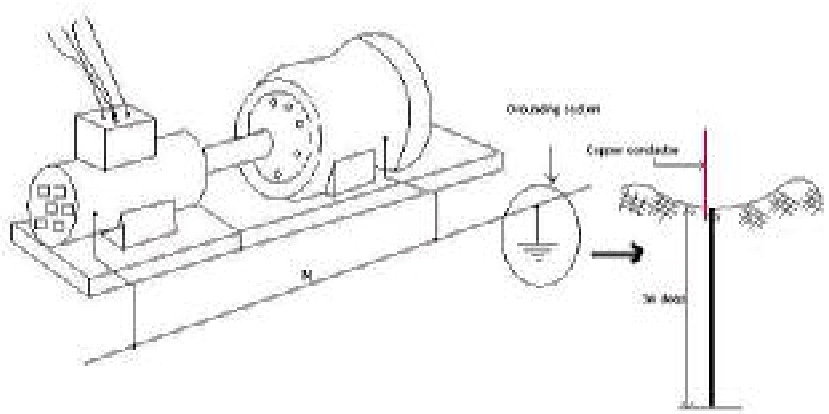
(2) Hook up one ammeter and one voltmeter to two switches permitted to select the phase for measuring. This solution is more economical but requires, in case of damage, intervention of a technician. Moreover, it does not permit a simultaneous reading of all measures.

In case of Smau Khney, we recommend the solution nº1. Following is the control system diagram:



### III.3.5 Grounding system

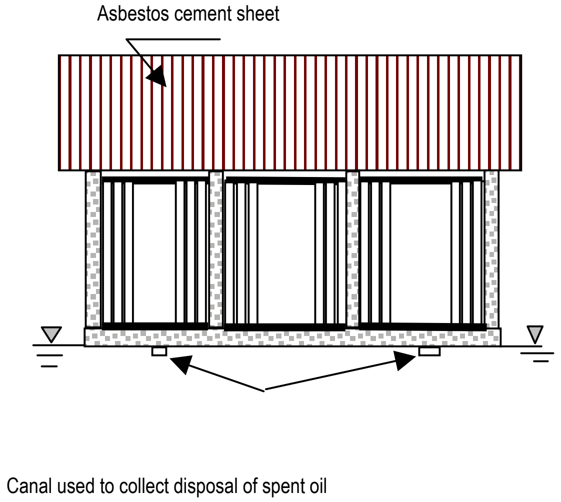
The neutral conductor and metal housing of both motor and generator were connected to a grounding rod with a copper cladding driven into the ground at about 3m deep at a place where the soil was always humid to ensure a low ground resistance. The protection against leakage current through the distribution lines needed a necessary protection through RCDs (Residual Current Devices) 500 mA installed on each distribution branch.

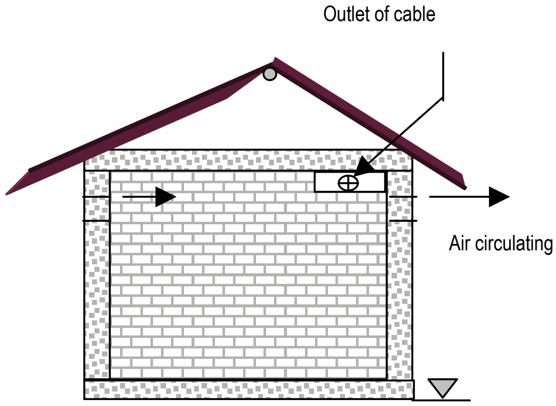


### III.3.6 A new power house

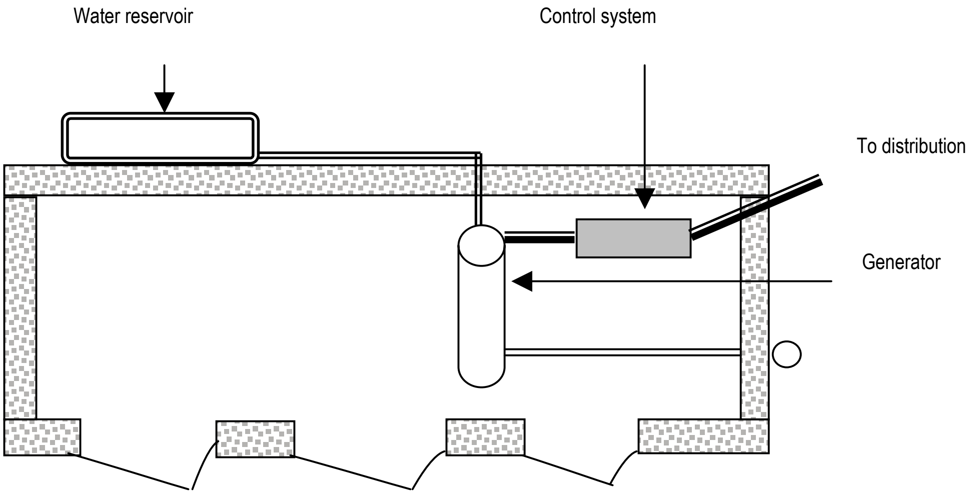
The investor built a new powerhouse (picture). It is composed of one compartment where are installed the generator, the fuel reservoir, the control system and the protection system boxes. The installation of all these equipment was conceived to allow an easy access. It was constructed in bricks with 7m long and 4.5m large, and plastered with mortar to avoid the rainwater into the powerhouse. The ventilation blocs are placed just below the roof in order to allow the circulation of air inside the powerhouse. Because the tiles are expensive, its roof is made of asbestos cement sheets much cooler that zinc or iron sheets.

Front View




Side View




Top View

# III.4 Electric poles

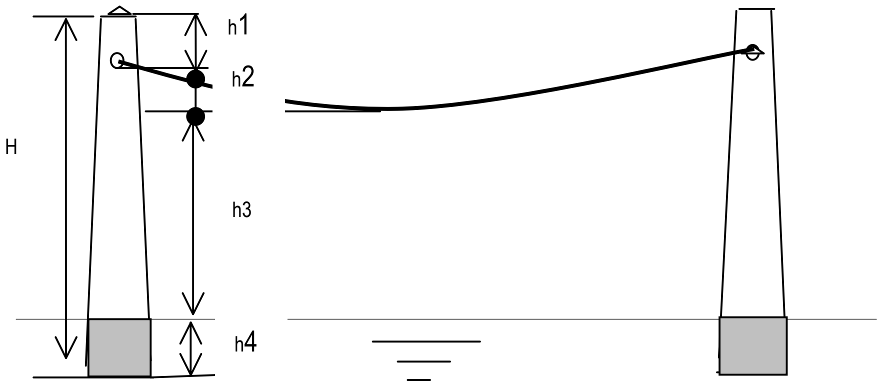
## III.4.1 Type of poles

In Cambodia, concrete and steel poles are commonly used to support the conductors, particularly in semi rural area because wooden poles are too expensive and difficult to find in many areas. The table below shows that in Cambodia, even if the wooden poles seem cheaper, the concrete poles results less expensive on the long run:

| | Wooden pole | Metal pole | Concrete pole |
|---|---|---|---|
| Price | 20 US$ | 40 US$ | 100 US$ |
| Life duration | 8 years | 15 years | 50 years |
| Depreciation | 2.5 US$/year | 2.6 US$/year | 2 US$/year |

## III.4.2 Determination of the length of pole

According to the Guide Book for Power Engineer done by Jica[3] in collaboration with MIME, EDC and EAC, the length of electric pole used to support the conductor at a point of crossing road shall be at minimum 6.5m high of its clearance and 5.5 high along roads. The formula hereafter permits to determine the length of the electric poles in rural areas in accordance with the technical specifications mentioned above.




The minimum length of a pole is determined as the sum of the following lengths, ordered by their relative contribution to the overall length:

$$H = h1 + h2 + h3 + h4$$

Where h1: distance from the top of the pole to the clamp, equal to 0.14m

h2: sag of the conductor (in design, we suppose that the maximum sag, 1m)

h3: clearance of conductor (6.5m at crossing road, 5.5m along roads)

h4: setting depth (h4=0.6+0.1H; see detail in 3.1.3.4)

[3] Japan International Cooperation Agency

- For installation along roads,

H=h1+h2+h3+h4
H=0.14+1+5.5+0.6+0.1H
H=7.24/0.9
**H=8m**

- For installation at crossing roads,

H=h1+h2+h3+h4
H=0.14+1+6.5+0.6+0.1H
H=8.24/0.9
**H=9m**

## III.4.3 Concrete poles

In Smau Khney, the concrete poles are only used to support the conductors of three-phase situated along main roads and at crossing roads. They have been fabricated by the owner of the electricity system. These poles are not pre-stressed concrete pole, but the owner put 6 steel-bars (diameter 12 mm) instead of 4 steel-bars to ensure a sufficient strength to resist the forces when they are under load. The original design of the poles were provided by EDC (Electricité du Cambodge). In total, 77 concrete poles were produced of which 16 poles of 9m long and 61 others of 8m long.

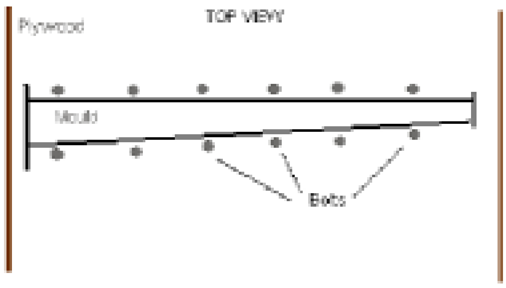
Two types of poles of 9m long have been realized:

- Poles of 9m long with 300mm x 300mm cross-section at the base and 160mm x 130mm section at the top (***called pole type 1***). These poles were used to support the conductor at places where the pole mainly counteracts forces caused by the conductor tension from several directions.
- Poles of 9m long with 300mm x 240mm cross-section at the base and 160mm x 130mm section at the top (***called pole type 2***). These poles are less stronger than that of type 1. They are used to support the conductor at crossing roads and places where the level of soil is very low in order to equal the height of poles along the lines.

Only one kind of 8 m poles , with dimensions of 300mm x 240mm cross-section at the base, and 200mm x 145mm at the top (***called pole type 3***) were used to support the conductor along roads. These poles only counteract the longitudinal force caused by the conductor tension.

### III.4.3.1 Casting concrete poles

***Preparation of soil***: a sand layer of 0.1m was put on the ground where the casting was foreseen in order to ensure that the surface of the ground is smooth. On this sand layer, large plywood sheets were installed on which the iron made mold, composed only of two sides screwed in the plywood was placed (see figure besides).

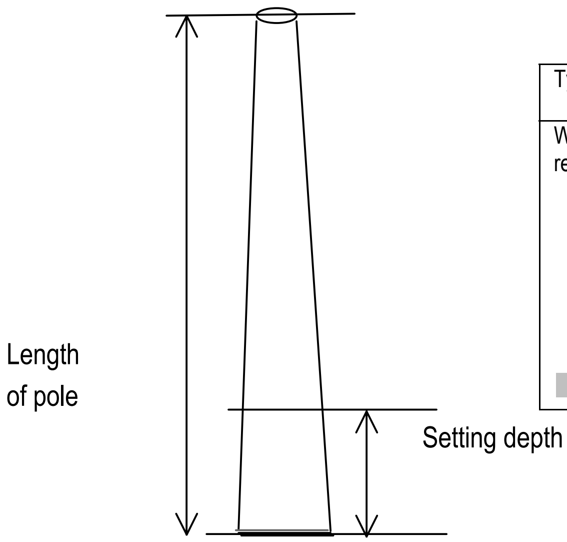


***Preparation of rebar***: Reinforcing steel or "rebar" is simply placed in the form prior to pouring the concrete. The inner surfaces of the mold were painted with oil to avoid adherence of concrete with the mold.

***Process of casting***: Once the mold and the rebar prepared, the concrete was poured into the mold. During this process, a vibrator was used to vibrate concrete to make it homogeneous. After 4 hours, the concrete became quite solid, the mold was unscrewed from the plywood and carefully removed without touching the pole. The mold was then replaced besides and the casting process repeated. With this process, the owner could produce 2 or 3 concrete poles per day with the same mold. After that, the owner keeps the concrete poles wet during one month in order to ensure that they were strong enough (it is estimated that concrete has its optimal strength within 28 days).

### III.4.3.2 Setting depth

According to usual technical standards, the setting depth should be 0.6m, plus 10% of the whole length of the pole. This depth may be increased somewhat in soft soil or if the poles are set on slope.

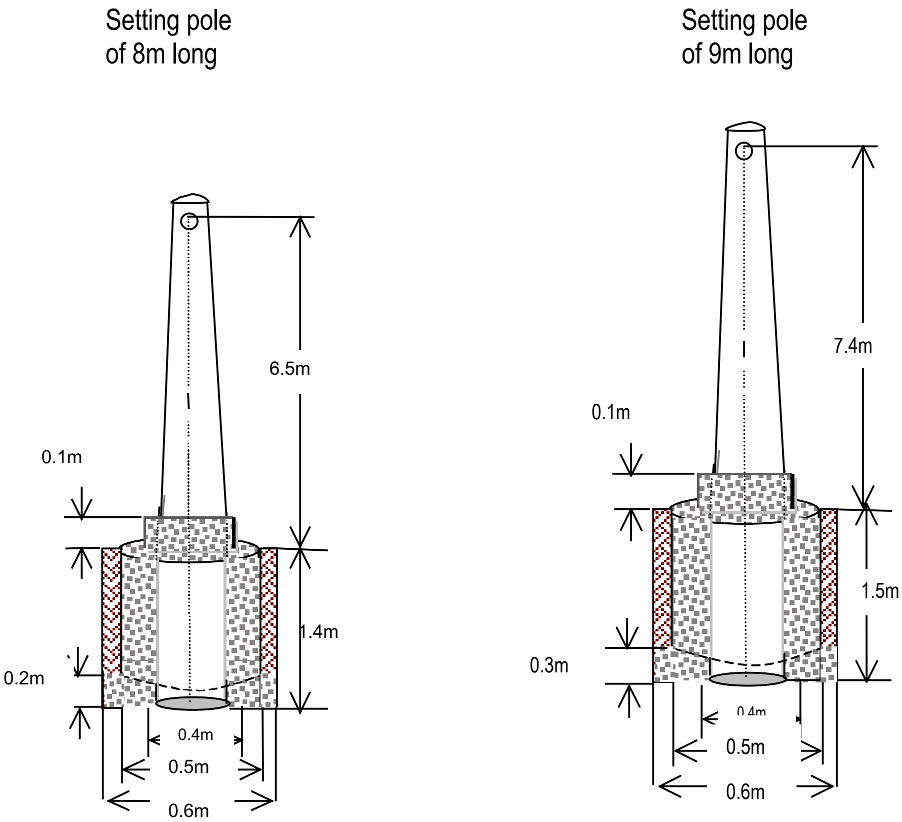



| Type of poles | Length of pole (m) | Setting depth (m) |
|---|---|---|
| Wooden pole, metal pole, reinforced concrete pole | 7 | 1.2 |
| | 8 | 1.4 |
| | 9 | 1.5 |
| | 10 | 1.7 |
| | 11 | 1.9 |
| | 12 | 2.0 |
| | 13 | 2.2 |
| | 14 | 2.4 |
| | 15 | 2.5 |
| | 16 | 2.5 |

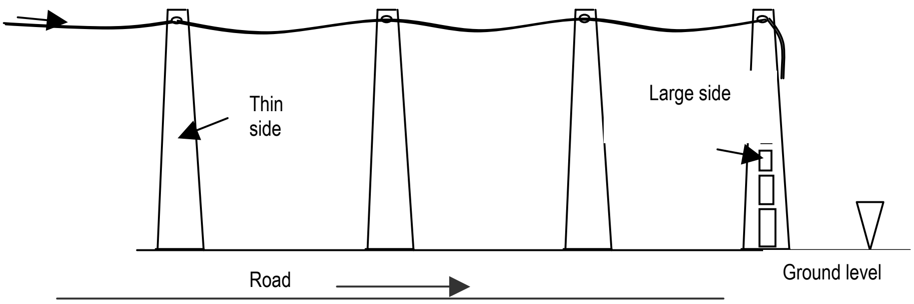
### III.4.3.3 Technique for setting poles

A special concrete ring type had been constructed to serve as a guide for the installation of the poles. It has 0.4m of inner diameter and 1.2m long (see the detail plan below).

Holes of 0.6m diameter with two different depths of 1.5m and 1.6m have been made. Concrete ring are placed in these holes. The electric poles are then introduced in the ring. Once the poles are in the straight position, concrete is poured around the poles. The following figure shows details of the setting of the poles of Smau Knhey mini-grid.

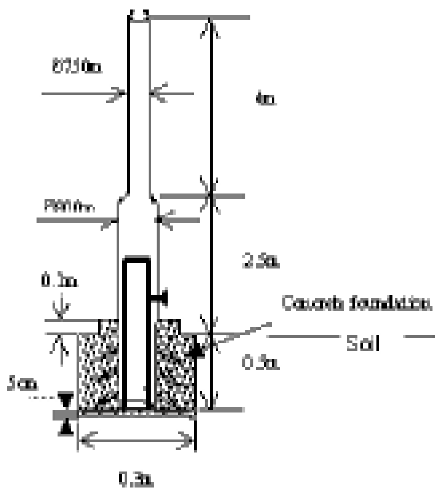



The thin side of the poles face roads except the for those being installed at the end of the distribution system so that they can counteract a single horizontal force (see in the below diagram of installation).




#### III.4.3.4 Metal poles

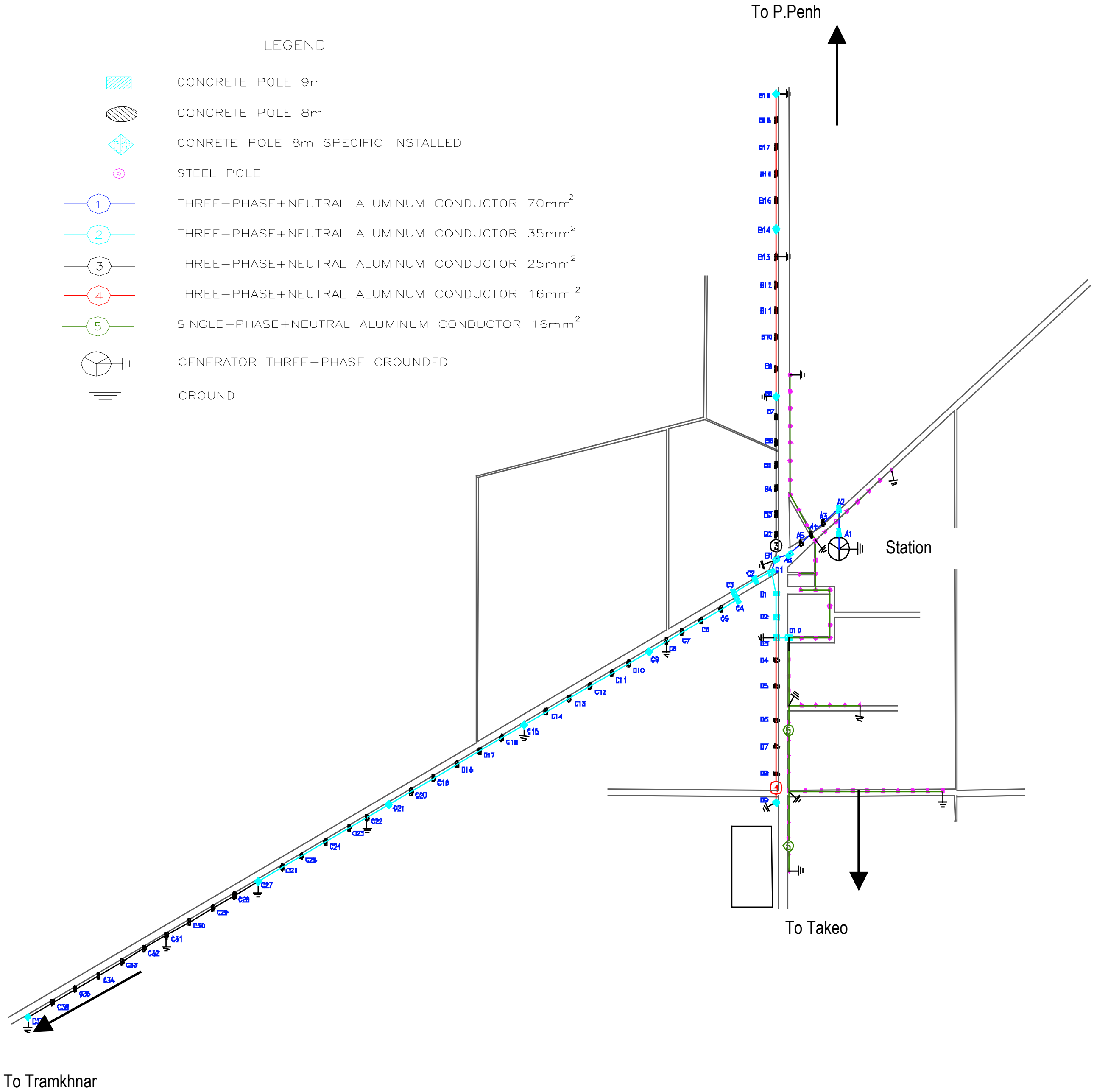
The metallic poles are used to support the conductor type single phase around the market and in the zone 3. They are all 6.5 m high. These poles are assembled from two different circle steel sections (800mm and 750mm). The pole of 750mm are inserted into that of 800mm and welded. The poles are soldered in a guide set in a concrete foundation. As in the case of the concrete poles setting, a concrete cap over the ground prevents any rainwater to avoid rusting problem. The detail technical setting of metal poles is shown below:



### III.4.3.5 Span of poles

The span of the electric poles is determined in accordance with the suitable sag (calculated in the next section), and the concrete places where the poles are to be installed. In the case of Smau Knhey, because the current main road is to be extended in coming years, the poles had to be installed at 13m from the axis of the main road (indication given by Department of Cadastre of Bati district). Considering this indication, all the places where the poles were to be installed would be just in front of the households. Some people refusing poles in front of their households, the spans are therefore not equal. The average span had been calculated for 40m, but it had to adapted from 42m to 45m.

### III.4.3.6 Plan of the poles installation



# III.5 Electric conductors

## III.5.1 Type of conductors

For electricity distribution, two materials are generally used: Copper and Aluminum. The copper is not used for low voltage distribution in warm countries because it gets soft when hot and loses about 40% of its strength compared to normal condition. The aluminum is more widely used but it only has two-thirds of the conductivity of copper. Comparing with conductors with the same resistance per unit length, an aluminum conductor requires 1.6 times the size of a copper conductor. Aluminum is preferred in many cases because its smaller weight-strength ratio permits longer spans. To increase the strength of aluminum conductor, aluminum strands can be wrapped around a steel core to obtain steel-reinforced aluminum conductor (ACSR).

In the case of Smau Khney, the distribution lines were designed for LV Aerial Bundled Conductor. This conductor is composed of three insulated stranded aluminum conductors wrapped around a messenger conductor. The messenger, which serves as a conductor and supports the weight of the entire bundle of conductor, is also isolated. This cable allows low maintenance costs and it is safer than single insulated conductor.

## III.5.2 Conductor sizing

The sizing of the conductors was made to allow the distribution of energy within acceptable voltage drops (about 10%). The calculation of the voltage drop has been made considering that the loads are uniformly distributed along the distribution lines.

The formula permits the calculation of the voltage drop is shown as follows:

$$\%VD = \left[\frac{r + 0.75x}{U^2}\right] \times P(kVA) \times 0.8 \times L \times 10^5$$

Where

| | |
|---|---|
| $P$ | = total loading on the line (kVA) |
| $L$ | = length of the line (km) |
| $r, x$ | = resistance and reactance of the conductor used (ohm/km) |
| $U$ | =voltage of operation (V) |

### III.5.2.1 Calculation of resistance and reactance

Generally, the value of the resistance and reactance of a used conductor is provided by the manufacture. But, in the case that they were unknown and not given, the determination of their value can be done, knowing the unit resistance (ohm/km) of a conductor that depends on (1) the material used and (2) its cross-section. The equation for the resistance of a conductor is the following:

$$r = \frac{18.4k}{A(mm^2)} ohm / km$$

Where

A = cross-sectional area of the conductor (mm²)
k = 1.0 for copper
1.6 for aluminum

The line reactance does not depend on the materials used for conductor. It depends on the side of the conductor and the equivalent spacing between conductors as well as the frequency of the power supply.

The equation for the reactance for a conductor is the following:

$$x = 2\pi f\left[19 + 46\log_{10}\left(\frac{s}{d}\right)\right]10^{-5}\ ohm/km$$

Where

$f$ = line frequency, usually 50 or 60 Hz

$s$ = equivalent spacing of conductors in meters

$d$ = overall physical diameter of the conductor (meters) = $\sqrt{\frac{4A}{\pi}}10^{-3}$

Note that if a stranded conductor or cable is used, the overall physical diameter of the conductor is larger than the diameter associated with the cross-sectional area A of the metal making up the conductor. The overall physical diameter of the cable also includes voids between the strands making up the conductor. For a single-phase configuration, the equivalent spacing is equal to the distance between phase conductors. For a three-phase configuration, the equivalent spacing is

$$s = \sqrt[3]{s_1.s_2.s_3}\ \text{m}$$

Where $s_1$, $s_2$ and $s_3$ are the distance (in meters) between the first, second and third, and third and first conductors.

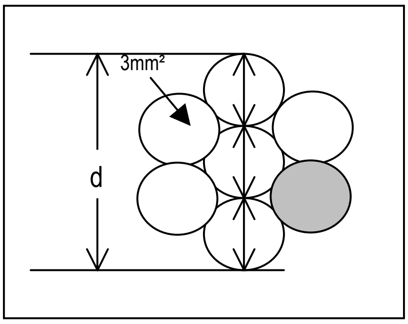
**Example for calculating R and X**

A single- phase line of copper conductor supplied by a 60Hz generator is being considered. This seven strand conductor has an overall diameter of 0.006m, the conductor spacing is 0.3m, and the area of the conductor is A=21mm². Therefore,

$$\Rightarrow r = \frac{(18.4)(1.0)}{21} = 0.88\ \text{ohm/km}$$

$$\Rightarrow x = 2.3.14.60.\left[19 + 46\log_{10}\left(\frac{0.30}{0.0060}\right)\right]10^{-5}$$

$$= 380(19+77)10^{-5} = 0.37\ \text{ohm/km}$$

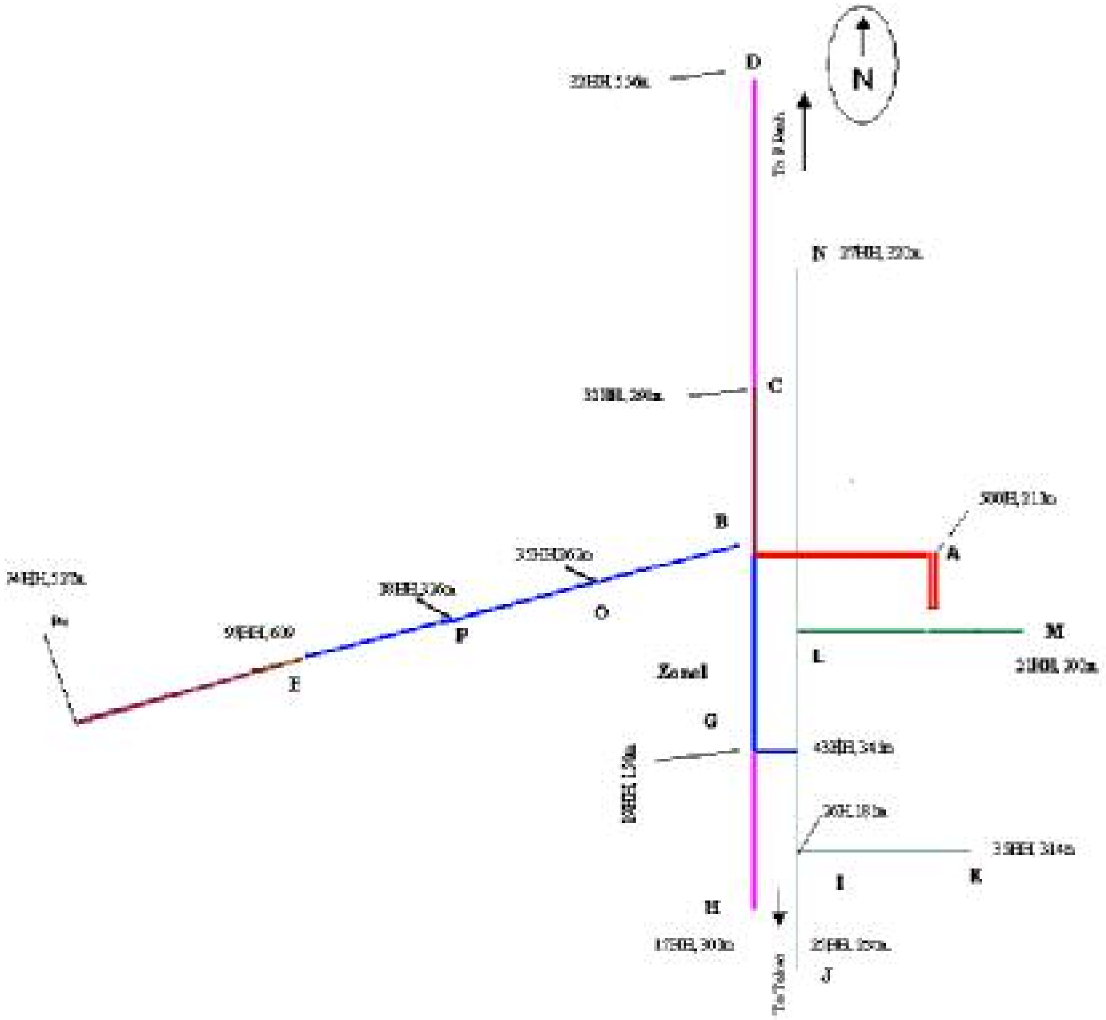



Cross-sectional view of a seven-strand conductor

### III.5.2.2 Results of conductor sizing in Smau Khney

As mentioned above, the sizing of the conductor has been made considering that the loads along the line are uniformly distributed.

The distribution network of the mini-grid is divided into three main branches: one line towards P.Penh, one line towards Takeo and another one towards Tramkhnar. All these distribution




lines are three-phase, four wire configuration. The calculation of the different sections of cable is made to minimize the voltage drop at less than 10% as well as lighten the cost of investment (see map below).

Red: Aluminum ABC Cable 4x70$mm^2$
Blue: Aluminum ABC Cable 4x35$mm^2$
Purple: Aluminum ABC Cable 4x25$mm^2$
Pink: Aluminum ABC Cable 4x16$mm^2$
Brown: Aluminum ABC Cable 1x16mm

In order to simplify the calculation, the formula has been mounted in an Excel spread sheet for computation. The following is an example of simulation to calculate the voltage drop of the conductor to be used in Smau Khney:

**CALCULATION OF VOLTAGE DROP**

| | | | |
|---|---|---|---|
| SECTION OF CABLE | mm2 | 70 | |
| INSULATION OF CABLE (NON / INSULATED) | N/I | I | |
| CONDUCTOR TYPE (CO / AL / ALM) | | AL | |
| LENGTH OF CABLE | m | 211 | |
| NUMBER OF HABITAS | n | 500 | |
| DISTRIBUTION OF LOADS | B/U | B | |
| UNIT POWER (KVA) | R/S | 0.3 | |
| VOLTAGE | V | 400 | *231* |
| TOTAL POWER ON THE LINE | KVA | 150 | |
| VOLTAGE DROP | % | 3.09% | |
| VOLTAGE AT THE END OF THE LINE | V | 388 | *224* |

**Cahier des charges :220 v+/-10%   soit '198 v/242 v  et   343 v/419 v**

An insulated aluminum conductor of 70mm² is used to supply electric power to 500HH located at the beginning of line of 211m from the generator (line: A-B). Considering that each average household consumption is 300VA (so to say 240W) and the voltage delivered from the generator is 400V three-phase (231V in single phase), the voltage value at the end of the line remains 388V in three-phase and 224V in single phase. The voltage drop (%VD) is therefore 3.09%.

By doing similar simulation and changing some data to conform to the real situation of this mini-grid, a table in which the results of the voltage drop are eventually obtained, and that is presented as follows:

| | Length of line (km) | Section of AL cable proposed (mm²) | Total power on the line (kVA) | Distributed configuration | Voltage value at the end of the line in three-phase (V) | Voltage value at the end of the line in single phase | Voltage drop (%VD) |
|---|---|---|---|---|---|---|---|
| From A-B | 211 | 70 | 150 | Three-phase | 400/388 | 224 | 3 |
| From B-O | 298 | 25 | 19 | Three-phase | 388/385 | 222 | 0.7 |
| From O-D | 556 | 16 | 9.6 | Three-phase | 385/380 | 220 | 1.2 |
| From B-G | 150 | 35 | 64 | Three-phase | 388/385 | 222 | 0.89 |
| From G-H | 301 | 16 | 5 | Three-phase | 385/383 | 221 | 0.4 |
| From B-P | 588 | 35 | 67 | Three-phase | 388/374 | 216 | 3.37 |
| From P-E | 609 | 35 | 36 | Three-phase | 374/366 | 211 | 2.1 |
| From E-F | 527 | 25 | 15.5 | Three-phase | 366/362 | 209 | 1.1 |
| From G-L | 345 | 16 | 27 | Single-phase | 378 | 222/218 | 1.89 |
| From L-M | 200 | 16 | 6.3 | Single-phase | 377 | 218/217 | 0.33 |
| From L-N | 320 | 16 | 8 | Single- phase | 376 | 218/217 | 0.63 |
| From G-I | 181 | 16 | 25.8 | Single-phase | 381 | 222/220 | 0.92 |
| From I-J | 236 | 16 | 7.5 | Single-phase | 379 | 220/219 | 0.42 |
| From I-K | 314 | 16 | 10.5 | Single-phase | 378 | 220/218 | 0.72 |

Note that the longest line of the system is along the road towards Tramkhnar, at 1883m from the grid. According to the result of calculation above, the voltage drop is about 10%. That is acceptable regarding to the specification set by the EAC (Electricity of Cambodia). Others have less than 5% of voltage drop value. Each result of simulation is presented in Appendix.

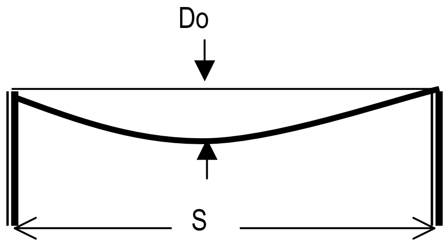
Conductors were ordered from a company called THINH PHAT manufacturing & Trading Co.Ltd, in Vietnam. These cables are also used by EDC in some places in the peri-urban area of P.Penh.

### III.5.3 Conductor sagging

After the most appropriate type and size of the conductor, pole, and pole hardware have been selected and installed, the conductor can be installed. This involves placing and tensioning the conductor. Tensioning the conductor is referred to "sagging" because these two parameters are directly related to each other and the proper tension "T" is generally determined through the sag.

The sag of a conductor is determined by the weight and tension of the conductor and its span. It depends on the span according to the following relationship:

$$Do = \frac{W \times g \times S^2}{8T} \quad (1)$$




Where

Do: Sag of line (m)

W: Unit weight of line (kg/m)

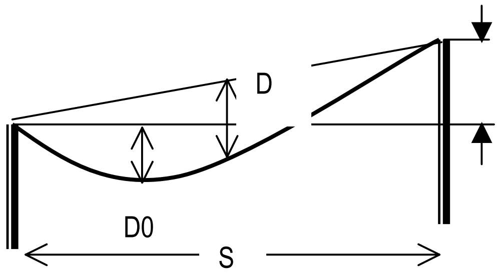
g: G-force (m/s²)

S: Span of line (m)

T: Tension of conductor (N)

This formula above is only applicable when the two poles supporting the conductor have the same height. In case that they do not have, slant sag will be appeared. The determination of this slant sag is made through the following formula:

$$Do = D\left(1 - \frac{h}{4D}\right)^2 \quad (2)$$




Where

D: Slant sag of line (m)

Do: Sag of line (m)

W: Unit weight of line (kg/m)

g: G-force (m/s²)

S: Span of line (m)

T: Tension of conductor (N)

In practice, the appropriate sag table must be provided by the manufacture. In case that it is not possible, the calculation to find the appropriate sag can be done based on the formulas mentioned above.

**Example** of calculation for the installation of bundled conductor 3 x 70² + 70. It is strung on two poles of 30m. The tension value at 20ºC provided by the manufacture is 344daN, so to say 3440N. Its linear weight is 1.01 daN/m or 1.01kg/m. The sag of the conductor will be thus:

$$Do = \frac{30^2 \times 9.81 \times 1.01}{8 \times 3440} = 0.32m$$

Therefore, the sag of the conductor strung on these poles must be 0.32m at the time of its installation.

In case that this conductor is strung on the two poles having two different heights, i.e., one pole is 1m higher than another one. The slant sag will be realized. Applying through formula (2), this slant sag (D) will be thus:

$$D0 = D\left(1 - \frac{h}{4D}\right)^2 \Leftrightarrow 16D^2 - (8h + 4D0)D + h^2 = 0$$

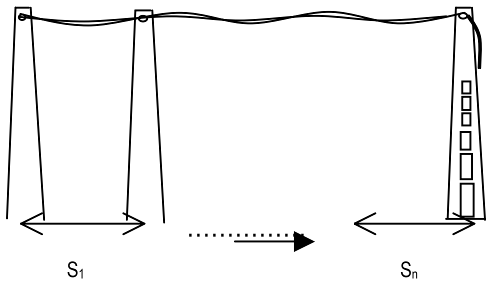
Considering that h=1m and D0=0.32m

$$\Rightarrow 16D^2 + 9.28D + 1 = 0$$

$\Rightarrow$ <u>D=0.44m</u>

When the spans of an installation section are not equally realized, an equivalent span ($S_e$) must be determined so that the tension of the conductor is selected based on this value. The formula below is used to determine the equivalent span.

$$S_e = \sqrt{\frac{(s_1^3 + s_2^3 + \dots\dots\dots\dots s_n^3)}{(s_1 + s_2 + \dots\dots\dots\dots s_n^3)}} (3)$$




After that, the calculation is made in accordance correspondingly with each span.

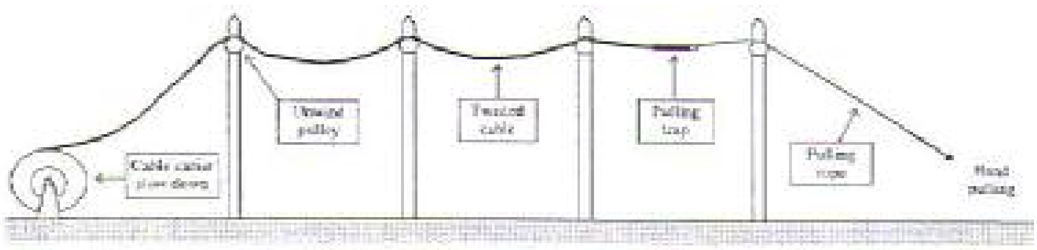
In the case of Smau Khney, as mentioned in 4.5, the spans of the electric poles installed in the area are not equally realized. The equivalent span of each section of conductor is therefore to be determined. Applying through formula (3), the equivalent span obtained of each section of cable is shown in the table hereunder:

| Nº | Section of conductor | Total length (m) | Equivalent span ($S_e$) taken for sag sizing |
|---|---|---|---|
| 1 | 70mm², three-phase | 211 | **35 m** |
| 2 | 35mm², three-phase | 1347 | **45 m** |
| 3 | 25mm², three-phase | 825 | **50 m** |
| 4 | 16mm², three-phase | 857 | **50 m** |
| 5 | 16mm², single-phase | 1596 | **30 m** |

The result of sag calculation is presented as follows:

| Nº | Type of conductor | Equivalent span ($S_e$) | Sagging |
|---|---|---|---|
| 1 | 70mm², three-phase | 35m | 0,4m |
| 2 | 35mm², three-phase | 45 m | 0,6m |
| 3 | 25mm², three-phase | 50 m | 0,8m |
| 4 | 16mm², three-phase | 50 m | 0,9m |
| 5 | 16mm², single-phase | 30 m | 0,3m |

### III.5.3.1 Installation of the conductor




Once the electric poles were installed, the conductor was strung over the poles. A reel was properly located with a stable base and positioned on the reel stand so that the conductor would not unwind from the bottom. All suspension clamps were already installed and checked to ensure that they were in proper position.

Pulleys were temporarily installed on each pole where the conductor was to be mounted. A rope (dealer line) was then passed through the pulleys and the end tied to the conductor on a fixed but rotating reel located at the end of the section being worked on. This rope would then be pulled over consecutive pulleys towards the beginning of the section, pulling the conductor along with it.

Once the conductor was pulled, it was dead-ended at one end so that the sagging could begin with minimum delay. To minimize delay, the specific span to be sagged within the entire section was selected before pulling the conductor. In this way, the sag is known and work on getting the proper sag can proceed immediately.

After the pulling and sagging process of this section of conductor has been accomplished, the conductor was attached on suspension clamp being fixed on each pole.

## III.6 Poletop hardware and connectors

### III.6.1 Poletop hardware

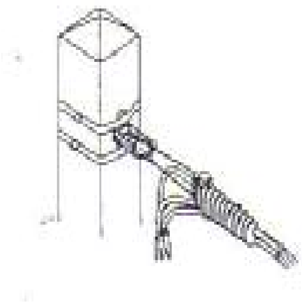
Poles and conductors are typically the costliest elements for most mini-grids. However, miscellaneous hardware, while costing relatively little, plays a critical role in ensuring the sustainability of the entire system. This includes the hardware necessary to ensure proper electrical continuity between various conductors used in the system and clamps or other hardware for securing the conductors to the poles. Poor use of this hardware can place the entire system in jeopardy.

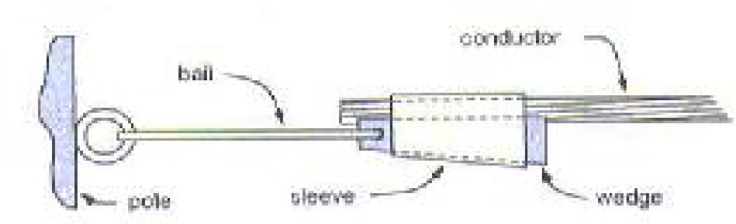
#### III.6.1.1 Suspension clamps

The suspension clamps are used to support the conductors for the distribution system. They are installed on the pole top at about 0.15m from the top. Several types of suspension clamp are available in the market and used for supporting various different sections of conductors. In case of Smau Khney these clamps were ordered from Vietnam They were used to support the three phase conductors of 70mm², 35mm², 25mm² and 16mm². The unit cost was 3.64 US$ each.

#### III.6.1.2 Dead-end clamps

The dead end clamps are made of plastic. They were used to deaden the conductor with the poles, particularly with the poles located at the end of lines (see details installation shown in the plan of installation). In its operation, the messenger conductor is slipped between the wedge and the sleeve. To place the conductor under tension forces, the wedge is placed into the sleeve, compressing the conductor against the sleeve. The clamping force increases as tension on the conductor is increased (see figure below).






The dead end clamps used in Smau Khney cost 4.29US$ each.

## III.6.2 Connectors

### III.6.2.1 IPC Connector 70/70mm²

The connector type IPC connector 70/70 mm² was chosen to use for making connection from one section of conductor to another one. On the entire distribution system, it needs about 28 units of this connector (2.21 US$ each).

### III.6.2.2 IPC Connector 70/25-16mm²

The connector type IPC connector 70/25-16mm² is commonly used to make connection from the power distribution network to the meters box installed on the electric pole, in which 5 meters have been installed (for service connections). It needs two connectors for each service connection: one is connected from a phase conductor and another is from the neutral conductor to the meter box. The cost per unit is 1,56 US$.

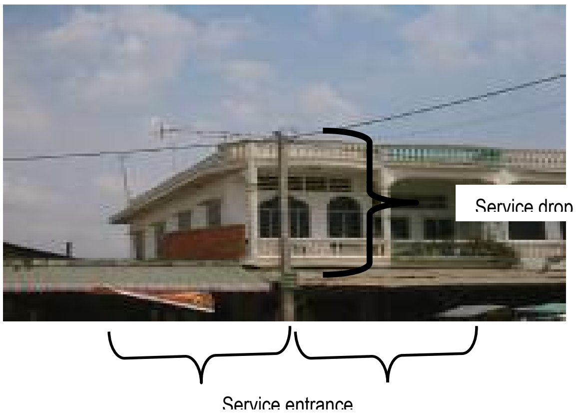
## III.7 Service connections

### III.7.1 Description

The service connection consists of two components: the service drop and the service entrance.

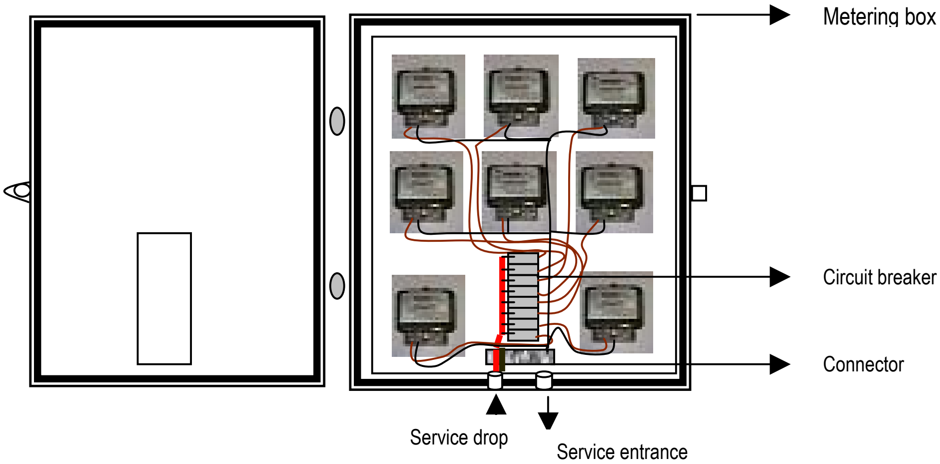
- **Service drop**: the connection made between the main distribution line to the metering box where is installed on the poles.
- **Service entrance**: the connection made from the metering box into the households.

The following is the picture of a service connection put in place for the mini-grid of Smau Khney:



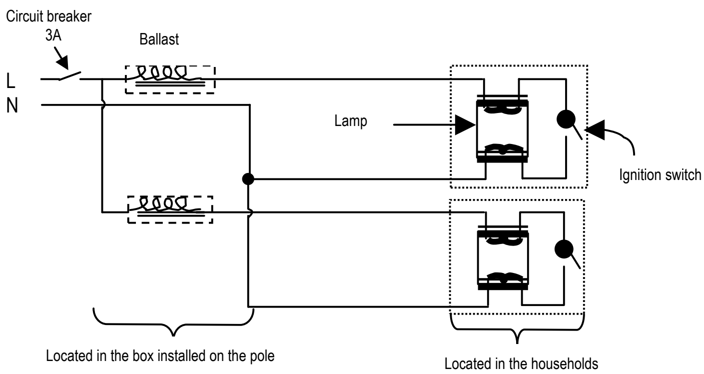

### III.7.2 Schema of the service connection

#### III.7.2.1 For metering connection




#### III.7.2.2 For MLS connection

In this case, the circuit breaker 3A has a role as on-off switch



## III.7.3 Service drop conductor

The conductor used to make connection from the main distribution lines to the metering box is a copper conductor. Its size is 10 mm² single-phase. This conductor is selected based on the result of the sizing and the technical specification of EAC (less than1% at the end line). The length of this conductor is only around 5 m, which causes a very little voltage drop less than 1% (see graph below permitted to size the service connection conductor).

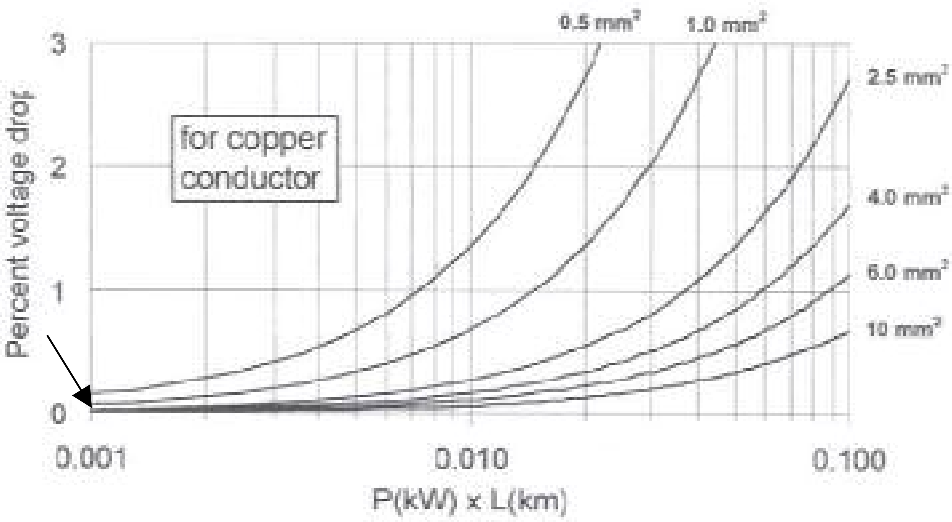



Fig. 10 . A graph to calculate the voltage drop at the end of a copper 230-V single-phase service drop serving one or more homes. The area of the conductor associated with each curve is indicated at the top and right of the graph.

## III.7.4 Service entrance

This connection is made from the metering box to the household. It comprises of a metering box in which are installed the meters, circuit breakers used to protect the short circuit and overload currents, a conductor of 10 mm² from the metering box to the household which is about 50m long.

### III.7.4.1 Metering box

The metering box is locally fabricated. It is made of metal. Its cost is about 8 US$/unit. This metering box permits to install 6 to 8 meters and a number of similar number of circuit breakers. There are 2 holes at base of the box. One of them is used for entrance of the service drop conductor and another one is used for the exit of the service entrance to the households.

### III.7.4.2 Circuit breaker


The circuit breaker chosen to protect the short circuit and the overload currents is LITAI type, 1P, DZ47-63(C), 3A, being complied with IEC 898, made in CHINA. It has capacity to protect the short circuit current up to 6000 A. Its cost is 0,6 US$/unit and can be locally purchased. It is used to install on the phase conductor just before the electric meter. According to the owner of the system, this circuit breaker functions well when there is a short circuit occurs on the users side.

### III.7.4.3 Electric meter

A good electric meter is important for the fairness of the service. So far, there has been no EAC requirement on the type of the electric meter to be used for rural electric supply systems.

Mr. Srey Sokhom conducted a test on the different types of electric meters to choose the most acceptable one.

For that purpose, 4 different types of the electric meters were installed in series for testing. Some of them have been bought from Vietnam and others were from local market. Before installation for testing, all these electric meters were calibrated by EDC (Electricity of Cambodia). The characteristic of each electric meter is presented in the table below:

| | | | |
|---|---|---|---|
| **EMIC**, C140, 220V, 5(20)A, 50Hz, 9000 tr/kWh.<br>Made in Vietnam.<br>Cost: 10 US$<br>Form: round<br>Bought from Vietnam | **OEIC**, Watthour Meter, type: MF-37E, 1 phase, 2-wire, 230V, date: 2004, 50Hz, 3(6)A, Nº 0160922<br>Made by Oriental Electric Industry Company, Vietnam<br>Licensed by Mitsubishi Electric Group<br>Cost: 15 US$<br>Form: Square<br>Bought from Vietnam | **IEC** 521, Watthour meter, 220V, 3(6)A, 50Hz, Nº 2001-053474<br>Shanghai Holley Elect Intrumet,<br>Made in P.R.China<br>Cost: 5 US$<br>Form: Square<br>Bought locally | **Sassin**, Kilowatt-hour Meter, 220V, 5(10)A, 50Hz, 1200tr/kWh<br>Type DD282, Class: 2.0 IEC 521<br>Year 2002<br>Made by Sassin International Electric Co, Ltd<br>Cost: 5.5 US$<br>Form: Square<br>Bought locally |
|  |  |  |  |

During the testing, these electric meters were connected to a load, and left functioning during 40 days from the date of the installation. The table below shows the results of the test indicating the period of testing and values of the produced kWh.

| Date of installation | EMIC, C140 | OEIC MF-37E | IEC 521 | Sassin DD282 |
|---|---|---|---|---|
| Started: 29/09/04 | 24.4 | 25.1 | 351.3 | 00 |
| Finished: 11/11/04 | 96.6 | 99.0 | 420.9 | 72.2 |
| Difference during 40 days | 72.2 kWh | 73.9 kWh | 69.6 kWh | 72.2 kWh |

Assuming that the cost of the connection is one of the main constraints for people to access to the electric system, *the electric meter selected by the entrepreneur was* ***Sassin, typed DD282, Class 2.0, IEC 521,*** *which costs* ***5,5 US$.***

### III.7.4.4 Service entrance conductor

The side of this conductor varies upon the peak power load of the consumers and the location where people are located. In Smau Khney, the population is quite dense and close to the electricity network (around 30m from the metering box). The side of copper conductors used by the entrepreneur for the service entrance varies from 1 mm² to 4 mm². According to the graph 7.3, the voltage drop at the end of the conductor is about 0,5% considering that the peak power demand of the consumer is 200 W.

# IV Brief assessment of the project

This assessment is based on information collected by the entrepreneur and the project team in July 2005.

## IV.1 Investment figures

Mr. Srey Sokhom the REE has invested about 40,000 US$ in the rehabilitation of the system, excluding the existing equipment and poles that he could take from the previous system. Here are following the detailed investment costs:

| Item | Investment cost (US$) |
|---|---|
| ***Production unit*** | ***10,020*** |
| New power house | 3500 |
| New genset | 2800 |
| New Synchro unit | 3650 |
| Water tank | 70 |
| ***Poles*** | ***14,920*** |
| 77 Concrete poles @ 100 $ | 7,700 |
| Installation of 72 concrete poles @ 35 $ each | 2,520 |
| 110 new iron poles @ 35 $ | 3,850 |
| Installation of 170 iron poles @ 5$ | 850 |
| ***Cables*** | ***13,234*** |
| Tri Phase aluminum cables (6.5km) | 7,600 |
| Mono Phase aluminum cable | 3,359 |
| Installation of cable (6.5 km x 350) | 2,275 |
| ***Connections*** | ***2,389*** |
| 50 Connection boxes @ 8$ | 400 |
| 290 circuit breaker @ 1 $ | 290 |
| 180 Connectors mono phase @ 1.56 | 280 |
| Wire to connect poor household (MLS) | 735 |
| 220 fluo lamps of 10W @ 2.2 $ | 484 $ |
| 800 capacitors @ 0.25 $ | 200 $ |
| ***Total:*** | ***40,563*** |

Considering the residual value of old equipment kept on the new system; $ 2,100, and the purchase value of the land ($8,600), the total value of the new system is now **$ 51, 263** so to say **$ 102.5** per household connected.

## IV.2 Consumptions figures.

As of now, there are 500 HH connected to the rehabilitated system of Smau Khney. This represents **99%** of the whole population living in the project area. There are 5 HH that are not connected, 4 of them because they still prefer to use battery, and one who was disconnected following 2 months of payment default.

Out of these 500 HH, 310 are connected by meter (they pay according to a meter, $0.56/kWh ) and 190 are connected on a fixed tariff basis ($0.97/month/Lamp of 10W). Actually, 30 HH who were initially served of fixed tariff switched to meter service after a few weeks.

Sales have increased by 64% compared to April 2004, thanks to the connection of the 220 more families and the improvement of the service. The average consumption per HH has decreased by 8% essentially due to the fact that the new connected HH are poor and consumed much less that the first connected HH.

The table below gives the figures of consumption of July 2005 and their comparison with 2004.

*Consumption indicators in July 2005.*

| | |
|---|---|
| Nb of kWh sold by meters | 3,620 kWh |
| Nb of kWh sold on a fixed tariff basis | 599 kWh |
| Nb of kWh provided for free (family) | 139 kWh |
| Total kWh provided to clientele | 4,358 kWh |

*Comparison April 2004 and July 2005*

| **Indicators** | **April 2004** | **July 2005** | **Changes** |
|---|---|---|---|
| Households connected | 280 | 500 | + 79% |
| Rate of connection | 56% | 99% | + 43% |
| Consumption | 2,656 kWh | 4,357 kWh | + 64% |
| Average consumption/HH | 9.5 kWh/mth/HH | 8.7 kWh/month/HH | - 8% |

## IV.3 Efficiency figures

As mentioned earlier in the report, the different improvement have allowed considerable energy saving and reduction of losses in the system. Here are following the efficiency data of the system based on the information of July 2005, and compared with 2004.

*Information from July 2005:*

| | |
|---|---|
| Number of liters of fuel consumed | 2,061 liters |
| Nb of kWh produced | 5,840 kWh |
| Total kWh provided to clientele | 4,357.5 |

*Efficiency parameters:*

| Parameters | April 2004 | July 2005 | Improvement |
|---|---|---|---|
| Fuel/ kWh produced | 0.42 | 0.35 | - 17% |
| Fuel / kWh provided | 0.7 | 0.46 | - 33% |
| Losses in % | ~40% | 25% | -15 % |

## IV.4 Financial management figures

The cost price of electricity has increased since April 2003, this being due to the dramatic peak of the fuel price ( Plus 100% in 3 years in Cambodia).

Therefore, despite an increase of the tariff of 300 riels/kWh, the financial results of the REE have not improved much and the ROI of investment is lower than the preliminary expectation (10 years instead of 7 years)

*Result of exploitation (July 2005)*

| | |
|---|---|
| Revenues (R) | • Meter: 3,620 kWh x $0.56/kWh = $ 2,027.5<br>• Fixed tariff (598kWh): 190 HH x $ 0.97 = $ 185.4<br>• **Total: $ 2,213** |
| Expenses (E) | • Fuel: 2061 liters x $0.683 = $ 1,407<br>• Oil: 20 liters x $ 1.8 = $ 36<br>• Reparation: $ 50<br>• Staff: $ 100<br>• License: $ 2.5<br>• Patents and taxes: $ 5<br>• Credit interest: $ 36 (during 2 years)<br>• **Total: 1636.5** |
| Depreciation (D) | • Cables: $14,000/15 y/12 m =$ 77<br>• Concrete poles: $10,200 / 25y/12m = $ 34<br>• Iron poles: $ 4,700 / 15y / 12 = $ 26<br>• Generator: $ 2,800 / 5y/12 m = $ 46<br>• Synchro: $ 3650 / 10y/ 12m = $ 20<br>• Power house: 3500/15y/12m= $19<br>• **Total: $ 222** |
| Result of exploitation | • **$ 354** |
| Cost price ( Sales/(E+D)) | • $(1636.5+222) /(3620+598)kWh<br>• **$ 0.44 so to say 1806 riels** |
| Return on investment | • Without incentives: 11 years<br>• With incentives: 9 years |

# Conclusion

The figures exposed above show that a normal Cambodian entrepreneur, with no initial education in electricity can, with some support but considerable commitment improve a rural grid and reach reasonable quality and safety standards. We hope that this report will help all those, like Mr. Srey Sokhom, wish to better serve energy to the rural population.

*Jean Pierre Mahé, Ky Chantan, 31 August 2005.*

## ANNEXES

Annex 1: Contract of incentive

Annex 2: Contract of power supply

Annex 3: Willingness to connect form

**Annex 1**

# Contract of Incentive
# Commune of Trapeang Sab

Nº TS1/08/04

***Between***

The Commune council of Trapeang Sab represented by Mr. Srey Preung, commune chief.

***And***

Gret-Kosan Partnership, hereafter referred to as "GK", represented by **Mr. Jean Pierre MAHE**, Project Manager;

Validated by the Provincial Authority, represented by **H.E Lay Sokha**, Governor and Chairman of PRDC Takeo (Provincial Rural Development Committee).

***Considering the present laws and regulations:***

**Contract and Investment**

- Law on Investment in the Kingdom of Cambodia dated August 04, 1994, as amended by the Law on Amendment to the Law on Investment in the Kingdom of Cambodia dated March 24, 2003;
- Sub-decree Nº 88 dated December 29, 1997 on the implementation of the Law on Investment;
- Decree Nº38 on Contract and Liabilities.

**Electricity Sector**

- Electricity Law promulgated by the Royal Decree NS/RKM/0201/03 dated February 02, 2001.
- Regulations on general condition of supply of electricity in the Kingdom of Cambodia dated January 17, 2003, are approved by EAC.
- License Nº015L issued by the Electricity Authority of Cambodia (EAC) dated November 22, 2002 to Mr. Srey Sokhom holding identification card Nº036693 TK dated December 31, 1998 for providing the Generation and Distribution Services at Phsar Samrongyorng Town, Smau Khney village, Trapeang Sab commune, Bati district, Takeo province.
- Guidebook for Power Engineers prepared by MIME, EAC and EDC dated December 2003.

**Administrative entities**

- Law on administrative management of the Commune/Sangkat dated March 19, 2001

**Environment sector**

- Law on Environmental Protection promulgated by the Royal Decree NS/RSM/1296/36, dated December 24, 1996.

## CONSIDERING THAT:

- The commune council of Trapeang Sab wants to improve the electricity services in the commune around the market of Samrongyorng.
- GK has received incentive from Energy Assistance to help the commune council of Trapeang Sab to extend the electricity services at Phsar Samrongyorng town, Smau Khney village, Trapeang Sab commune, Bati district, Takeo province.
- For that, the commune council of Trapeang Sab has created a commune electrification committee, hereafter referred to as CEC, to follow up the electrification of the area and manages the incentive funds on behalf of the commune council.
- This CEC is composed 4 commune council members including the commune chief as the chief of the committee, the deputy commune chief, two women of the commune council, the chiefs of the 4 concerned villages and the clerk of the commune council (see the document creating the CEC and members in Annex). The CEC is selected, approved and reports to the commune council of Trapeang Sab.
- When there is a change of the commune council or chief(s) of the village(s), the commune council shall meet and agree on the new composition of the CEC.
- The Commune Electrification Committee will provide incentive to the investor for improving the quality of the present electricity system and providing for making connection for the poor people or those being outside the present electricity system of Phsar Samrongyorng town, village Smau Khney, commune Trapeang Sab. This incentive amount now equals to 45 US$ per household to be connected.
- There are so far 280 HH being connected to this electricity system. The objective after the rehabilitation is to supply electricity for 500 HH in the whole area, so to say 220 HH yet to be connected.
- Mr. Srey Sokhom, investor of the electricity system of Phsar Samrongyorng town, Smau Khney village, Trapeang Sab commune, licensed by the EAC on November 22, 2002 (see in annex), presently resides in the Smau Khney village, Trapeang Sab commune, Bati district of Takeo province, has been chosen by the CEC as the local electricity investor for receiving this incentive. He has engaged to connect the households that are not yet connected to the electricity system in the area with the financial support provided by the CEC.

***The following has been agreed:***

**Article 1: Objective of the parties**

(a) The CEC and GK joint together to help the people to get connected with the electricity system of Phsar Samrongyorng town, Smau Khney village, Trapeang Sab commune, Bati district of Takeo province.

**Article 2: Role of the CEC**

*Identification of household to be connected:*

(a) The CEC shall identify all the households that are likely to be connected, either poor or outside the present area.

(b) The CEC shall fill in and co-sign a willingness to connect (WTC) form for 220 the potential clients.

*Creation and management of the Commune Electrification Fund (CEF)*

(a) The CEC shall open a Bank account in a local Bank called Commune Electrification Fund and manage the funds received from GK.
(b) The signing parties of the CEF shall be shared by the members of the CEC and the chief of project of GK.
(c) The CEC shall provide regular report of the CEF to the GK and the commune council.

### ARTICLE 3: ROLE OF GK

**Technical support**

(a) GK will provide technical support to Mr. Srey Sokhom to improve and extend his system in accordance with the specifications and guidelines mentioned in the contract of power supply made between the CEC and Investor.

**Financial support**

(a) With the support of Energy Assistance, GK will provide an incentive of 45 US$/HH for connecting a maximum 220 of remote and poor HH.
(b) The total amount of incentive to be transferred on CEF will be based on the number of willingness to connect documents effectively signed by the potential clients, investor and a member of the CEC (see form in attachment).
(c) The CEC shall manage those incentive according to the contract NºTS2/08/04
(d) The chief of project of GK will co-sign all disbursements from the Bank account.
(e) GK will provide an additional 2 US$ per household for the management cost of the CEC. This money shall be shared by all members of the CEC. The CEC shall provide then to GK a report of the use of these administrative funds. The report shall be signed by all members of the CEC.

### ARTICLE 4: PROCEDURE

(a) Once the money is in the bank account, the CEC is entitled to disburse to the investor half of the incentive as an advance corresponding to the households having expressed an approved WTC, so to say 220HH x 22.5=**4950 US$** after the concrete poles are erected.
(b) The remaining half of incentive shall be disbursed when the households are connected, and this being checked by the CEC. For that, the investor shall submit a request to the CEC for at least 30HH connected at each time.
(c) The final 1000 US shall be disbursed only when all households having an approved WTC are connected.

### Article 5: Coming into force

The contract herewith comes into force on the date of the signing thereof by the parties.

### Article 6: Duration of the contract

This contract is made for one year. If the incentives have not been disbursed at the end of the contract, they shall be reimbursed to GK.

**Article 7: Cancellation of the contract by GK**

In case there is a major failure in the delivery of the incentive such as diversion of money or suspension of the activity, GK reserves the right to suspend the delivery of incentive. If no solution is found between the CEC of Trapeang Sab, the funds shall be returned to GK, and the contract will be cancelled.

**Article 8: Cancellation of the contract by CEC**

In the case of CEC wishes to cancel the present contract, they shall inform GK, and send back the funds to GK.

**Article 9: Disputes, disagreements**

- The signers of the contract herewith agree to endeavor to settle out of court any dispute that may arise in its enforcement.
- Should such mediation fail, recourse shall be taken with the tribunal of Takeo

*Made in Trapeang Sab September 09, 2004.*

| | |
|---|---|
| Commune chief of Trapeang Sab | Representative of Gret-Kosan |
| Validated by | |
| Governor and Chairman of PRDC Takeo | *District chief of Bati* |

| | | | |
|---|---|---|---|
| Mr. **Hing Yim** | Ms. **Hol Yoeun** | Ms. **Kim Sophon** | Ms. **Sor Sokly** |
| Commune Deputy chief and member of CEC | Commune council member and member of CEC | Clerk and member of CEC | Commune council member and member of CEC |
| Mr. **Keo Ngeth** | Mr. **Kim Phong** | Mr. **Soun Koun** | Mr. **Kird Doeun** |
| Chork village chief and member of CEC | Smau Khney village chief and member of CEC | Roleang Kreul village chief and member of CEC | Sangké village chief and member of CEC |

*Document is made in 4 copies.*

Annex 2

# Power Supply Contract
# the electricity system of Smau Khney, Trapeang Sab commune

Nº TS2/08/04

***Between***

The Commune Electrification Committee of Trapeang Sab, hereafter referred to as " CEC", represented by Mr. Srey Preung, commune and CEC chief.

***And***

The investor of the electricity system of Phsar Samrongyorng town, village Smau Khney, commune Trapeang Sab, hereafter referred to as "Investor", represented by Mr. Srey Sokhom, owner of the system.

***Considering the present laws and regulations:***

**Contract and Investment**

- Law on Investment in the Kingdom of Cambodia dated August 04, 1994, as amended by the Law on Amendment to the Law on Investment in the Kingdom of Cambodia dated March 24, 2003;
- Sub-decree Nº 88 dated December 29, 1997 on the implementation of the Law on Investment;
- Decree Nº38 on Contract and Liabilities.

**Electricity**

- Electricity Law promulgated by the Royal Decree NS/RKM/0201/03 dated February 02, 2001.
- Regulations on general condition of supply of electricity in the Kingdom of Cambodia dated January 17, 2003, are approved by EAC.
- License Nº015L issued by the Electricity Authority of Cambodia (EAC) dated November 22, 2002 to Mr. Srey Sokhom holding identification card Nº036693 TK dated December 31, 1998 for providing the Generation and Distribution Services at Phsar Samrongyorng Town, Smau Khney village, Trapeang Sab commune, Bati district, Takeo province.
- Guidebook for Power Engineers prepared by MIME, EAC and EDC dated December 2003.

**Administrative entities**

- Law on administrative management of the Commune/Sangkat dated March 19, 2001

**Environment sector**

- Law on Environmental Protection promulgated by the Royal Decree NS/RSM/1296/36, dated December 24, 1996.

# CONSIDERING THAT:

- The commune council of Trapeang Sab wants to improve the electricity services in the commune.
- For that, the commune council of Trapeang Sab has created a commune electrification committee, hereafter referred to as CEC, to follow up the electrification of the area and manages the incentive funds received from GK on behalf of the commune council.
- This CEC is composed 4 commune council members including the commune chief as the chief of the committee, the deputy commune chief, two women of the commune council, the chiefs of the 4 concerned villages and the clerk of the commune council (see the document creating the CEC and members in Annex). The CEC is selected, approved and reports to the commune council of Trapeang Sab.
- The CEC has opened a bank account called CEF (Commune Electrification Fund) to manage the incentive received from Gret-Kosan according to the contract NºTS1/08/04.
- When there is a change of the commune council or chief(s) of the village(s), the commune council shall meet and agree on the new composition of the CEC.
- The Commune Electrification Committee will provide incentive to the investor for improving the quality of the present electricity system and providing for making connection for the poor people or those being outside the present electricity system of Phsar Samrongyorng town, village Smau Khney, commune Trapeang Sab. This incentive amount now equals to 45 US$ per household to be connected.
- There are so far 280 HH being connected to this electricity system. The objective after the rehabilitation is to supply electricity for 500 HH in the whole area, so to say 220 HH to be connected.
- Mr. Srey Sokhom, investor of the electricity of Trapeang Sab licensed by the EAC on November 22, 2002 (see in annex), presently resides in the Smau Khney village, Trapeang Sab commune, Bati district of Takeo province. He engages to connect the households that are not yet connected to the electricity system in the area with the financial support provided by the CEC.

***The following has been agreed:***

## CHAPTER 1

## GENERAL CONDITIONS

### Article 1: Objective of the contract

The purpose of the contract herewith is to spell out the terms of the electricity services in Phsar Samrongyorng town, khum Trapeang Sab, Bati district of Takeo province and the conditions of delivery of the incentive.

### Article 2: Description of the system

The electricity system is located at Phsar Samrongyorng town, Smau Khney village, Trapeang Sab commune, Bati district of Takeo province (see in the license document).

**Article 3: Number of the connections**

There are so far 280 households already connected to the electricity system. The objective is to connect more 220 households after the new rehabilitated electricity system is put in place.

**Article 4: Coverage area**

The contract is applicable in the commune of Trapeang Sab, Bati district of Takeo province. The detail of the covered area is shown in the license document issued by EAC in annex. Within this area, the conditions related to the extension of the system will apply.

**Article 5: Duration**

The duration of the contract is 15 years.

**Article 6: General obligation of the CEC**

***The Commune Electrification Committee:***

- Shall list all households to be connected to the electricity system.
- Shall facilitate the investor in dealing with the Provincial and Central Administrations, as the need shall be.
- Shall ensure that the works implemented by the investor do not affect any damage on the environment as indicated in the license document issued by EAC in annex.
- Shall intervene immediately if a dispute arises between the investor and the users, particularly in the situation of non-payment.
- Shall ensure that the work performed by any person or contractor close to the network does not damage the facilities.
- Shall support the investor in educational and awareness-raising activities related to the service provided.
- Shall disburse to the investor half of the incentive corresponding to HHs having expressed an approved WTC (willingness to connect) once the poles are erected.
- A remaining half of incentive shall be disbursed when the households are connected, and this being checked by the CEC.
- The CEC recognizes the right of the investor to depreciate equipment financed by the incentive with the conditions that the investor pays commune fee set in the Article 13.
- For that, the investor will submit a request to CEC for at least 30 HH connected at each time.
- The final 1000 US$ shall be disbursed only when all households having an approved WTC are connected.
- Should mediate between the investor and the landowner to install electric poles in the private properties (if needed). If the mediation fails, the investor is not liable to connect the households that are further on the concerned line.
- Shall ensure that the terms of the present contract are respected by all parties involved.

**Article 7: General obligation of the investor**

- The investor shall comply with the Electricity law of the Kingdom of Cambodia, other Laws and Sub decree relating to the Laws.
- The investor shall comply with the provisions of Rules, Regulations and Procedures on the electric power generation and distribution services, the provisions of service condition, the conditions issued by EAC.
- The investor shall start the rehabilitation of the system just after the signing of this contract and ensure the upkeep and maintenance of the equipment making up this electricity system so as to ensure an optimal operation (proper quality of electric power supplied, proper overall condition of the equipment, decrease of energy losses….), and then sell electricity through the Minimum Level of Service (flat rate) or meter service according to technical specifications recommended by EAC.
- The investor owns the generation and distribution of electricity system in the area.
- The investor shall finance the rehabilitation and the extension of the electricity system.
- The investor shall connect at least 500HH in which 220 households are yet to be connected. The list will be provided by the CEC.
- The investor shall be subjected to the environment obligations as specified in the Environment Law.
- The investor shall be responsible for any cost related to the operation of the electricity system such as license fee…etc.
- The investor will automatically extend the electric network according to the conditions mentioned further in this document.
- The investor shall connect according to the conditions mentioned further in the document.
- The investor shall make the financial statement and its electric power service report in accordance with the EAC's adoption as indicated in its License document.

## CHAPTER 2
## SUPPLYING ELECTRIC POWER TO THE USERS

### Article 8: Connections

- The investor shall connect all households at the request of interested people in the concerned area.
- The connection includes the installation of a meter on the nearest pole. The users shall install the cable from the pole to the households.
- The meters shall be installed in a box unit of maximum 6. A circuit breaker adapted to the power demand for each service connection shall be also equipped (see in annex). In case the area is at risk (risk of flooding), a RCD should be installed.
- The fluorescent lighting installed in the user's households should be equipped of electronic ballast. In case that the users still use the fluorescent lamp functioning with magnetic ballast, they should install a capacitor according to the technical recommendation of the investor.
- The cost of connection is set according to the EAC's rule. This includes a meter, a circuit breaker and connectors. The investor owns the meter that is selected according to the standard of EAC.
- If any part of the connection system breaks down (not intentionally) within 3 month after installation, it is the duty of the investor to repair or replace it. After this period, the household shall cover the cost of reparation or replacement.
- In case that a meter has been intentionally broken or modified, the investor is entitled to cut the supply for the household, and the household has to pay the cost of replacement or reparation.

### Article 9: Authorization for disconnection

- If a user fails to pay a bill within 12 days from the date of the bill, the investor shall be at liberty to disconnect the supply. This disconnection will be temporary within 3 months from the date of disconnection. If the bills remains not paid within this period, the disconnection shall be permanent.
- If the investor found that any user is stealing electricity for consumption without authorization, he can ask EAC to fine in accordance with Art 68 of the Cambodia Electricity Law.

**Article 10: Reconnection**

- If a household having been disconnected has paid the outstanding bill during the temporary period, the investor is allowed to charge only a small reconnection fee with approval of EAC (Regulation 85).
- If the household still has not paid the outstanding bill after the period of 3 months, the investor is allowed to disconnect permanently the service supply. In this case, the household will pay the overall cost of connection to be reconnected (Regulation 48).

**Article 11: Special disposition for poor people**

- The investor must connect the poor people listed by the CEC at minimum level of service defined further on. The cost of connection will be covered as an advance by the investor. This advance shall be clearly mentioned in the supply agreement.
- This minimum level of service includes a maximum two lamps of 10W in the households, a cable to make connection from the pole, and a current limiter (no socket).
- In case that the households want either to equip more lamps or have a meter, they have to connect by meter.
- When passing from the MLS to meter connection, the households shall pay the materials for connection according to the EAC's rule, and repay the advance to the investor.
- If this connection system breaks down (not intentionally) within 3 month after installation, it is the duty of the investor to repair or replace it. After this period, the household shall cover the cost of reparation or replacement.
- If they want to stop consuming the electric power from the network, they shall just inform the investor for disconnection.

**Article 12: Supply**

- The investor shall pass a supply agreement with all households.
- The investor shall submit the supply agreement forms for consumers to EAC for approval (see in attachment). This agreement shall contain provision for allowing the consumer to terminate the supply agreement at any time by giving the investor a valid notice of termination. This agreement may be reviewed and revised by EAC from time to time (Regulation 42).
- The investor shall supply electricity according to conditions of license document issued by EAC (see in Annex). Once the new system is put in place, he shall supply electricity at least 6 hours per day (from 17h00 to 23h00) from Monday to Friday and 11 hours per day for Saturday and Sunday.
- The voltage drops at the end of the distribution line should be less than 10%.

- The electric power quality supplied shall follow the standard of EAC.

## CHAPTER 3

## REGULATIONS, RATES, FEES

**Article 13: CEC fees**

- The investor shall pay a yearly fee of 800 000 Riels (200 US$) to the Commune Electrification Committee of Trapeang Sab at the end of year 2005. This fee will be taken from the revenues. It shall not be considered as an expense. This amount will be re-evaluated according to the rate of riels to US$.
- The investor shall bring this fee to put in the CEF account at the local bank with the presence of a CEC representative.
- This fee shall be used for social issues to provide incentive to help poor people to have access to energy services. The CEC shall decide the amount of incentive to be given per HH. The CEC will be entitled to cover administrative cost at 2 US$/HH.

**Article 14: License and price of electricity**

- The Investor shall comply with the conditions indicated in the license as well as the selling price of electricity set by the Electricity Authority of Cambodia (see in Annex).
- The poor people who get connected with the minimum level of service shall pay 4000R/lamp (10W)/HH/month to the investor. These tariffs will the subject to approval by EAC. The investor should apply to EAC for approval.
- All other taxes will be put in additional to the tariffs.

**Article 15: Repair of damage caused by users**

The users shall have to bear the cost of repairing damage caused by them (such as the connection cable..).

## CHAPTER 4

## CONDITIONS OF REHABILITATION AND EXTENSION

**Article 16: Initial infrastructure of the electricity system**

- The capacity of the system is to supply electricity for 500HH.

- The construction of the initial infrastructure shall last a maximum of 12 months.
- The equipment must respect security, environmental conditions and regulations

## A. Generation

### *Coupling, Three-phase (four-wire)*

The investor shall install the coupling of the distribution lines from the split phase to three-phase, "EWY" in order to supply electricity through three-phase plus neutral (400V outgoing voltage of the station, map in attachment).

### *Control system for generation*

The investor shall construct a system to control the voltage, current, frequency and power as well as install breakers to protect the overload and fault current (see map attached).

### Grounded system (Earthing)

The investor shall realize the grounded system at the station in order to use the ground as a conductor for the returning current called single-wire earth-return (SWER) that can avoid the electrocution from a direct contact (see map attached).

### Powerhouse:

The investor shall construct a powerhouse to protect the machine and conserve the disposal of used oil and fuel. In this powerhouse, the cleanness shall be applied (see map attached).

## B. Distribution

### *Poles:*

According to the guideline of MIME, the investor shall use electric poles with the clearance of 6.5m high along the road and 7.5 m high across the road. The span of these poles varies from 35m to 50m depending on sections of the used conductors (detail map attached).

### *Cables:*

The cable used in the low voltage distribution should mostly be ABC isolated (Aerial Bundled Cable). For low loads, the investor may use single wire as specified in the map attached.

***Installation:***

The investor shall install the conductor on the poles. The detail of stringing is shown in annex.

**Article 17: Conditions of extension**

The investor will automatically extend the electric network if the distance to the next house is less than or equal to 15m and there are at least 4 demands for connection.

If the investor wants to extend the electric network beyond the licensed area, he has to apply for it and get his license modified from EAC.

## CHAPTER 5

## INSPECTION AND MONITORING

**Article 18: Access by the CEC and PDIME**

- Any member of CEC can enjoy access during the daytime to the facilities and check the contract document held by the investor.
- The CEC reserves the right to perform any inspection or check what they deem to be appropriate.
- The PDIME (Provincial Department of Industry, Mimes and Energy) has obligation to follow up the work in the first 12 months during the construction phase to make sure that the investor respects the technical specifications.

**Article 19: Controls**

The CEC is entitled to conduct any control regarding the working conditions of meter installed. In case of malfunctioning, the CEC shall enforce the users or investor to change the meter according to circumstance.

## CHAPTER 6

## COMING INTO FORCE, EXPANSION, SUSPENSION AND CANCELLATION OF THE CONTRACT

**Article 20: Coming into force**

The contract herewith comes into force on the date of the signing thereof by the parties.

**Article 21: Conditions of coming into force**

- The investor shall start realizing the works just after the signing of this contract.

- The construction of the whole system shall not exceed 12 months.

**Article 22: Cancellation of the contract by investor**

If the investor wants to stop activities before the expired date of this contract, he shall inform by written notice to the CEC and the EAC in advance. If EAC agreed, he must follow the conditions of EAC and labor Law of Cambodia regarding the staffs and employees.

**Article 23: Cancellation of the contract by CEC**

In case, the investor hasn't followed the terms of the contract and failed in delivering proper service, the CEC shall inform the EAC. If the EAC decides to remove the license, this contract will automatically be cancelled.

**Article 24: In case of cancellation**

- If there is a cancellation of the present contract, and the investor continues to operate, he shall repay to the CEC 3000 US$ minus amounts already paid to the CEC.
- In case the investor stop operating and sell the system to a new investor, the present contract will be automatically transferred to the new investor.

**Article 25: expansion/renew contract**

- At the date of expiry of this contract, the investor may ask for expansion the contract by a written notice to the CEC and EAC at least 3 months before expired date.
- If the CEC and EAC approve on the expansion, the CEC and investor shall meet together to negotiate CEC fee.
- If a new investor is selected and buy the system from the old investor, the CEC may renew the contract with the new investor.

**Article 26: Disputes, disagreements**

- The signers of the contract herewith agree to endeavor to settle out of court any dispute that may arise in its enforcement.
- Should such mediation fail, recourse shall be taken with the Electricity Authority of Cambodia.

**Article 28: Signature**

Made in Trapeang Sab:………………………..

| | |
|---|---|
| Chief of CEC | Investor<br>Mr. Srey Sokhom |

Validated by

| | |
|---|---|
| Governor and Chairman of PRDC Takeo | Director of PDIME Takeo |

*District chief of Bati*

| | | | |
|---|---|---|---|
| Mr. **Hing Yim**<br>Vice commune chief and member of CEC | Mrs. **Hol Yeun**<br>Commune member and member of CEC | Mrs. **Kim Sophan**<br>Commune clerk and member of CEC | Mrs. **Sor Sokly**<br>Commune member and member of CEC |
| Mr. **Keo Ngeth**<br>Chork village chief and member of CEC | Mr. **Kim Phong**<br>Smau Khney village chief and member of CEC | Mr. **Sous Kon**<br>Roleang Kreul village chief and member of CEC | Mr. **Kirt Deun**<br>Sangké village chief and member of CEC |

*Document is made in 5 copies*

Annex 3

# Willingness to connect form (WTC)

Mr or Mrs:……………………………………….

House No: ………………………………………

Village:……………………………………………

Commune, District:…………………………….

Mr(s)………………….engages to connect to the electricity system when it will be put in place.

Mr (s). …………………engages to:

- ☐ Connect by meter, and pay a connection fee of 15 US$. The tariff of electricity is 2000R/kWh.
- ☐ Connect the minimum of service, so to say one or two lamps of 10W plus cable from the pole to the household and a current limiter. The tariff of electricity is 4000R/lamp of 10W/month.

Signatures

Mr (s)…………………………………………….

Mr. Srey Sokhom, investor:………………………………….

Mr. ……………………., member of CEC……………….