No.

Follow-up Study to the Renewable Energy Master Plan in the Northern Part of the Socialist Republic of Vietnam

Final Report

Main Report

October 2004

Japan International Cooperation Agency
Economic Development Department

Preface

In response to a request from the Government of the Socialist Republic of Vietnam, the Government of Japan decided to conduct a study entitled "Follow-up Study to Renewable Energy Master Plan in the Northern Part of the Socialist Republic of Vietnam" and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team led by Mr. Katsuhiko Otaki of Proact International to the Socialist Republic of Vietnam six times from March 2003 to October 2004.

The team had intensive discussions with the officials of the Government of the Socialist Republic of Vietnam on off-grid rural electrification. They examined the feasibility of off-grid micro hydro electricity model plan through a pilot project from technical, financial and institutional viewpoints, and compiled the final results in this report.

I hope this report will contribute to the promotion of rural electrification in remote areas of northern Vietnam and to the strengthening of bilateral relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Socialist Republic of Vietnam for their close cooperation throughout the study.

October 2004

Tadashi IZAWA
Vice President
Japan International Cooperation Agency

October 2004

Tadashi IZAWA
Vice President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

I am pleased to submit to you the report of the Follow-up Study to Renewable Energy Master Plan in the Northern Part of the Socialist Republic of Vietnam.

This study primarily aimed to demonstrate the feasibility of off-grid micro hydropower through construction of a pilot plant. Off-grid micro hydropower is a promising electrification method in northern mountainous areas, which was presented as one of model plans in the preceding study; “Study on Renewable Energy Master Plan in the Northern Part of the Socialist Republic of Vietnam”. We thoroughly examined financial and organizational factors as well as technical issues to achieve “sustainability” in the pilot village where the villagers are empowered to do the daily operation and maintenance of the pilot plant. In addition, for the smooth execution of off-grid projects in Vietnam, we formulated off-grid rural electrification manuals based on the study results. These manuals are designed for providing practical guidebooks to the officers in charge of off-grid projects and villagers in charge of management of micro hydro plant.

I highly appreciate the suggestions given to me by the authorities concerned of the Government of Japan and your Agency. Also, comments made from the Ministry of Industry and the Department of Industry of Hoa Binh Province, the counterparts of this study, are reflected in this report.

In view of the underlying strong need for rural electrification in Vietnam, it is strongly recommended that the Government of Vietnam push forward the implementation of off-grid rural electrification taking the study results into consideration. In order to accelerate it, we suggest that the Government of Vietnam implement the capacity building of officials and engineers in provinces, undertake the micro hydropower resource survey and the formulation of guidelines for village-level operation and management of micro hydropower.

I would like to take this opportunity to express my sincere gratitude to your Agency, the Ministry of Foreign Affairs and the Ministry of Economy, Trade and Industry. I also wish to express my deepest appreciation to all the relevant agencies of the Socialist Republic of Vietnam for their friendship and close cooperation during the study period.

Very truly yours,

Katsuhiko Otaki
Team Leader
The Follow-up Study to Renewable Energy Master Plan
in the Northern Part of the Socialist Republic of Vietnam

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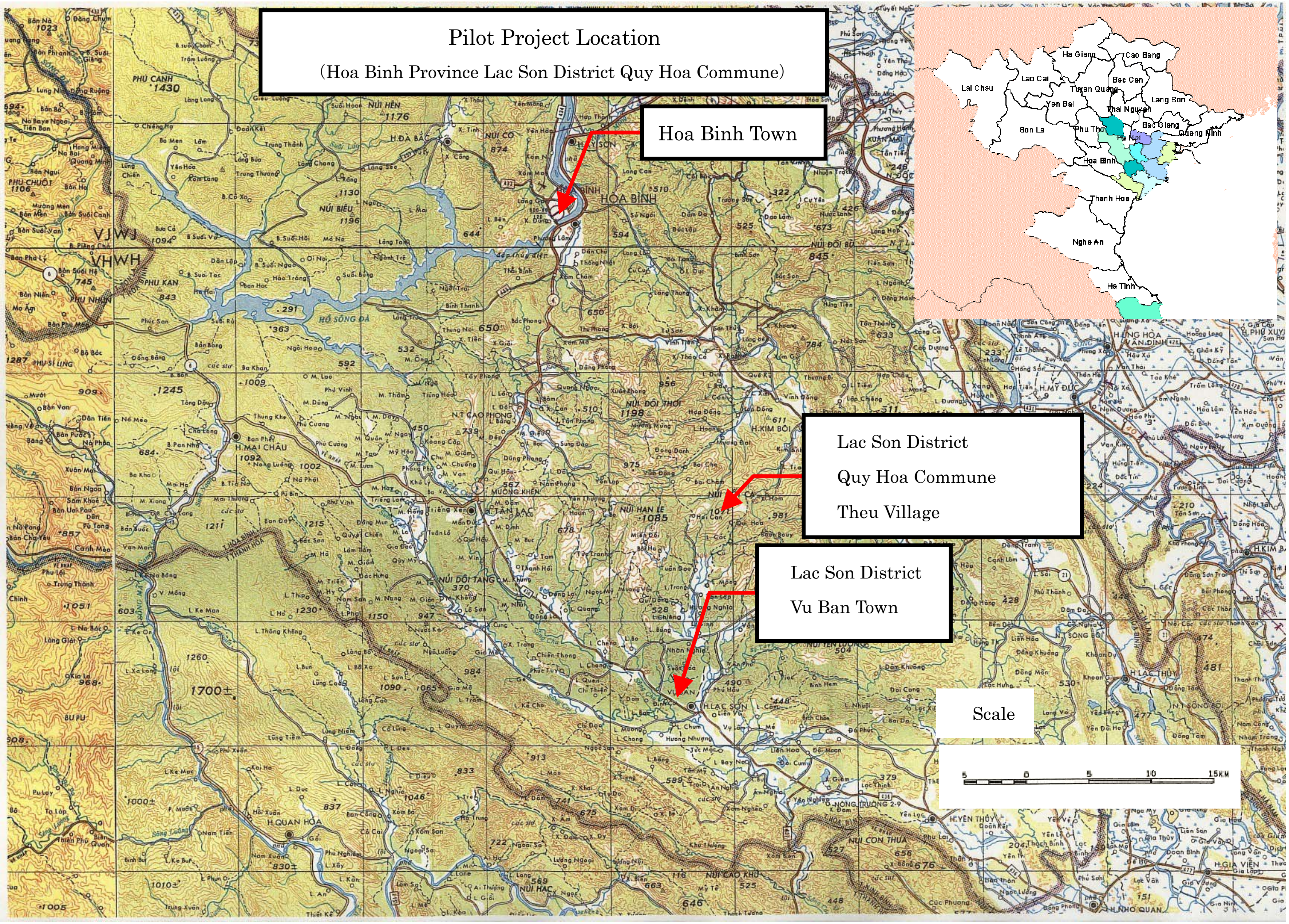
Acronyms and abbreviations

CDM	Clean Development Mechanism
CEMA	State Committee for Ethnic Minorities Affairs
CEU	Community Electricity Unit
DARD	Department of Agriculture and Rural Development
DOI	Department of Industry
DPI	Department of Planning and Investment
EDME	Enterprise for Designing and Manufacturing Electrical Equipments
EIRR	Economic internal rate of return
ELCB	Earth Leakage Circuit Breaker
EVN	Electricity of Vietnam
FIRR	Financial internal rate of return
F/S	Feasibility Study
GOV	Government of Vietnam
HH	Household
HPC	Hydro Power Center
IE	Institute of Energy
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
MARD	Ministry of Agriculture and Rural Development
MCB	Main Circuit Breaker
MOF	Ministry of Finance
MOI	Ministry of Industry
MP	Master Plan
MPI	Ministry of Planning and Investment
NPV	Net Present Value
ODA	Official Development Assistance
O & M	Operation and maintenance
OJT	On-the- job training
PC	Power Company
PPC	Provincial People's Committee
PVC	Polyvinyl Chloride
RARE	Rural Area Renewable Energy Facility
$	US dollar ($1=15,600VND as of October 2004)
VAT	Value Added Tax
VND	Vietnamese Dong
WB	World Bank

135 Program	Program on the Socio Economic Development in Mountainous, Deep-lying Remote Communes with Special Difficulties
Pico-hydro	Inexpensive 100W class propeller turbine generator for individual household
Village Hydro	A concept of micro-hydro scheme sustainable for power supply in rural communities, which is proposed in this report


Pilot Project Location
(Hoa Binh Province Lac Son District Quy Hoa Commune)
Hoa Binh Town
Lac Son District
Quy Hoa Commune
Theu Village
Lac Son District
Vu Ban Town
Scale
5 0 5 10 15KM
Lai Chau
Lao Cai
Ha Giang
Cao Bang
Bac Can
Tuyen Quang
Yen Bai
Lang Son
Thai Nguyen
Son La
Phu Tho
Bac Giang
Quang Ninh
Ha Noi
Hoa Binh
Thanh Hoa
Nghe An
Ha Tinh

Pilot System Facilities

Intake weir（renovated by villagers）

Headrace（newly built）

Head tank

Powerhouse

Water-turbine and generator

Distribution system

Introduction

Use of electrification is one of the desperate needs in rural areas in developing counties. In Vietnam, large-scale grid extension projects have been remarkably advancing toward the goal of the Government of Vietnam to electrify all the communes by the year 2010. However, grid electrification only reaches the center of communes in most cases while leaving surrounding villages un-electrified because economic efficiency to extend the grid to those villages is low. There are a number of those un-electrified villages in northern mountainous areas. Rural electrification targeting those villages has become one of the crucial policy challenges in Vietnam for alleviating poverty and narrowing the gap between the towns and villages.

Aiming at utilizing renewable energy and promoting rural electrification by off-grid power generation, Japan International Cooperation Agency (JICA) had conducted "Renewable Energy Master Plan in the Northern Part of the Socialist Republic of Vietnam (the master plan study)" from 2001 to 2002. In the survey, "Village Hydro", a model plan for village electrification with micro-hydro power, was proposed. There have been few examples of successful off-grid electrification in Vietnam mainly due to the difficulty in managing power plants by the villagers rather than due to technical problems. Furthermore, local engineers who should play central roles in off-grid electrification don't have enough experience. This survey started in March 2003 in response to a request to JICA for verifying the validity of promising Village Hydro. With this background, this study was designed to demonstrate feasibility and sustainability of Village Hydro as a model for off-grid rural electrification by carrying out a pilot project and to disseminate the knowledge to the local engineers.

It is necessary for the local engineers to strengthen the ability to draw up off-grid electrification plans. In building up their capacity, know-how on designing and constructing the pilot system and methods on operation and maintenance of the system can be critical items to learn. Furthermore, during this study, a model of village organization that is capable of not only operation and maintenance but also financial management was developed. A broad range of knowledge and information obtained by the study have been put together into two manuals, one on designing and construction for local engineers who will be in charge of drawing up electrification plans, and the other on management and maintenance for the villagers.

We would be highly grateful if this report could be used as a text to promote off-grid electrification down the road and could be of help toward improvement of people's life in the northern Vietnam who are waiting for electrification.

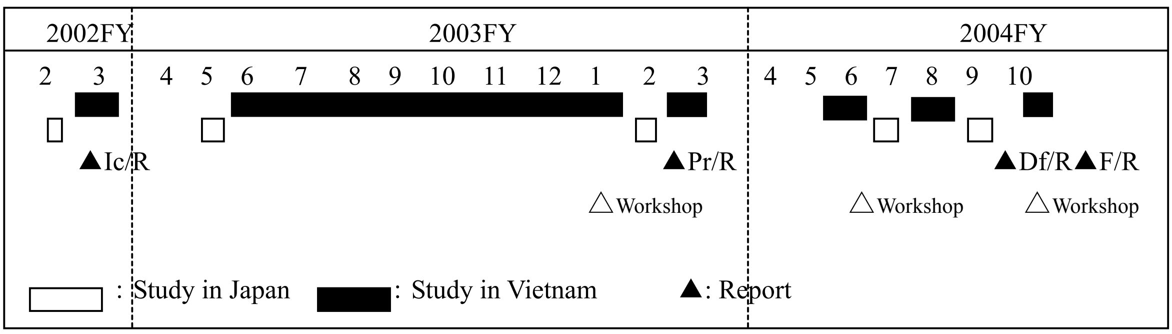
Outline of Study

Focusing on rich micro hydropower resource in northern Vietnam, this study was primarily intended to demonstrate the sustainability and replicability of off-grid micro hydro electrification system through carrying out a pilot project based on the model plan of Village Hydro. To this end, we established an organizational structure having the DOI at the top. We designed and constructed the pilot system and transferred the methods of operation and management to the villagers providing training courses.

The pilot system was built with domestic technologies and materials available in Vietnam, and monitored for a long time. The key concept of "simple and easy operation" has been demonstrated successfully. Longer-than-usual training and monitoring after the commissioning of the pilot system proved to be highly effective in developing the sustainable operation and management mechanism. In addition, it was also an important theme for us to disseminate what we had achieved to the people concerned in Vietnam, especially to the DOI. We made two manuals based on the results of the pilot project, and presented the technical and organizational achievements to the relevant organizations through workshops and other opportunities. We also recommended some action plans including arrangements for financing to the Government of Vietnam for the full-scale implementation of Village Hydro.

1.Study Schedule

In the original timetable, this study was to be completed in March 2004. However, because a substantial time was needed to select the pilot site, the pilot plant was completed 6 months behind the schedule. With this delay, the whole schedule was revised in order to secure enough time for the training and monitoring, and the draft final report was presented in September 2004.



2.Study Topics

First survey in Vietnam : Consulting with counterparts on implementation of follow-up
(March 2003) **study / Surveying potential sites for pilot plant**

We presented the study items and schedule of this study to the Vietnamese side and exchanged opinions on the current status of rural electrification as well as the study plan. Furthermore, we visited Lao Cai province that had requested to implement a pilot project and discussed the data on potential sites.

Second survey in Vietnam : Building the pilot system / Technical workshop
（June 2003 to January 2004）

①Coordination and selection of the pilot site (June to August 2003)

After finding out the progress of grid electrification plans conducted by EVN and provinces, we decided that it would be appropriate to carry out the pilot project in a outlying village in Hoa Binh province. At several un-electrified villages we conducted site surveys and consulted with relevant organizations

②Coordination on the maintenance system at the village (September to October 2003)

After the consultation, we selected Theu village in QuyHoa commune, Lacson district, Hoa Binh province as the pilot site. The plan on the construction and management of pilot plant was agreed at a villagers meeting, and we started detail designing.

③Preparation for construction work and subcontracts (October to November 2003)

After obtaining the permission for the construction plan from Hoa Binh provincial people's committee, we contracted with a consultant, manufacturer of turbine-generator and construction company. The construction work was started on November 21st, 2003.

④Construction management and commissioning / Technical workshop (November 2003 to January 2004)

The construction work of the pilot system and the lead-in wire connections by the villagers proceeded under our supervision. The first workshop on technical issues together with a ceremony to celebrate the completion of the pilot power plant was held on December 23rd at the site, and attended by many governmental officials, donors and Hoa Binh provincial people's committee members. The pilot system including the distribution system was fully completed in mid-January 2004. Fifty-four households were electrified at the first stage.

Third survey in Vietnam：Follow –up and monitoring on operation and maintenance

（February to March 2004）

Finding out the operational conditions of the pilot system, we gave instructions especially on operation procedures in case of low power output. In addition, by giving guidance on electricity contract and tariff, the management work of the pilot system was fully started.

Fourth survey in Vietnam： Follow-up and monitoring / Management workshop

（May to June 2004）

Based on the first stage results of the pilot system operation, we assessed possible risks for long-term operation and gave guidance on maintenance. Furthermore, we discussed and agreed with the villagers the revision of electricity tariff based on a financial analysis. We held the second workshop to present and discuss the management issues of Village Hydro. Vietnamese governmental officials, donors such as the World Bank and DOI staff from eight provinces in northern Vietnam attended.

Fifth survey in Vietnam: Follow-up and monitoring / Discussion on dissemination

(July 2004)

Monitoring on the operation and management in the rainy season was implemented. A small reservoir was built as a countermeasure against the low power output in the dry season. Operation and maintenance practices for the power plant were reconfirmed. Also, we drew lead-in wires to unconnected households as the second phase and gave instructions on the management. Furthermore, we exchanged views on Village Hydro dissemination plan with relevant governmental organizations and donors.

Sixth survey in Vietnam: Presentation on the draft final report / Workshop on promotion of off-grid rural electrification

(October 2004)

Smooth operation, maintenance and management of the pilot system by the villagers were reaffirmed. Finally, we held the third workshop to exchange views on the challenges and action plans for the promotion of off-grid rural electrification by Village Hydro based on the results of this pilot study with government officials and donor organizations.

3.Study team

The Ministry of Industry (MOI) is the formal counterpart of this study. The MOI organized a working group including EVN and the Institute of Energy (IE) to conduct collaborative work with the study team. Mr. Nguyen Manh Hung, deputy director of Energy Petroleum Department of MOI, acted as chief coordinator on the Vietnamese side. In addition, Mr. Quach The Hung, director of DOI of Hoa Binh province kindly gave us appropriate advice and arrangements. Thanks to the cooperation of a number of relevant parties in Vietnam, this study was smoothly carried out with a lot of fruitful achievements

On the Japanese side, a joint team between PROACT International and Tohoku Electric Power conducted this study. The study team members and their responsibilities were as follows.

Responsibilities	Name
Team leader / Sustainable operation	Katsuhiko Otaki
Micro hydropower planning	Adam Harvey
Reliability improvement	Kenichi Kuwahara (from May 2004)
Civil engineering / Engineer training	Noriyuki Yoshida
Electric & machinery engineering / Engineer training	Yasumasa Yamazaki
Socio-economic survey / Institutional development	Chiyoko Miyata
Program coordination	Shoichi Shimada (until March 2004)
Ditto	Akira Watanabe (from May 2004)

Chapter 1 Background and Study Objectives

1-1 Background

In the northern mountainous region of Vietnam, the electrification rate is relatively low due to its difficult geographical conditions. Many communes and villages still have no electricity. The Government of Vietnam (GOV) views that rural electrification is an important policy topic, because it is related to the high-priority agenda of poverty reduction and rectifying imbalance between cities and rural areas. The GOV is accelerating the grid extension to remote areas with the assistance from the World Bank. The implementing agency of grid extension is the Electricity of Vietnam (EVN). The goal of EVN is to electrify 90% of villages by the national grid by the year 2010. However, the grid extension is sometimes difficult for villages located in rugged mountainous terrain or in the outskirts of commune. In such cases, it is necessary to develop off-grid systems. EVN clearly stated that off-grid rural electrification is sometimes unavoidable for outlying villages. In Vietnam, it is stipulated that Provincial People's Committee (PPC), not EVN, is responsible for off-grid electrification. (Prime Minister's decision #22:1999)

Thus, it is assumed that about 10% of villages need off-grid rural electrification. Renewable energy sources such as micro hydropower and solar power are regarded quite feasible in Vietnam. However, there are few examples of off-grid rural electrification projects. Worse than that, some small off-grid hydropower stations built in the past were forced to stop operation and eventually abandoned because of inadequate maintenance work. We need to understand why off-grid electrification is so hampered. First, it can be pointed out that there have not been developed feasible off-grid model plans that can be followed. Those who are in charge of off-grid rural electrification are eager to see appropriate models of off-grid electrification that are suitable for rural villages both financially and technically. Although many study reports have been issued on off-grid systems proposing many ideas and development plans, there have been few projects actually implemented and continuously monitored to check the long-term sustainability. We recognized, therefore, that it was our goal to show good examples to local people as well as government officials regarding how to design off-grid systems and how to get the investment money.

Second, shortage of capable staff in rural areas who can lead off-grid projects is a serious problem. There are many potential sites in remote areas suitable for off-grid development, but the shortage of planners or developers makes the work of site evaluation or project planning, the first stage of development, difficult. Off-grid projects have been halted due to this problem. In this pilot project, we tried to give necessary training and prepare manuals for the sake of local staff's capacity building.

1-2 Objectives

Given this background, the objectives of this study were to build a micro hydropower (Village Hydro) pilot system in a typical isolated village in northern Vietnam and to demonstrate its sustainability and replicability. Also, OJT technology transfer for the capacity building of province level authorities was pursued during the study. It is our goal that the model plan demonstrated in this pilot project spreads out nationwide and leads to further off-grid rural electrification.

＜Goals＞

①Demonstration of the sustainability and replicability of off-grid rural electrification by the concept of Village Hydro from financial, managerial(institutional) and technical viewpoints.

②Capacity building targeting the Department of Industry (DOI) of Provincial People's Committee that is responsible for off-grid rural electrification.

③Preparation of manuals based on the results of this pilot project to create knowledge base for future off-grid projects.

1-3 Organizational Structure

Our goal is that the organizations involved in this pilot project undertake follow-on development projects using the knowledge and experience gained through the project. As for the technical side, we aimed at using 100% domestic technologies and collaborated with Vietnamese organizations. We selected machinery and equipment manufactured and marketed in Vietnam. We designed the pilot plant considering the technical standards in Vietnam and tested some equipment before deciding to use for this plant. Today's Vietnamese technologies have evolved into remarkably high degree, which made the system design easier than we thought. It was a good timing to start this pilot project. Consequently, we could build the pilot plant with Vietnamese technologies completely. This is an important achievement in facilitating Village Hydro in Vietnam.

As for the management of Village Hydro, we tried our best to transfer various know-how to the Vietnam side. We selected consultants and manufacturers that have good potentials and asked them to get involved from the early stage of this project so that they can accumulate knowledge and experience as much as possible. Also, we kept transferring key information and technologies to DOI that is designated as the central organization for off-grid development.

The most important part of this pilot project is to develop a workable management mechanism of Village Hydro. We tried to develop management rules and practices as much as in detail paying attention to people's acceptance and capacity to learn. Usually, after-commissioning training is short and insufficient in ODA projects. In our project, in contrast, we secured a long monitoring period for intensive training until the villagers mastered necessary skills to run the pilot plant on their own after this project. With all these efforts, we could achieve "more-than-expected" results in the end.

The organizational structure of this pilot project is shown below.

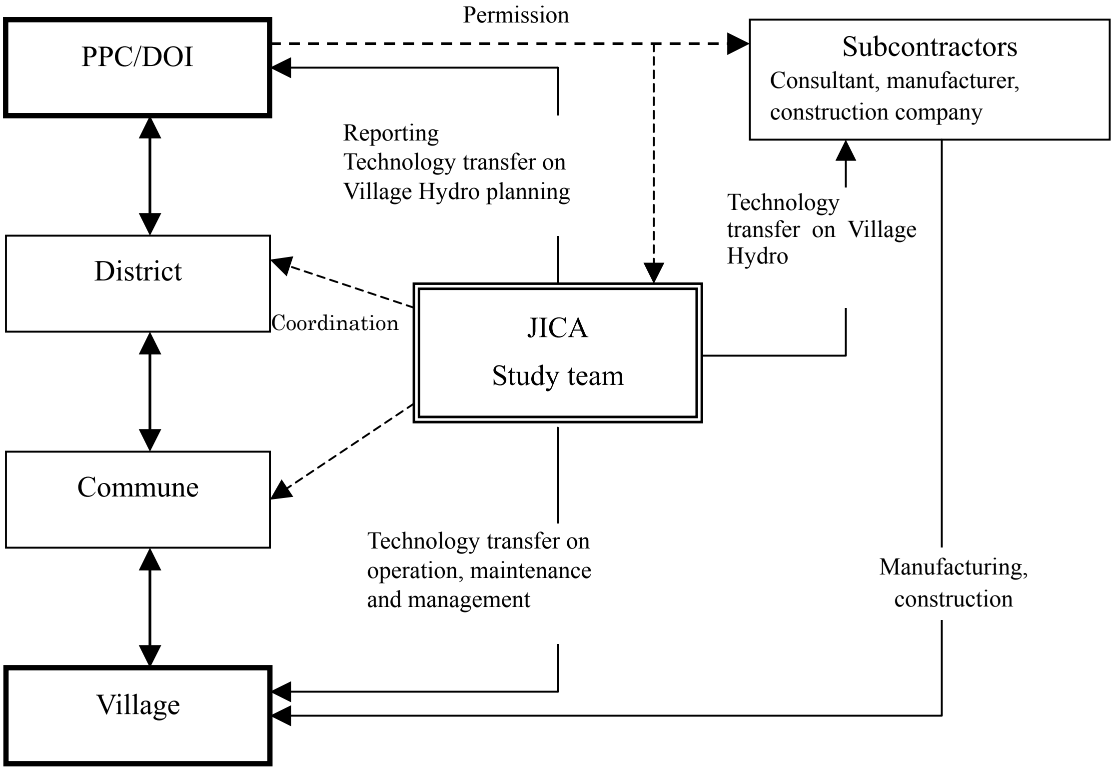


Figure 1-3-1 Related organizations of pilot project

1-4 Project timetable

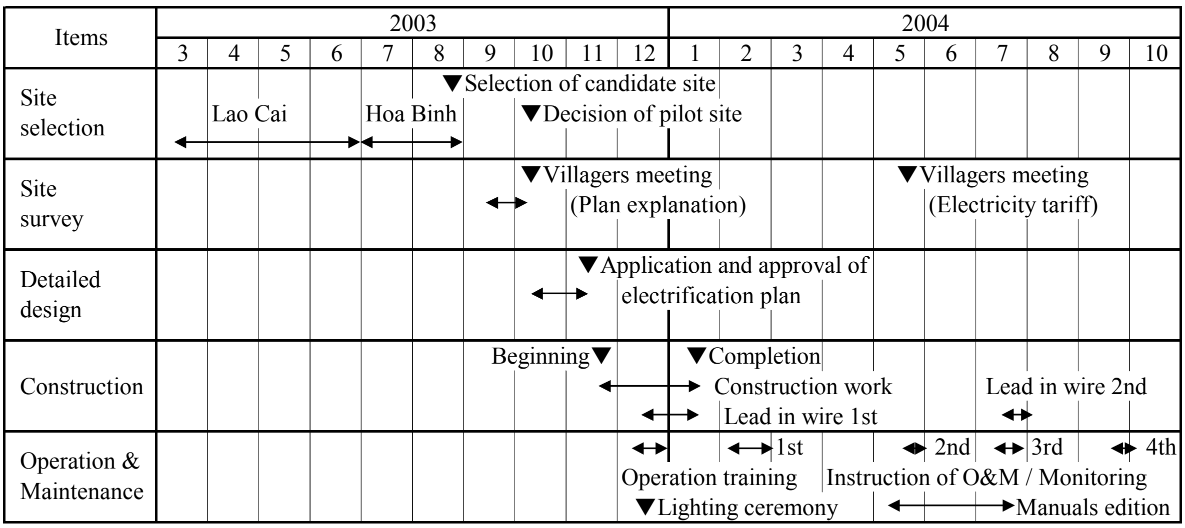


Figure 1-4-1 Pilot project timetable (actual)

Chapter 2 Outline of Pilot Village

2-1 Selection Criteria

The criteria used for selecting the pilot village are as follows:

① There is an appropriate potential site of micro hydropower.
- ◆The site is located on the slope of a hill
- ◆The water flow is rich and it is easy to have enough head.
- ◆Existing irrigation channels and terraced rice fields are well maintained
- ◆ Possible to secure some water in the dry season.

② Securing a sufficient monitoring period, for at least five years, is possible. (No grid extension plan for the next five years)

③ The villagers can afford an electricity tariff, connection charge and electric appliances

④ Villager's proactive participation in the electrification project can be expected, because of their strong unity and eagerness for electrification.

⑤ Dissemination of pilot project information can be facilitated due to easy access to the site.

Since Village Hydro is a small-scale electrification scheme targeting one village, it doesn't have to be demonstrated in commune centers. Accordingly, we searched for an appropriate "village", not a commune, in HoaBinh province, and finally selected Theu village, Quy Hoa commune, LacSon district of HoaBinh province as the pilot village.

2-2 General Outline of Pilot Village

2-2-1 Quy Hoa commune

Quy Hoa Commune, where Theu Village belongs to, is located two-hours by car from Hoa Binh town and is a 30-minute drive from the Lac Son district center. The center village is Kha.

Table 2-2-1 Number of villages and households in QuyHoa commune

	Village Name	Total No. of Household	No. of household electrified by National Grid	Remark
1	Thung 1	59		
2	Thung 2	66		
3	Doi 1	48	79	
4	Doi 2	52		
5	Theu	78		
6	Ve	72	27	
7	Thang 1	61	124	＊1
8	Thang 2	76		
9	Kha 1	56	92	
10	Kha 2	70		
11	Cao	100	81	
12	Coc	59	28	
13	Ram	52	＊2	
14	Kem	45		
15	Ngoc	48	30	
16	Cu 1	41	56	
17	Cu 2	45		
		1028	517	＊3

＊1：Some households are electrified by grid from neighbor commune.

＊2：Number of electrified households is not identified.

＊3：Population 5,400 As of October 2003

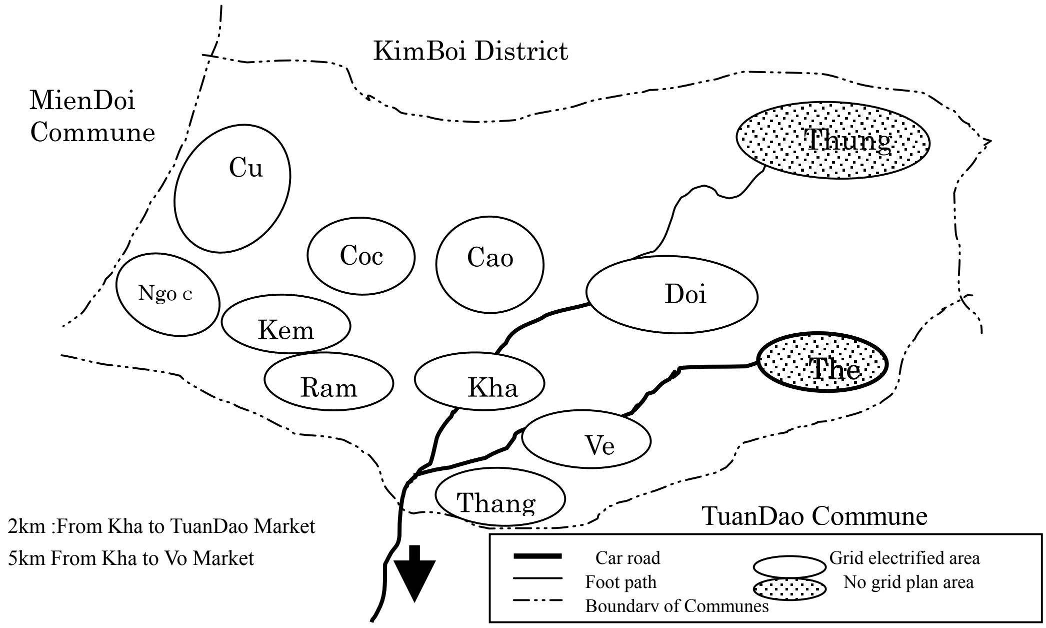


Figure 2-2-1 Village allocation in QuyHoa commune

Electrification by the national grid has been promoted in the commune since 2002. Electricity is already supplied to most of villages at present. However, some villages in the commune like Ve and Ngoc extended low voltage line from neighboring village by themselves. People in the commune usually use electricity for electric lamps, TV sets, fans. Some rich households have electric cookers, refrigerators, water pumps and rice mills.

In the grid-electrified area of the commune, an electricity management group is responsible for tariff collection, facility maintenance and other relevant work under the supervision of the vice president of commune people's committee. The group is buying electricity at 450VND/kWh (390VND+VAT) from the Power Company（Lac Son branch office） and selling at 700VND/ kWh. The surplus is used for facility maintenance, member's salary and others. The Government of Vietnam (GOV) has regulated electricity tariff in rural areas since February 1999 to help rural people. The ceiling retail price is 700VND/kWh, and Quy Hoa Commune also follows the regulation. However, some villages that independently extended low voltage lines have their own tariffs of 1,000 to 1,200VND/kWh.

Quy Hoa Commune has its own rules on electricity usage, which is basically following the power company's regulations. The steps for electricity supply in Quy Hoa Commune are given below.

①Fill application form and submit it to the electricity group
②Sign electricity buying and selling contract (Quy Hoa Commune original form)
③Installation of watt-hour meter and lead-in wire by the electricity group

2-2-2 Theu village

（1） Village outline

Theu is a Muong tribe village with 78 households and about 390 populations, which is located 4km distance from the center of Quy Hoa commune. Although the road to Theu village is not in good condition, 4WD vehicles can reach the center of village and contacts with outside of the village are common. Houses are mainly built along the main road. Though the village was originally composed of Theu hamlet in upstream area and Mai hamlet in downstream area, the two hamlets merged into Theu village. Now, Theu village can be divided into three zones such as Zone 1 in the upstream area, Zone 2 near the school (formed by households moved from upstream and downstream areas), and Zone 3 in the downstream area.（See Figure 2-2-2）

Table 2-2-2 Households and population of Theu village

Zone	No.of households	Population
1	31	164
2	25	120
3	22	102
	78	386

＊As of October 2003

（2） Village life

The villagers are farming terraced rice fields to harvest two crops annually. Basically their livelihood is self-sufficient, they obtain cash income by selling livestock at neighboring markets. Rice, maize and cassava are their main products, and they sell surplus at the market, if any. According to the villagers, they sell bamboo shoots and chickens for earning small amount of money and sell pigs for large amount of money when necessary. They said cows and buffaloes are hardly sold because those are important work forces. According to the village leader, the annual income of year 2002 was around 1.2 million VND per household, which was estimated from annual harvest volume of rice, maize, cassava, and cash income from livestock sales (estimation by the village leader).

They normally sell agricultural products and livestock at Tuan Dao commune market next to Quy Hoa commune on Saturdays or at NanNghia commune Vo market on Wednesdays and Sundays. The Vo market is the biggest market in the area of neighboring six communes. It is possible to get almost all necessary items there. The only public facility in the village is a school that is now used as a kindergarten. There is no clinic and no telephone lines in the village. Each household has a water pipe to use stream water for drinking.

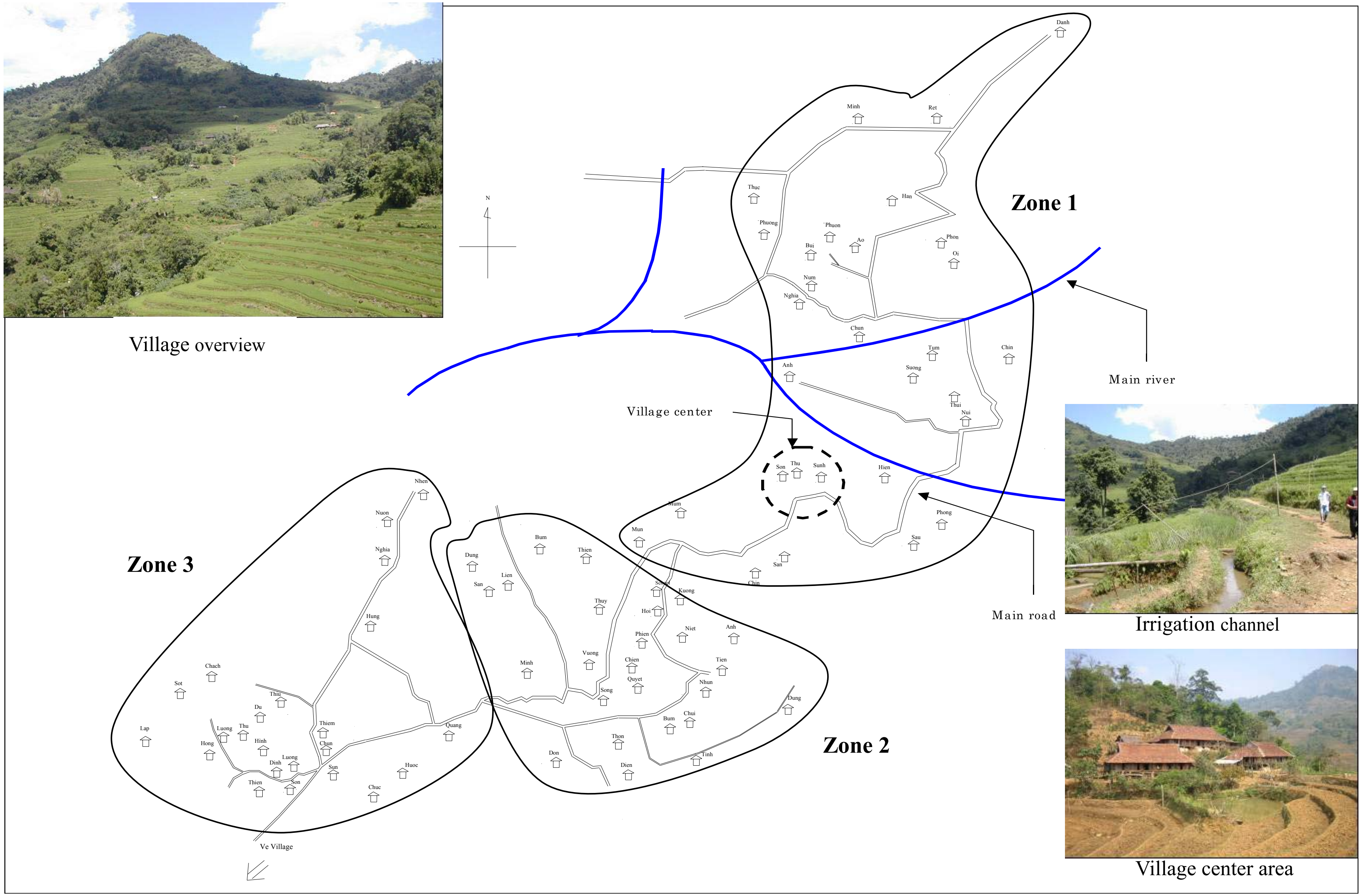


Figure 2-2-2 Household location in Theu

(3) Typical house

Figure 2-2-3 A typical house in Theu

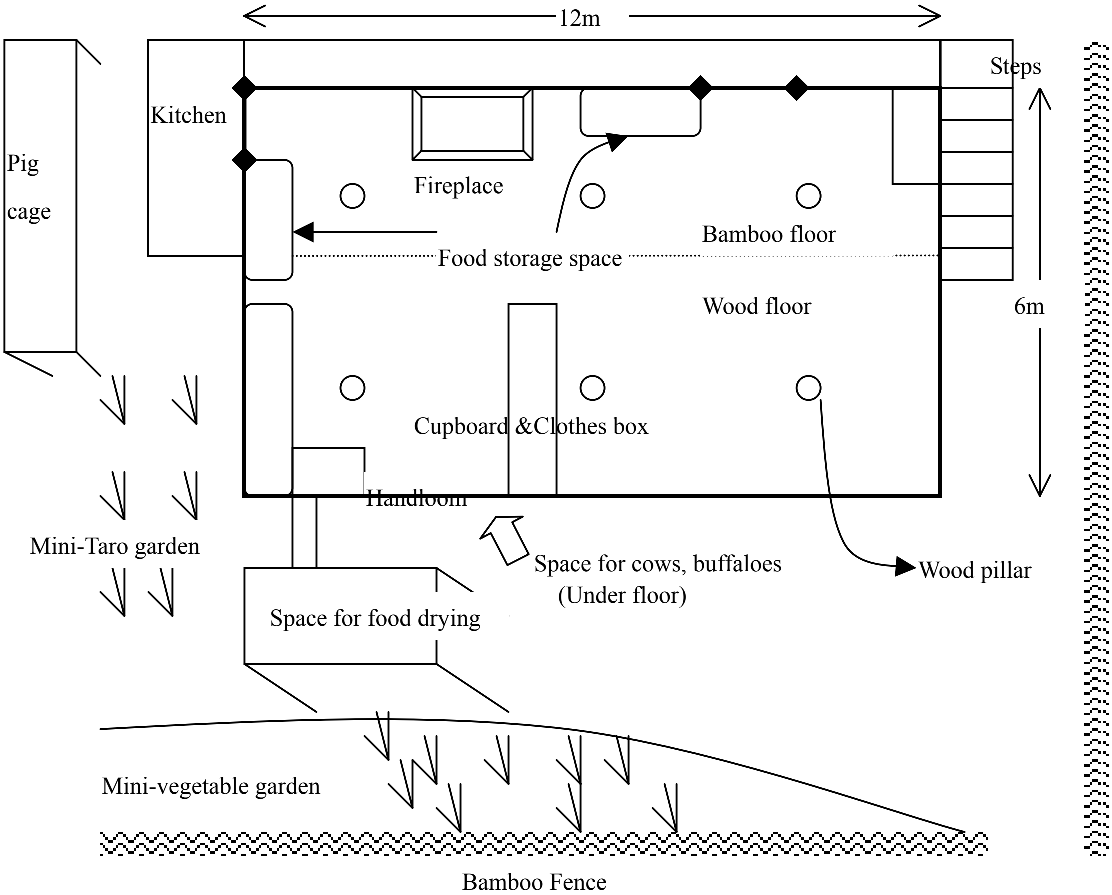


Figure 2-2-4 An example of typical house layout

Typical houses in Theu village are large-sized stilt houses, which are common among the Muong people. In this village, typical houses have strong wooden columns to support the weight of tile roof. There are some houses with straw roofing, however. In this type of stilt houses, the villages keep cows, buffaloes, and store farming tools and firewood, under the floor. Some households build pig cages near their houses. Chickens and ducks are kept around. Inside the houses, since there are no partition walls, closets or cupboards are used to divide one large room into separate spaces. Harvested rice is also kept in the storage space inside the room.

（4） Electricity usage

In October 2003, 54 households were using electricity from pico-hydro generators including the case of co-ownership. However, car batteries were not used. Primary electric appliances used in the village were electric lamps（25W bulbs and 40W fluorescent lights were popular）, black and white TV sets and electric fans. About a half of the households were using radios with dry batteries. Un-electrified households, which didn't have pico-hydro generators, used kerosene lamps for lighting.

Table 2-2-3 Electric appliances in Theu

Electric Appliance	Electric Light		TV		Fan	Radio	Cassette-Recorder
	Bulb	Fluorescent	B/W	Color			
No. of Households	53	35	26	4	25	33	15
Ownership rate	68%	45%	33%	5%	32%	42%	19%

＊ As of October 2003

Figure 2-2-5 An electric bulb (left) and a kerosene lamp (right)

Rechargeable 6-volt batteries are widely used for flashlights or headlights used in the nighttime.

Figure 2-2-6 A 6V battery（left）and a head light（right）

（5） Organizations in the village

1） Village leaders and other organizations

Three leaders, a village leader, vice-leader and secretary of communist party, are responsible for the administration of the village. Also, there are veteran’s union, women’s union, farmer’s union, youth union, elder group and other groups in the village.

2） Irrigation channel management group

There are five main irrigation channels that are used by about 80% of households in Theu village. Those channels belong to the village and are maintained by five supervisors (three individuals and two representatives from veteran’s union and elder group). The five supervisors and the village leader form an irrigation channel management group, and collect maintenance fee from the users twice a year after harvests.

Example: Owner of 1000m2 rice field

User fee：5kg rice（before milling） or 10,000VND/year（5,000VND × 2 times）

Chapter 3 Design of the Pilot System

3-1 Comparison with the Model Plan

Village Hydro is off-grid electrification system is designed to enable the villagers to carry out daily operation and maintenance, and therefore has the following characteristics:

(1) Limited plant capacity and simple design
(2) Tailored design for easy operation and maintenance by villagers
(3) Using local technology, domestic equipment and materials for easy construction and repair
(4) Low construction cost

Table 3-1-1 shows a comparison of specifications between the pilot system in Theu village and the run-of-river micro hydropower model plan proposed in the MP study. Major changes are as follows:

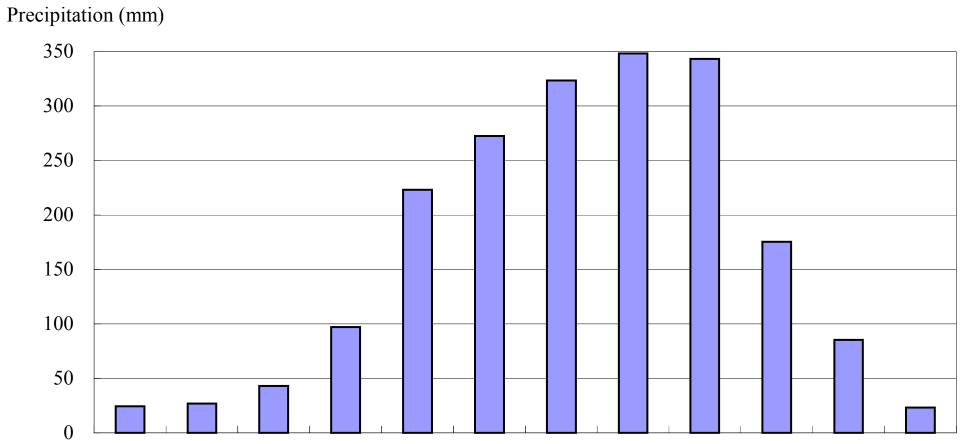
(1) For civil structures, bricks were mainly used because they are inexpensive and durable.
(2) A Turgo impulse turbine, which is smaller than a Pelton turbine, was used.
(3) A synchronous generator, available in the market, was used instead of an induction generator that was proposed in the original plan
(4) A battery charging system was canceled because of no request

Table 3-1-1 Comparison with the model plan

Items	Comparison of specification	
	Pilot system	Model plan
(1) Basic specification		
a. Type	Run of river type	
b. Output	9kW	
c. Head	60m	
d. Water volume	$0.03m^3/s$	
e. Distribution system	Low voltage 220V, Single phase 2 lines	
(2) Genaration facilities		
a. Weir	Combined with irrigation system	Combined with irrigation system
b. Intake	Combined with irrigation system	Combined with irrigation system
c. Settling basin	Additional installation by brick masonry with mortar	Omission
d. Headrace	No-lining or brick masonry channel	No-lining channel
e. Head tank	Reinforced concrete	Reinforced concrete
f. Penstock	PVC pipe（φ200）	PVC pipe（aboutφ200）
g. Powerhouse	Fiber cement roofing Building by brick masonry with mortar	Fiber cement roofing Building by wooden panel
h. Water turbine	Turgo type	Pelton type
i. Generator	Synchronous	Induction with self exciter
j. Controller	Dummy load controller	Dummy load controller
k. Batery charger	Omission	Install for remote houses
l. Tailrace	Brick masonry channel with mortar	No-lining channel

3-2 Basic plan of pilot project

The monthly precipitation in the LacSon district of HoaBinh province decreases significantly from November to April. (See Figure 3-2-1) We need to formulate a hydropower development plan based on the low water flow in the dry season, because the project calls for year round supply of electricity.



Season	Dry				Rainy						Dry		Total
Month	1	2	3	4	5	6	7	8	9	10	11	12	
Rainfall	24.5	27.0	43.1	97.1	223.2	272.5	323.6	348.5	343.3	175.4	85.3	23.3	1,986.8
Irrigation	No	Yes								No			

Source: Meteorological data provided by IE

Figure 3-2-1 Monthly average precipitation in Lac Son district

We estimated from an interview with elderly people in the village that the water flow we can use in the dry season would be around $0.01m^3/s$. The catchment area of the intake point is approximately 1 km^2. To obtain the maximum power output in the dry season, we decided to build the powerhouse at the bottom of a long slope where we have a head of about 60m. Hence, it was expected that the power output (the firm output) would be nearly 3kW in the dry season, which would meet the electricity demand for lighting in the whole village. We assumed that each household would use about 40W for lighting. On the other hand, in the rainy season the power output can be increased because of high water flow. Assuming that the electricity demand per household would grow to 100W in the future, the necessary maximum output would go up to about 8 kW. Therefore, we set the maximum water flow we use in the rainy season at $0.03m^3/s$ and developed the pilot hydropower plan based on the maximum power output of about 9 kW.

Table 3-2-1 Key data of pilot project

Item	Data	Note
(1) Scale of demand	78 households	There is a school and no clinic.
(2) Catchment area	1 km^2	
(3) Output (max)	9 kW	
	< 3 kW (Feb-Mar)	In the dry season
(4) Head	60 m	
(5) Water volume	$0.03m^3/s$	
	< $0.01m^3/s$ (Feb-Mar)	Estimated water flow in the dry season

3-3 Design of civil structures

Civil structures in this pilot project were designed based on the idea to utilize existing irrigation facilities as much as possible and to make the villagers easily maintain the structures. We can expect the following benefits:

(1) Construction period becomes shorter and construction cost is reduced.

(2) The villagers can repair the structures using local technology.

(3) The villagers always pay attention to the conditions of structures.

3-3-1 Renovation of existing irrigation facilities

(1) Weir and intake

To accommodate an increase of water to be taken from a stream, the villagers renovated an existing weir and intake by stone masonry and reinforced them with mortar before the rainy season to prepare for floodwater.

Figure 3-3-1 The weir and intake after renovation

(2) Existing channel

An existing no-lining channel was renovated to accommodate the increased water flow by excavating it wider and deeper. The dimensions marked with ◎ in the table below were applied. A margin depth of 0.1m was secured, assuming that the channel may be used to supply more water for other purposes in special occasions.

Table 3-3-1 Dimensions of no-lining channel

Channel type		No-lining channel									
Water slope		1/500					1/250				
Side slope i		1 : 0.6					1 : 0.3				
Width of water surface W (m)		0.40	0.60	0.80	1.00	1.20	0.40	0.60	0.80	1.00	1.20
Water volume Q (m^3/s)	0.01	0.20									
	0.02				0.10				0.10		
	0.03		◎	Water depth			◎				
	0.04		0.30	h =	0.20	(m)	0.30				
	0.05		0.40				0.40	Water depth: h=		0.20	(m)
	0.06						0.50				
	0.07							0.30			
	0.08										
	0.09			0.40	0.30						
	0.10							0.40	0.30		

Note : Gray cells indicate that the water flow speed is less than 0.3m/s.

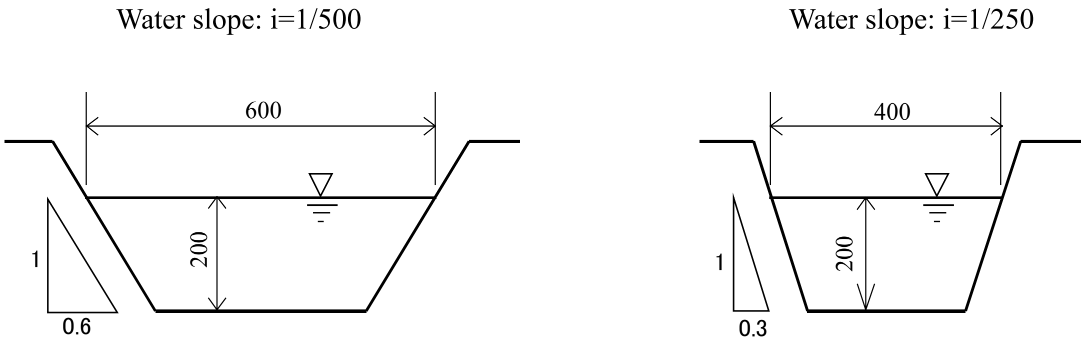


Figure 3-3-2 Cross section of the irrigation channel after renovation

Figure 3-3-3 The existing channel after renovation

There are three small gullies in the course of the channel. In the rainy season, rock-falls may occur at these gullies causing the blockage of channel. A large-scale facility will be required to prevent the channel from blockage. Therefore, we decided to leave the intersections untouched. If blocked, the villagers should repair the channel.

Water leakage prevention is important in no-lining channels. In particular, leakage in the dry season needs to be reduced. In this project, clay is used to seal the channel where water loss by leakage is significant.

(3) Reservoir

We decided to use an existing storage pond as a reservoir to cope with water shortages. See 6-1-1 “Increasing supply capacity: A reservoir” for details.

3-3-2 New channel structures

The pilot system has a new section of headrace. Also, a spillway and tailrace are all new. For these new channels, we used brick masonry. Finishing with mortar improves the roughness coefficient of surface. The dimensions marked with ◎ in the table below were applied.

Table 3-3-2 Dimensions of concrete channels

Channel type		Concrete channel				
Water slope		1/250				
Side slope i		Vertical				
Width of water surface W (m)		0.40	0.60	0.80	1.00	1.20
Water volume Q (m^3/s)	0.01					
	0.02			0.10		
	0.03	◎				
	0.04					
	0.05					
	0.06					
	0.07		Water depth			
	0.08	0.30	h =	0.20	(m)	
	0.09					
	0.10					

Note : Gray cells indicate that the water flow speed is less than 0.3m/s.

(　　　)

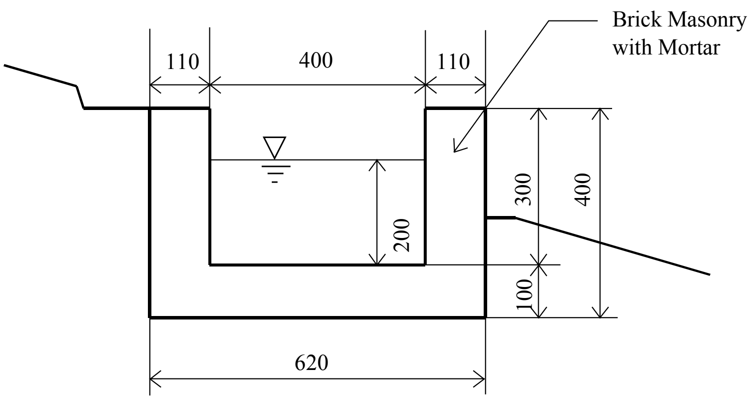


Figure 3-3-4 Cross section of the new channel

Figure 3-3-5 The new channel

In the pilot system, a silt basin was installed in the new headrace to remove sand in water.

Figure 3-3-6 The silt basin

3-3-3 Head tank

The inner width of head tank is set at 0.80 m to reduce the volume of excavation. As a result, it was necessary to extend the length of tank for settling the sand in water.

Table 3-3-3 Required length of sand settling section of the head tank

Internal width W＝0.80 (m)		
Water volume Q (m^3/s)	0.01	L = 0.50 (m)
	0.02	0.50
	0.03	1.00
	0.04	1.00
	0.05	1.50

L : Length of silt settling section of head tank

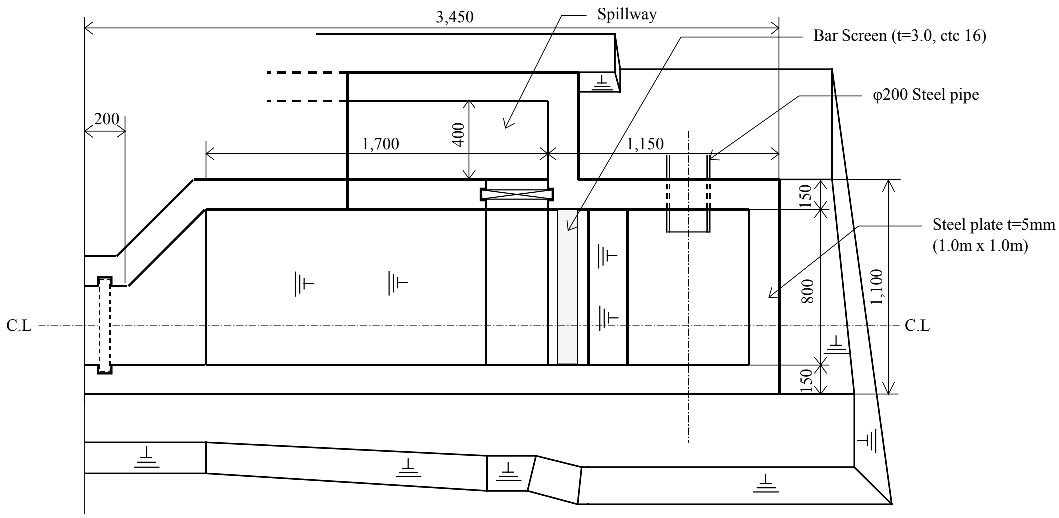


Figure 3-3-7 Plan of the head tank

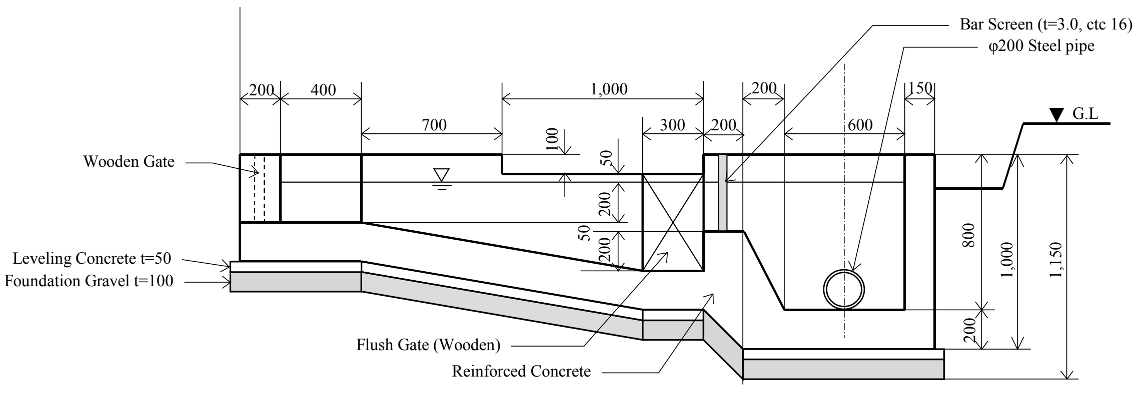


Figure 3-3-8 Cross section of the head tank

Since an excavation of more than 1m in depth was necessary, reinforced concrete was used for the head tank, taking into account soil pressure under empty conditions and water pressure under water-filled conditions. A steel trash rack (bar screen) and a steel lid to cover the entrance area of penstock were installed to prevent rubbish from entering the penstock.

When we use an existing irrigation channel as a part of headrace, it is usually necessary to consider a bypass channel to secure water flow for irrigation downstream. However, at this site we do not need it because the head tank is located at the end of the channel and there is no demand for irrigation downstream. An overflow width of 1.00 m was applied to the head tank spillway channel to allow an overflow volume of more than 0.03 m^3/s.

Table 3-3-4　Head tank overflow width

Overflow depth h (m)	Overflow length L (m)	h/L	Coefficient C	Overflow width B (m)	Overflow Q (m^3/s)
0.10	0.20	0.50	1.620	1.00	0.051
0.08	0.20	0.40	1.585	1.00	0.036
0.07	0.20	0.35	1.581	1.00	0.029

Figure　3-3-9　The head tank

3-3-4　Penstock

(1)　Selection of PVC pipe

Generally, road condition to the target area of Village Hydro is bad, and it is difficult to transport a power supply unit for welding steel pipes to the site. Also, pipes are to be installed only by manpower. In consideration of these conditions, we searched for lightweight pipes that can withstand the water pressure. We confirmed that pressure-resistant PVC pipes are available in Vietnam. PVC pipes are inexpensive, lightweight, and easy to connect on site. For this reason, we decided to use them in the pilot system.

Figure 3-3-10 PVC pipes and a flange joint

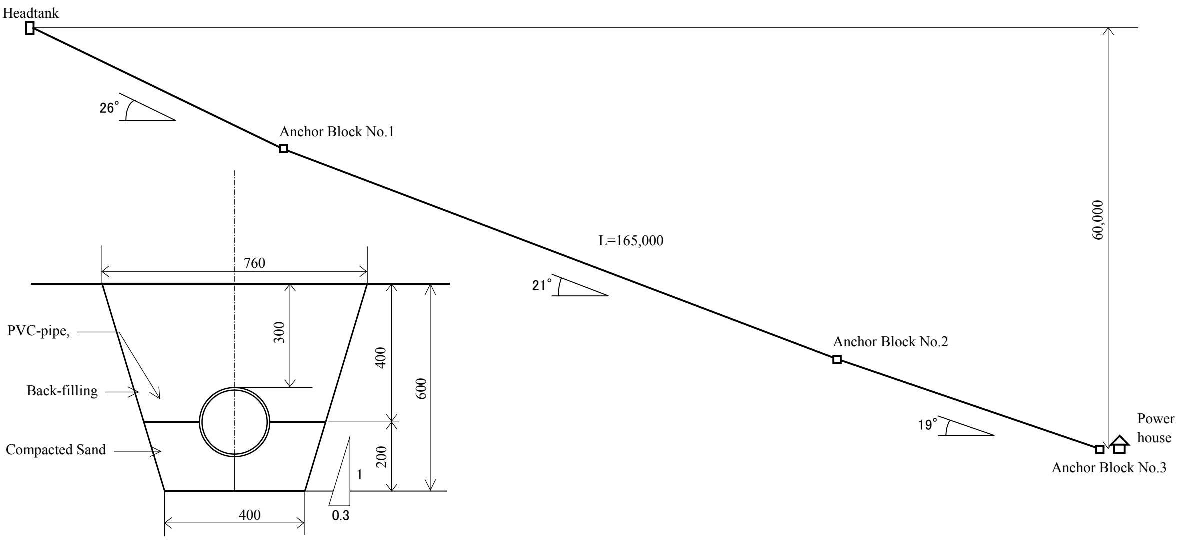


Figure 3-3-11 The layout of penstock

The inner diameter of the penstock was determined based on the result of friction loss evaluation. Although we can reduce the construction cost by using small diameter pipes, we need to give up a part of the power output because of large friction loss. In the pilot system, the cost effectiveness was carefully examined under the condition that the friction loss should be less than 10% of the gross head. Consequently, the 200mm diameter PVC pipes, which minimize the unit cost per output, were selected. As a result, the friction loss against the gross head of 60 m is less than 2 m.

（2） Design of anchor blocks

In case of buried penstocks on gentle slopes, having a gradient of less than 17 degrees, the weight of pipes and water inside is supported by the ground. On steep slopes, anchor blocks are necessary to support a part of the weight. Anchor blocks hold pipes at bends. Dimensions of anchor blocks are determined taking into account the components of weight of the penstock and water and the forces from expansion and contraction of the penstock. In the pilot system, three anchor blocks, two at bends on the slope and one at the entry to powerhouse, were installed. A steel joint pipe was used at each anchor block, and it was connected to the PVC pipes with flange joints. The anchor block at the entry to powerhouse was designed large enough so that it can support the weight of PVC pipes and water. In positioning the intermediate anchor blocks, the slope gradient was measured after trench excavation, and a certain degree of freedom was given to the point of installation to adjust to the unit length of PVC pipe.

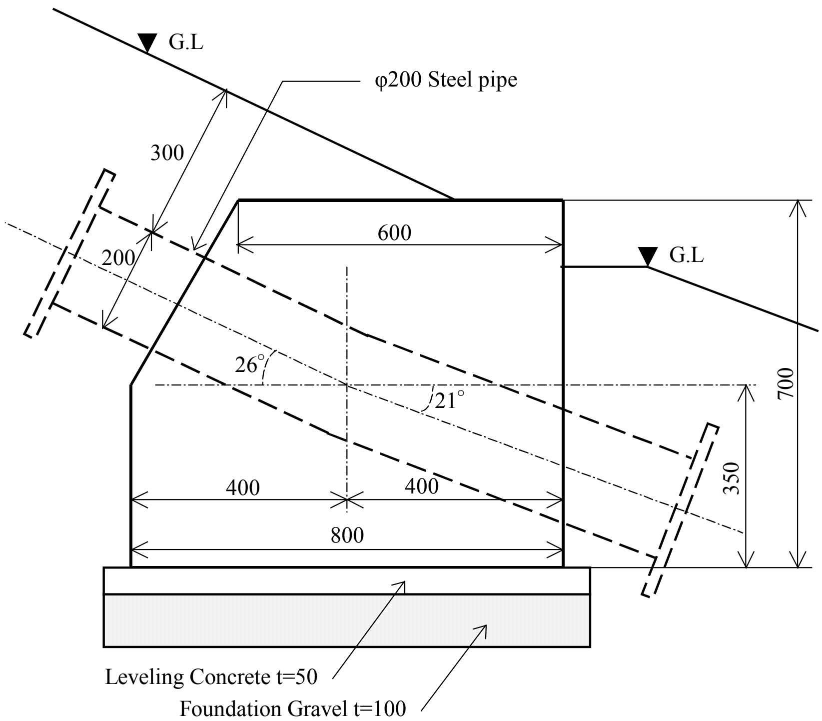


Figure 3-3-12 Cross section of an anchor block

The surface of PVC pipes is smooth, and the stability of backfill soil may partially deteriorate on slopes exceeding 20 degrees. However, the area is only 200 mm wide, and sliding is unlikely to occur because vegetation grows quickly.

3-3-5 Powerhouse

(1) Foundation of the powerhouse

A reinforced concrete foundation was built to withstand the weight of the water turbine/generator unit and the vibration of the water turbine.

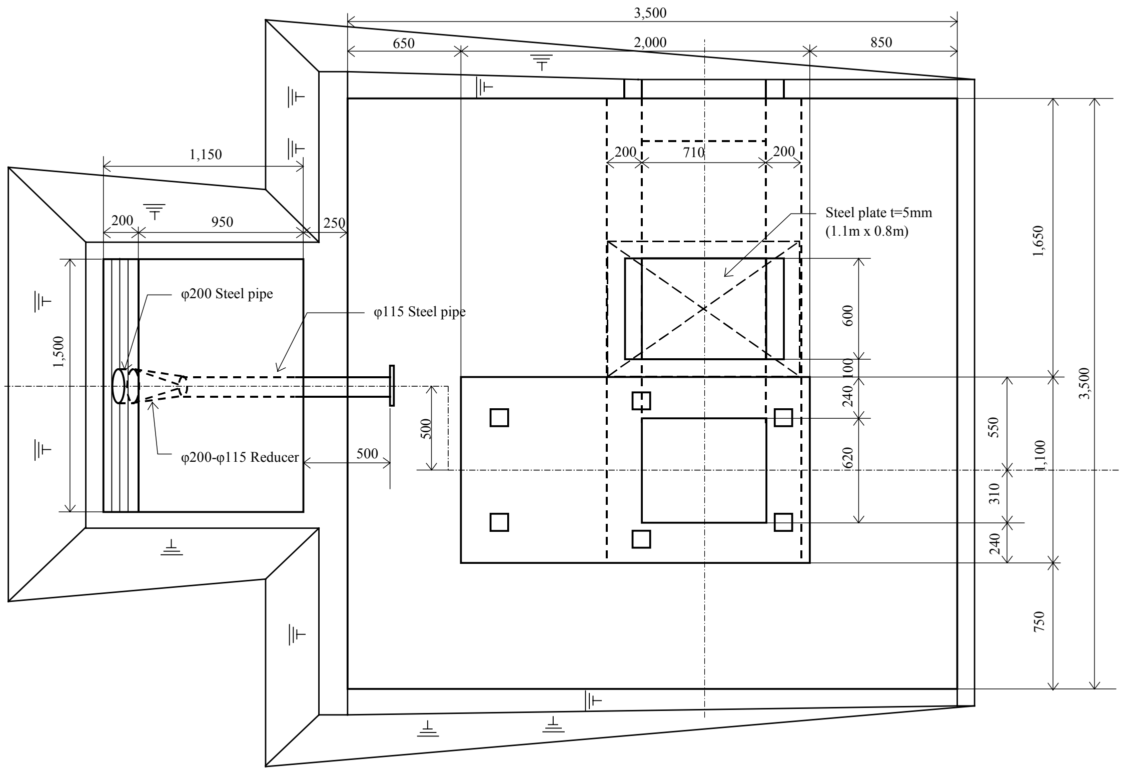


Figure 3-3-13 Foundation of the powerhouse

(2) Tailbay

A tailbay was built underneath the foundation to house a water-cooled dummy load.

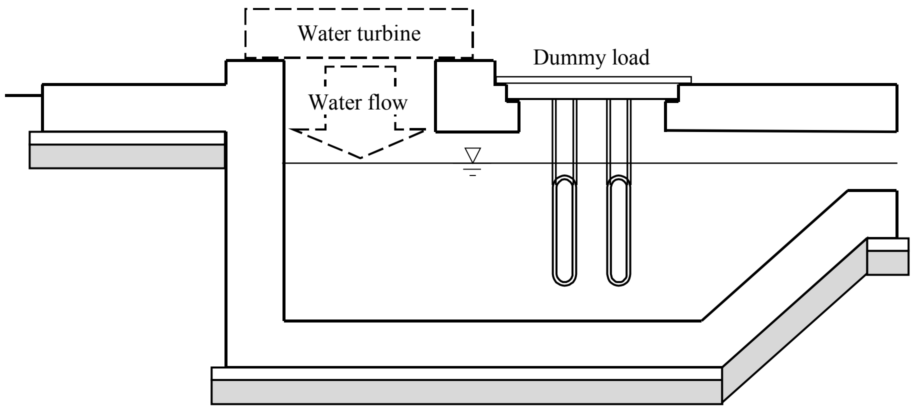


Figure 3-3-14 Cross section of the tailbay

（3） Building

The powerhouse building was made of brick masonry with mortar finish and safe from fires. A door was installed on each side of the building to allow clearance for carrying in the water turbine/generator. The height of building is more than 2 m considering the position of power cable outlet. Fiber-cement slates, commonly used in Vietnam, were used as the roofing material. The roof is sloped in one direction to drain rainwater downstream to prevent damages to the powerhouse.

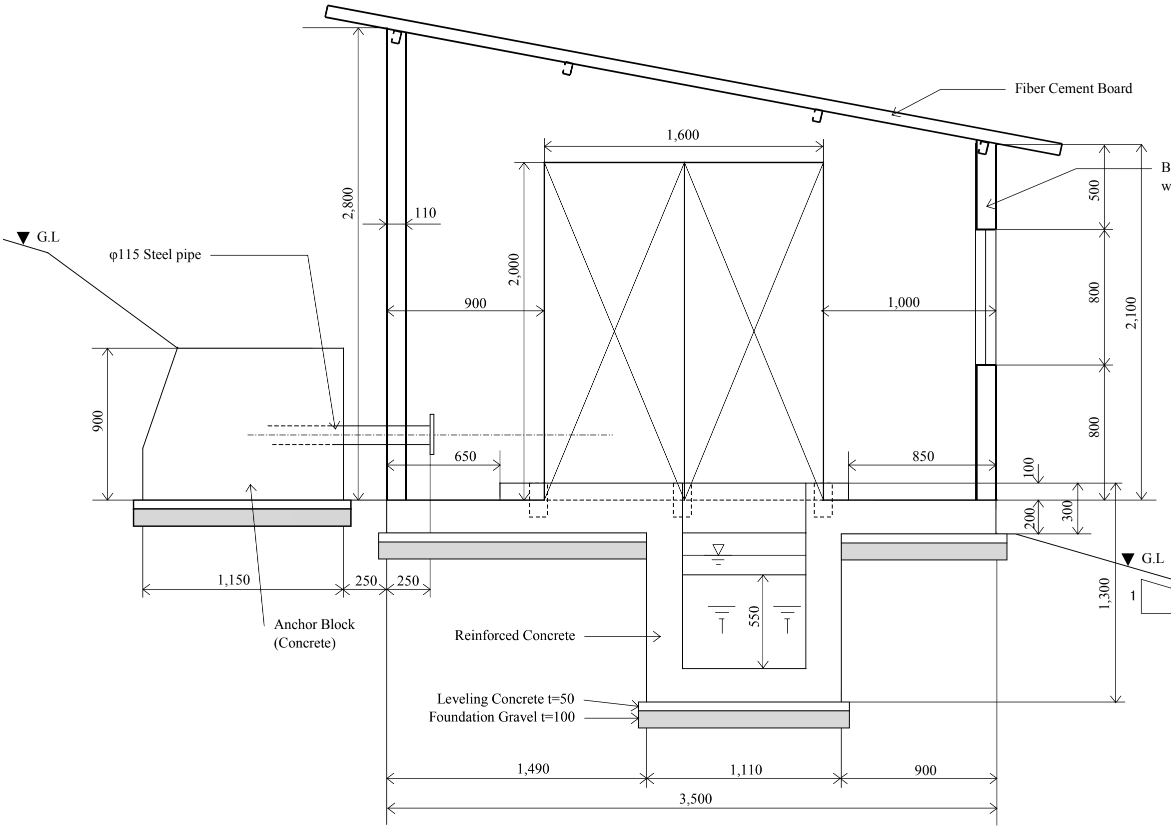


Figure 3-3-15 Section of the powerhouse

3-4 Design of Electro-Mechanical Equipment

3-4-1 Water turbine

Impulse water turbines are desirable for high head schemes like the pilot system. In the pilot system, a Turgo impulse water turbine, one of impulse turbines, was selected to meet the condition of 60m head. Turgo turbines are durable, smaller than other types and keep high efficiency at part flow. A water turbine manufacturer in Hanoi manufactured the water turbine. If Village Hydro is widely implemented in the future, price of such small turbines will go down and their quality will be improved.

Figure 3-4-1 The Turgo impulse turbine

Table 3-4-1 Water turbine specifications

Item	Specifications
Type	Turgo impulse turbine (1jet)
Gross head	60m
Maximum flow	0.03m3/s
Diameter	330mm
Rotation speed	1500 rpm

Figure 3-4-2 The turbine/generator unit: turbine casing (left) and generator(right)

3-4-2 Generator

In the model plan of the previous MP study, we planned to use a low cost induction motor as a generator with a set of capacitors for excitation. However, we found that Vietnamese small synchronous generators appeared in the market recently. These generators, suitable for off-grid generation, are inexpensive, only $200 for a 12kW unit, and readily available. It is clear theoretically that synchronous generators are superior to induction generators for off-grid generation. Therefore, we decided to use the Vietnamese single-phase synchronous generator after testing its performance.

Table 3-4-2 Generator specifications

Item	Specifications
Type	Self-excitation single phase synchronous generator
Rated voltage	220V
Rated current	54.5A
Rated capacity	12kW
Power factor	1.0

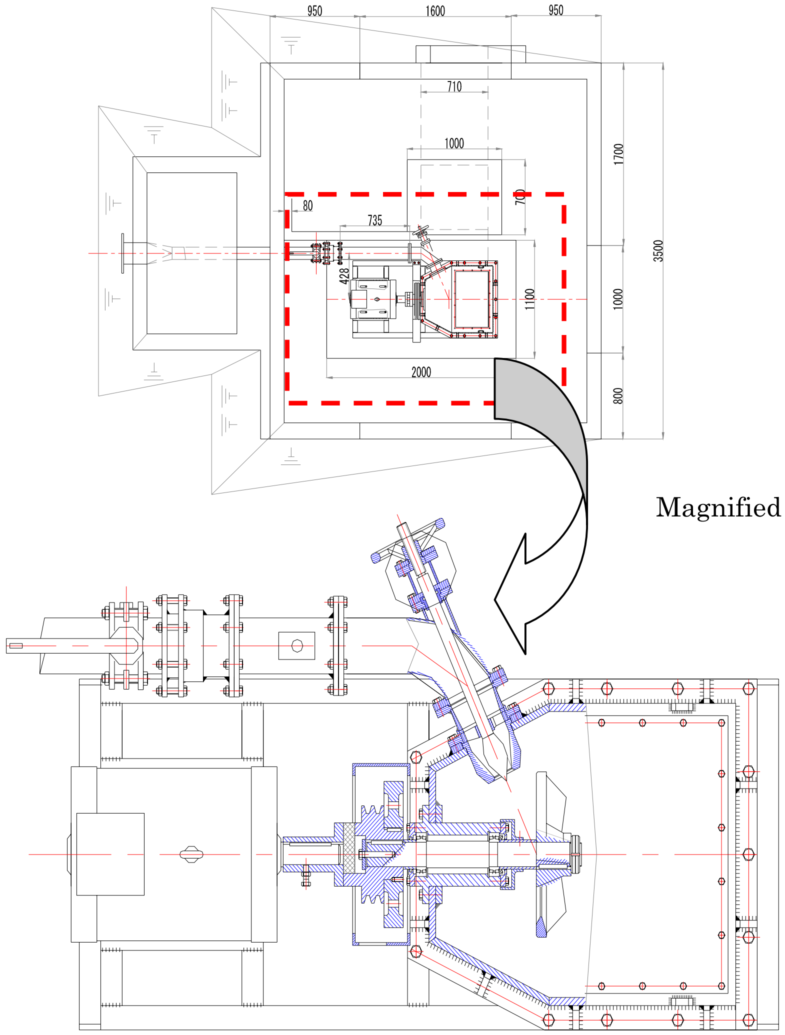


Figure 3-4-3 Plan of the turbine/generator

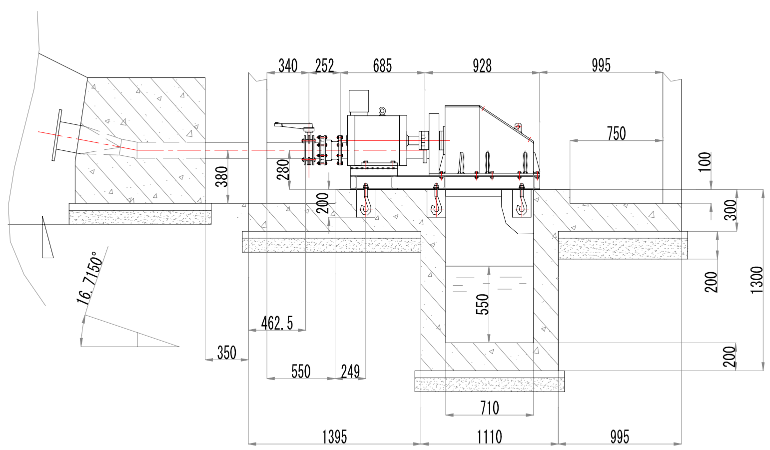


Figure 3-4-4 Cross section of the turbine/generator

3-4-3 Governor

A speed governor is a device that controls the rotation speed of a water turbine within a certain range to supply good quality electricity. In Vietnam, electronic dummy load governors for small hydropower stations have been developed and are available in the market. In addition, the dummy load governors are simple in construction, responsive and easy to use. For these reasons, we selected an electronic dummy load governor that was made in Vietnam.

(1) Principle of operation of dummy load governors

The dummy load governor maintains the rotation speed of water turbine by balancing the generator output with the combined load of village load and dummy load. When the village load changes, the governor controls the power to the dummy load in such a way that the combined load is held constant. As a result, the generated power output is always used. It can prevent the damage to the generator caused by over-speed, when the village load is suddenly cut off. We tested the governor in workshop before installation and confirmed its performance.

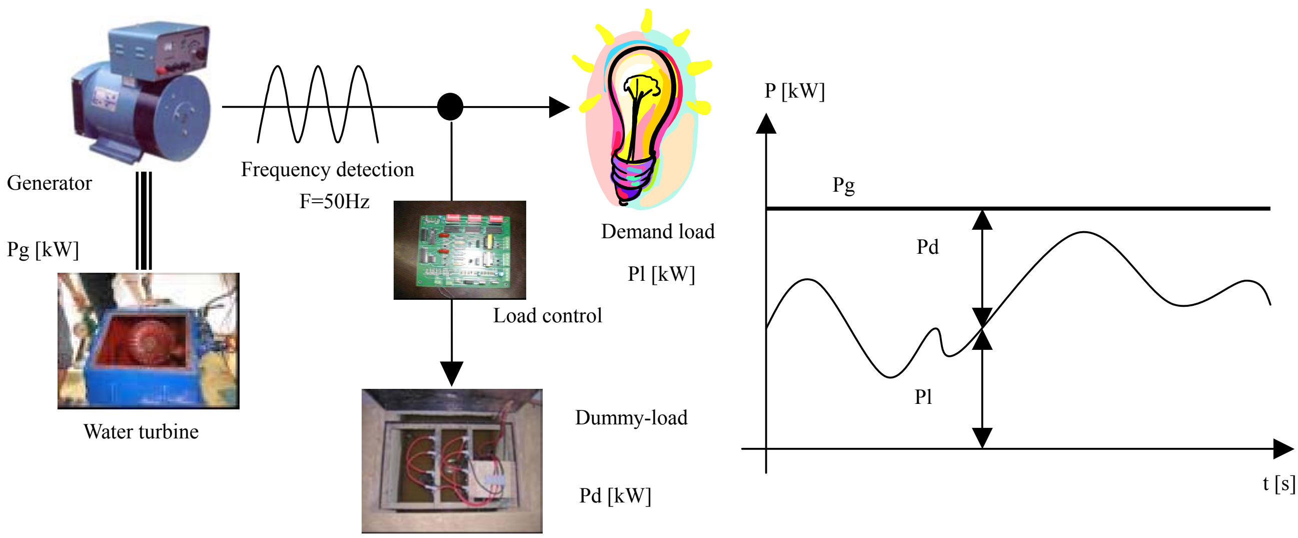
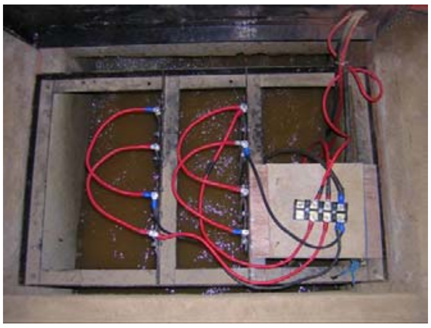


Figure 3-4-5 Function of dummy load governor

(2) Selection of a dummy load

A dummy load consists of several heater elements that work as resistance. The capacity of dummy load used in the pilot system is 12kW, equal to the rated generator output. The water-cooled dummy load was installed in the tailrace.

Heater Elements



Setting of the dummy load

Figure 3-4-6 Dummy load

3-4-4 Operation control and protective relay

Village Hydro is a small power station that must be maintained by the villagers. The system configuration is designed focusing on ease of operation, simplified maintenance and cost reduction. A voltmeter, ammeter and frequency meter are installed. Also, an over-current relay, over-voltage relay, and frequency relay are installed as safety devices, and a lightning arrester is installed to protect equipment from lightning. The single-phase two-wire connection diagram, sequence diagram and component specification used in the pilot system are shown below.

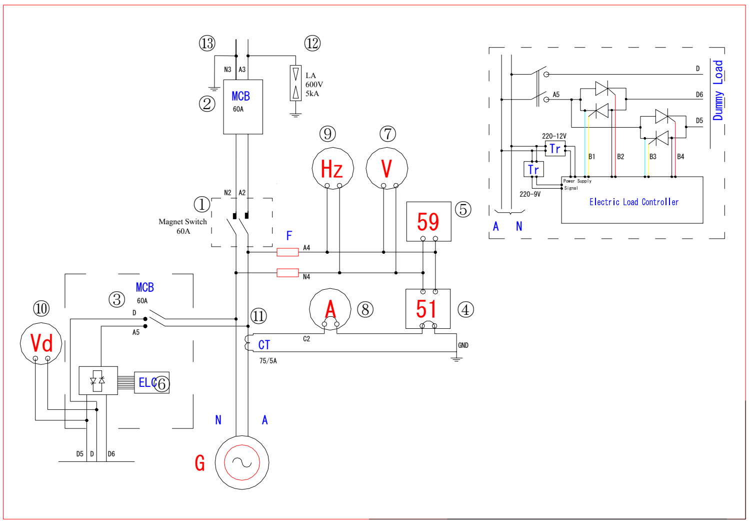


Figure 3-4-7 Schematic diagram of single phase system

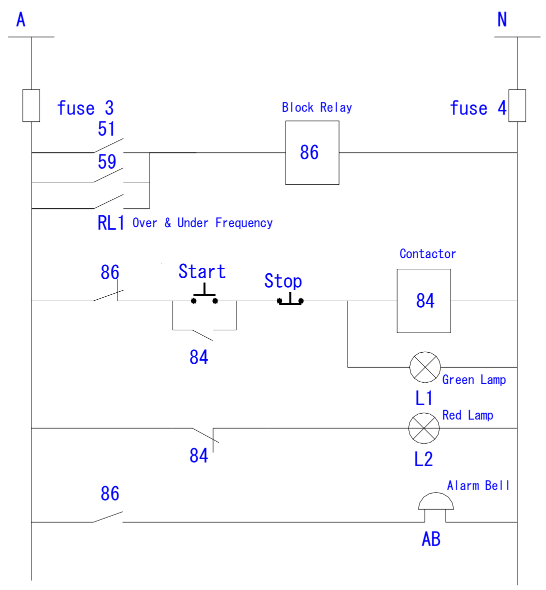


Figure 3-4-8 Sequence diagram

Table 3-4-3 Control system specifications

Classification	No.	Device	Specification	Function
Switch	①	Contactor	100A (> 60A)	For system connection and separation
	②	MCB for transmission	60A	Over-load and short-circuit protection
		It is also possible to install ELCB for earth leakage protection.		
	③	MCB for Dummy Load	60A	Dummy load short-circuit protection
Protective Relay	④	Over Current Relay (51)	7.5-97.5A (0.5-6.5A) On Time 0-10s Delay Time 0-30s	Over-load and short-circuit protection
	⑤	Over Voltage Relay (59)	220-300V On Time 0-30s Delay Time 0-30s	Over-voltage protection
	⑥	Over & Under Frequency Relay (OF, UF)	OF 55Hz UF 45Hz On Time 5s Type : Set in ELC	Over- and under- frequency protection
Instrument	⑦	Potential meter	0-300V	Measurement of voltage
	⑧	Current meter	0-150A	Measurement of current
	⑨	Frequency meter	45-65Hz	Measurement of frequency
	⑩	Potential meter for DL	0-300V	Measurement of dummy load
Transformer	⑪	Current Transformer	75 / 5 A	For meters and relays
Lightning Protection	⑫	Lightning Arrester (LA)	600V 5000A	Apparatus protection from lightning
	⑬	Earthing (One line multiple grounding system)	< 4 Ω	

3-5 Design of Distribution Facility

Theu village stretches more than 2km along the main road from northeast to southwest. The powerhouse is located close to the village center. Location of houses in Theu village is shown in Figure 3-5-1. The supply area can be divided into two areas, the east side and west side. Houses are scattered and mostly located along the main road. Therefore, we planned to draw the distribution lines connecting populated areas. At the same time, it was required to ensure the minimum voltage of 200V at the end of distribution lines. The distribution system is a single-phase two-wire 220V system, which is standard for Village Hydro.

We used concrete poles and insulated aluminum cables, so that the villagers can use the distribution system even after the grid connection. Also, we installed cut off switches at the Pole No.4 for planned outage in the future.

Table 3-5-1 Supply areas

Distribution zones	Number of households	Zone distance (m)	Number of poles
L0	1	122	3
L1	29	1,058	23
L2	42	1,324	35
L3	7	366	10
Total	79	2,870	71

The basic specifications for the distribution lines and other materials are shown in the table below according to the Vietnam's technical standards.

Table 3-5-2 Basic specifications for distribution lines and other materials

Item		Type	Size
Supporting structure			
	Steel reinforced concrete pole	H7.5m - Type B	H=7.5m,Designed load 380kgf
		H7.5m - Type C	H=7.5m,Designed load 440kgf
	Concrete pole base	Concrete M150	L=0.7m,W=0.7m,D=1.2m
	Support wire	Support wireband, and others	Concrete block, steel wire, and others
Low voltage cable			
	Cable	Aluminum insulated cable	Sectional area size: 35,50,70,95mm^2 (Selected from the voltage drop calculation)
	Steel cross-arm	L-type angle (single)	One L-type arm: L 63x63x6 (mm)
		L-type angle (double)	Two L-type arms: L 63x63x6 (mm)
	Insulator	Ceramic insulation for low voltage	Insulation standardized in Vietnam

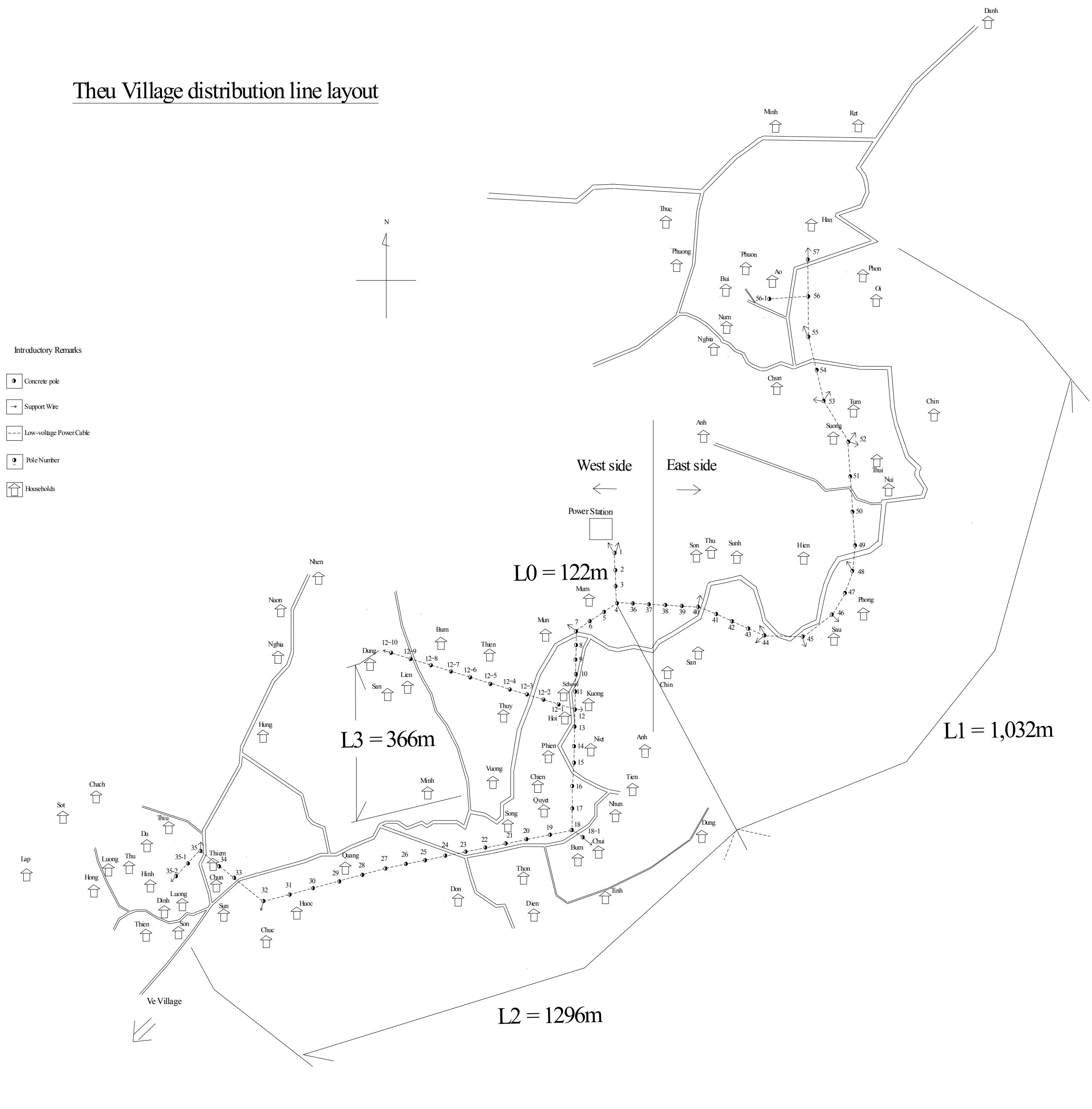


Figure 3-5-1 Distribution line layout

3-5-1 Cables

Aluminum-insulated electric cables, which are standard in Vietnam, were used. Sizing of cables was conducted based on a voltage drop simulation. The voltage drop allowed in this pilot system is 20V. The conditions of the voltage drop simulation are as follows:

(1) Generator voltage is 230 V.

(2) Load power factor is 0.8

(3) Demand per household is 100 W.

As a result, the combination shown in the table below cleared the voltage drop requirements.

Table 3-5-3 Combinations of cable diameters

Zone No.	Zone	Cable type
L0	Power house～4	AL-PVC70mm^2
L1	4～36～57	AL-PVC35mm^2
L2	4～25	AL-PVC70mm^2
	25～35～35-2	AL-PVC50mm^2
L3	12～12-10	AL-PVC35mm^2

3-5-2 Poles

High-load electric poles (H7.5m-C type) were used at some locations, such as the end of distribution line, where poles should withstand large cable tension, and standard-load electric poles (H7.5m-B type) were used at other locations. The poles were selected to meet the requirements of 40m cable span and 4m cable clearance above the ground, which are specified in the Vietnam’s technical standards.

Table 3-5-4 Technical specifications for reinforced concrete poles

Item	Specification	
Type	H7.5-B	H7.5-C
Length（m）	7.5	7.5
Breaking load (kg)	380	440
Concrete weight (kg)	480	480
Steel weight (kg)	55.86	59.28
Total weight (kg)	535.86	539.28

3-5-3 Lead-in wire

A lead-in wire and associated equipment are the property of each household. We selected PVC-M cables for lead-in wires considering durability and reliability. We used wood poles as posts for lead-in wires because they were easily found in the village. The electricity (watt-hour) meters and circuit breakers were low-cost type.


Figure 3-5-2 House connection
(Left:Lead-in wire and post, Right:Watt-hour meter and circuit breaker)

The installation work of lead-in wires is the responsibility of the CEU members. For this reason, we provided OJT training to them on the installation of lead-in wires and necessary equipment.


Figure 3-5-3 Installation of lead-in wire

3-5-4 Grounding

The single-line multiple grounding system, which is standard in Vietnam, was used. This system does not require the installation of overhead ground wire to protect against surges from lightning, and has the advantage of low equipment cost.

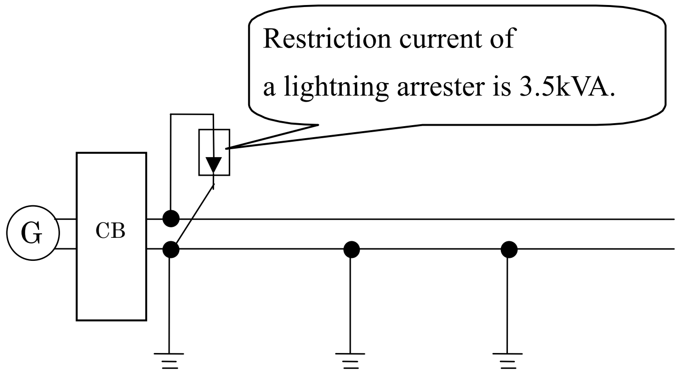


Figure 3-5-4 Single-Line Multiple Grounding System (Standard Type)

Since lightning frequently occurs near the project site, we installed lightning arresters at a 200m interval to improve protection against lightning. (Figure 3-5-5) Grounding resistance is 4 ohms at the powerhouse and 30 ohms at the ground points in distribution lines, in order to make it easier for a surge current to flow toward the powerhouse. The difficulty of ground fault protection is a disadvantage of this system.

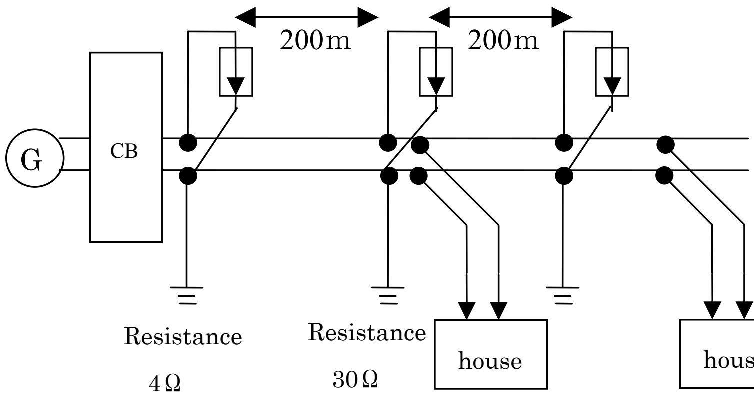


Figure 3-5-5 Single-Line Multiple Grounding System (Improved Type)

3-6 Technology Transfer to DOI

In Hoa Binh province where the pilot project was implemented, there are 30 staff members at the DOI, and five of them are responsible for electrification. Those responsible for electrification have been mainly engaged in electrification projects by the grid, and they do not have much experience in projects related to off-grid rural electrification. Therefore, in order for them to engage in rural electrification by Village Hydro, the capacity building on the electrification planning, from hydropower scheme design to pilot operation and management by villagers, is an urgent issue. It is desirable to carry out this capacity building on an OJT basis from the site survey stage to accumulate practical experience.

In the pilot project, since the lead-time to construction was short, technology transfer to the DOI was done through presentation and discussion based on design documents that we prepared. The contents of technology transfer are shown in the following table.

Table 3-6-1 Contents of technology transfer to HoaBinh DOI

Stage	Contents
Preliminary survey	Presentation on the basics of off-grid electrification by micro hydropower
Site survey	Presentation on a pilot electrification plan Site visiting for survey and participation in villagers meeting
Planning	Presentation on the functions of facilities Practical training on basic design of facilities Review of pilot system design
Construction and commissioning	Inspection of facilities Presentation on the construction of pilot system

Although we carried out the preliminary survey of this pilot site, the DOI commented, "It is common that the DOI surveys candidate sites for off-grid rural electrification, and designing work should follow the DOI's preliminary survey." This view is appropriate because the DOI can collect village data easily and they can decide candidate sites taking various factors, such as the grid extension plan, into account. However, hydropower planning is not straightforward. It should consider the conditions such as geography and water flow of each site. The DOI has limited experience, and therefore it is desirable to accumulate and share information among the people concerned. Regarding the capacity building of DOI, basics of off-grid rural electrification should be transferred to them as a first step, and then OJT style electrification planning targeting actual sites should be conducted. Results of OJT planning work must be shared. In addition, the Village Hydro Design Manual for Planners in which the knowledge acquired through the pilot project is summarized will be utilized as a textbook for training the DOI staff who are in charge of electrification planning.