CHAPTER 6
FEASIBILITY STUDY FOR THE REHABILITATION EXISTING NAM PHA MICRO-HYDROPOWER PLANT

6.1 Introduction

Nam Pha micro-hydropower plant (18kW) was built in 1998 by the donation of Mini promotion for Local Project (European Union), and under authority of Ministry of Agriculture and Forest of Lao PDR. The main objective of this project is multipurpose as for both irrigation and electricity supply.

The objective of this study is to demonstrate the technical viability and economic feasibility on the rehabilitation. The economic indicators Net Present Value (NPV), Benefit-Cost ratio (B/C) and Internal Rate of Return (IRR) are used to evaluate the viability of the project.

6.2 General Information of the Project

Nam Pha Micro-hydropower plant (MHP) located in the middle of Nam Pha River. It had been supplied electricity for only one village in Luang Prabang district where it is consisted of 150 households. The overview of Nam Pha MHP is shown in figure 6.1 and (more details will be described in appendix C, Section C.2).

Figure 6.1 The Overview of Nam Pha MHP.

6.2.1 Significant Problem

During site visit of Nam Pha MHP, the data collection was reviewed to evaluate current condition of project. Some problem is found and described by the following :

1) Power house has a flood problem during rainy season and need to be reconstruct,

2) Electro-Mechanical work such as: turbine-generator, control system an electrical equipment disables and need to be replaced, and

3) The operation staffs lack of knowledge and effective skill for operation and maintenance.

6.2.2 Technical Information

According to the objective of study, the data information of Nam Pha MHP such as that its technical data is vital for rehabilitation project. The rehabilitation purpose for this project also considered of existing equipment without enlargement of hydropower plants' basic technical and modify may plant structure if necessary.

1) Layout of Nam Pha MHP

The project is developed for multipurpose as the major purpose is for irrigation and the minor is for electricity supply. The general plan layout is shown in figure 6.2.

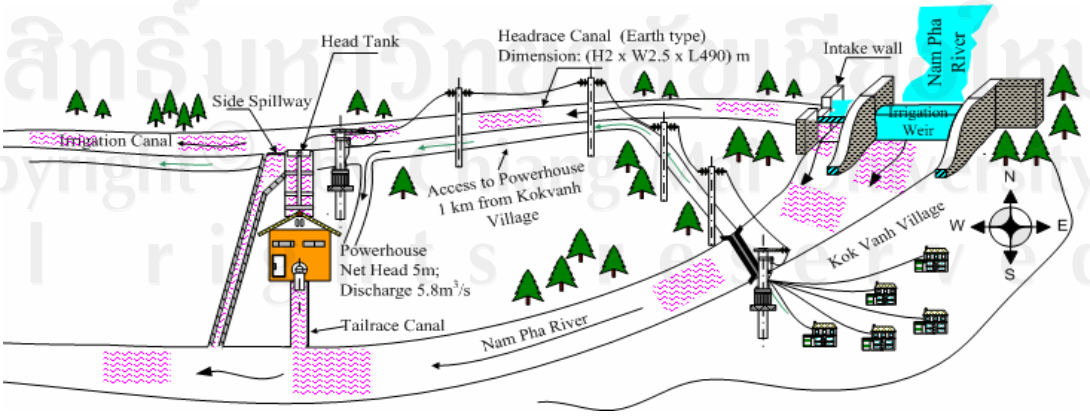

Figure 6.2 The existing general plan of Nam Pha MHP.

2) The Work Flow of Nam Pha MHP Project

After site visited and based on the reality condition, the rehabilitations scheme of the project is proposed by the concept of modification with the simplified plant structure, easy to operate and maintenance and to minimize cost. The work flow of this study is as follows :

a) Modify intake structure,

b) Replace earth canal with steel pipe,

c) Reconstruction for powerhouse,

d) Change the parts of mechanical work such as turbine and control system,

e) Change for new electrical equipment such as generator, transformer and control system, and

f) Install new distribution line.

6.2.3 Concept of Modified Plant Structures

The work flow outline for new plant structure and plant facilities of Nam Pha MHP by modification plant structures are shown in figure 6.3.

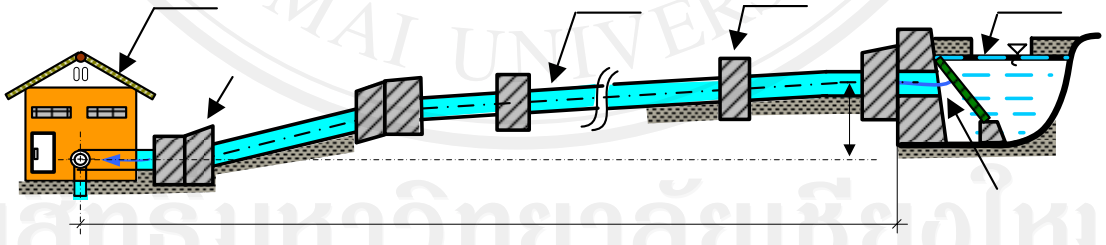

Figure 6.3 The conceptual design plant's structures of Nam Pha MHP (Not to Scale).

1) Description of the Civil Work

Civil structures are used to control the water that runs through a micro-hydropower system. Conveyances are a large part of the project work. It is important that civil structures are located in a suitable site and designed for optimum performance and stability to reduce cost and to ensure a reliable system. For more details see appendix C, Section 3.1.

2) Piping Work

The piping work is often the most expensive item in the project budget. Selection suitable pipe diameter work is depended on the standard size of steel pipes from manufacture [22]. The maximum flow rate from the previous study is 0.58 m^3/s and gross head is 5.5 m. The design length of the pipeline is approximately 490 m (see figure 6.3). The details of pipe are summarized as follows (See details in appendix C**,** Section C.3.2).

Summary data of pipe

- Total pipe length 490 m,
- Type of pipe Wrought Iron or Schedule 40 Steel Pipe,
- Inside Pipe diameter 478 mm,
- Friction loss 0.484 m at pipe length 100m.

Therefore, head loss due to friction loss at 490 m pipe line is :

(0.484 m x 4.9) = 2.3 m.

a) Estimate the Effective Head

As a result of selection the suitable pipe diameter, it is indicated that head loss due to the friction loss that is as high as 2.3 m with pipe diameter at 478 mm and total pipe length of 490 m (excluding the minor head loss), so the effective head that is gross head after deduction the head losses seems to be very low. The effective head at the pipe diameter 478 mm is :

The Effective head = 5.5 m - 2.3 m = 3.2 m.

3) Mechanical Equipments

a) Turbine Selection

To select the suitable turbine, the standard typical range of turbine (See in table 2.3 in chapter 2) is used as a guide line. The cross-flow and propeller turbine are a preliminary consider at the effective head of 3.2 m and the water flow rate of 0.58 m^3/s.

- Specification Turbine

(i) The cross-flow turbine is an impulse turbine that requires a high head to be really efficient, but it will "work" on heads as low is less than 10 meter. The design for the MHP plans claims a 60% of combined efficiency [13]. The general specification of the turbine was recommended [18].

- Turbine type: Cross-flow,
- Size Small size,
- The flow rate: 0.1 m^3/s -7 m^3/s,
- Power Output: 30-1000 kW and
- Head is not less than 5-100 m.

(ii) Propeller turbine is normally used for low head and small scale hydroelectric power plants [8] and Hydro-eKID Type S is available for low head but need for large water flow rate. It was considered for this study. The characteristic and specification of turbine is in figure 6.4.

Figure 6.4 The characteristic and specification of turbine [8].

From the specification of turbine, it was found that the cross-flow turbine is not suitable for this study where the head is less than 5 m [10]. While the propeller type is available for head and flow rate but the power output seem to be very low. It can be calculated by the power equation [8].

$$Power\ Equation: \quad P = 9.8 \times Q\, x\, H_e \times 0.7 \qquad (kW)$$

Therefore, P = 9.8 x 0.58 x 3.2 x 0.7 = 13 kW.

As results, the power capacity is lower than the power capacity from the previous study at 18 kW. Therefore, the expansion pipe diameter can reduce the loss

and the power capacity will be increased while the flow rate is fixed at 0.58 m^3/sec. The propeller turbine type S of Hydro-eKID [8] is selected and the structures of Hydro-eKID type S are shown in figure 6.5.

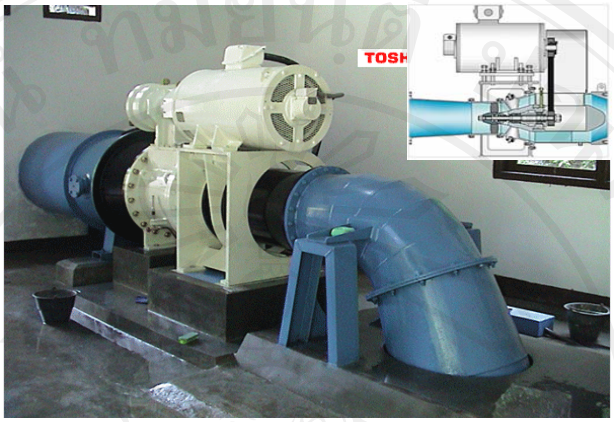

Figure 6.5 The Structures propeller turbine and generator type S [8].

The following is the study detail of piping work (See appendix C, Section C.3.2). The piping work is summarized as follows :

a) Summarized details of piping work at pipe inside diameter (575 mm)

- Type of pipe Wrought Iron or Schedule 40 Steel Pipe,
- Inside Pipe Diameter 575 mm,
- Friction loss 0.192 m at 100 m length,
- Total friction loss (0.192 m x 4.90) = 0.94 m.

b) Determination the Effective head *(H_e)*

The effective head (He) of this project is determined by the gross head of 5.5 m, water flow rate of Q = 0.58 m^3/s by deducting the head loss between intake and tailrace with 4.90 m long (See details in appendix C, section B.3.2). The particular details are summarized as follows :

$$Effective\ Head = Hg - H_{loss}\ (m)$$

Where, H_{loss} = *Major head Loss - Minor Head Loss*

Remark: Because of the pipe plans to lay as the straight line, it is assumed that the minor head loss is defined in very small. It is therefore included in calculation.

Therefore, *Effective head* = 5.5 m - 0.94 m = 4.56 m

From the specification data of turbine, water head and flow rate, the turbine data for new micro-hydropower plant can summarized as flows :

- Effective Head 4.56 m,
- Discharge 0.58 m^3/s,
- Efficiency is not less than 70 % [8]
- Turbine output 18.16 kW/at head 4.56 m.

- Turbine Output (P) = 9.81 x 0.88 x 4.56 x 0.7 = 18.16 kW.

4) Electrical Work

a) Generator and Control System

The project is an isolated grid system. A synchronous generator is therefore used. It must be driven at a constant speed to generate steady power at the frequency of 50 Hz to meet the rated frequency of electricity system of Lao PDR. The number of pole in the generator determines the speed. The selection the size of generator should consider capacity output and specific speed of the turbine.

Based on the power output of turbine that is 18.16 kW, the generator which is 20 kVA is selected and its specification is shown [10].

- Type Synchronous generator,
- Number of poles 4 Poles,
- Power Output 20 KVA,
- Rated Frequency 50 Hz,
- Rated Voltage 220/380 V.

b) Distribution Line

The electricity generated is directly planned to supply to the village with 22kV/ 0.4 kV distribution line. The scheme of power line of the project is shown in figure 6.6.

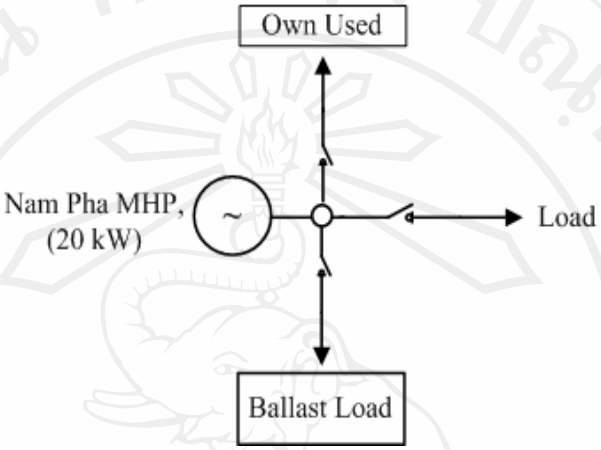

Figure 6.6 The schematic of single line diagram of distribution line.

5) Technical Assumptions

According to the existing data and new equipment, the technical assumption is summarized in table 6.1.

Table 6.1 Summary of technical data of Nam Pha MHP project.

No.	Data	Indexes
1)	Gross head	5.5 m
2)	Effective Head	4.56 m
3)	Water flow rate	0.58 m^3/s
4)	Inside Pipe Diameter	575 mm
5)	Turbine type	Propeller
6)	Installed Capacity	18 kW
7)	Plant Factor**	~ 50%
8)	Annual Energy Generation Potential	78,840 kWh/year

Note: ** The plant factor is assumed only 50% due to the main purpose as for irrigation. It might not be enough of water supply for summer and plant season.

6.3 Estimation Costs of the Project

Costs estimate on rehabilitation for Nam Pha MHP are based on the cost reference for Small hydro Power Plant in the Northern Laos [10] and from information from various manufactures, which have experience with EGAT. All cost estimation are based on 2005 price project and 2007 for planning of construction.

6.3.1 Cost Category

The estimation cost has been broken down in to major items as follows :

1) Mechanical equipment

The costs of mechanical equipments consist of turbine runner, governor, inlet valve and auxiliaries. It was estimated as term of lump sum cost.

2) Electrical Equipment

The cost of electrical equipment, i.e., generator, main transformer, power plant equipment and station auxiliaries was estimated based on lump sum cost

3) Transmission Line

The 22kV distribution line system is selected for this project, with 1.0 km long from power station to the village connect to step-down transformer and to (22/0.4 kV) distribution line.

4) Civil work

The civil work include intake, powerhouse and tailrace canal. The cost of civil work was estimated based on the information obtained from the previous project in Lao PDR [10].

5) Piping Work

The costs of piping work include steel pipe and support. It is estimated based on the quantity of pipe with the total length of pipe from the intake to turbine.

6) Miscellaneous/Overhead Cost

For estimation of the total project cost, the indirect miscellaneous costs shall be added to estimate direct construction cost. It was roughly estimated by taking 10% the project cost [10].

6.3.2 Estimation Costs

The cost of each item for the rehabilitation the existing Nam Pha MHP of (18 kW) is shown in table 6.2 (The details of estimation cost sees appendix C, Section C.3.2).

Table 6.2 Summary the Estimation Costs for rehabilitation the existing Nam Pha MHP project.

No.	Items	Total Amount (US$)
I.	Mechanical Work*	
1)	Turbine auxiliary and control system (set)	17,800
	Sub Total	17,800
II.	Electrical Work	
1)	Generator Control System *	6,840
2)	Main Transformer** (set)	6,000
3)	Distribution Line (1.0 km long)**	10.000
	Sub Total	22,840
III.	Civil Works**	9,064
IV.	Piping Work***	
1)	Water pipe (Type Steel)	84,670
2)	Pipe Support	12,700
	Sub Total	97,370
	Total equipment cost	147,074
V.	Miscellaneous (10%)	14,707
	Grand Total	161,781

Note: * Estimation Cost based on the Unit Cost reference (US$/kW) work sheet of Hydro e-KID (See appendix D, table D.3)

** Cost of civil work includes cost of intake wall, powerhouse and tailrace and estimated cost are based on cost reference of Small hydropower plant project in Northern Province of Lao PDR [10].

*** Cost of piping work is taken from computing by using the standard pipe diameter [22].

6.4 Economic Analysis

According to the technical assumption Nam Pha MHP project could entirely produce the average energy of 78,840 kWh/year. The minor extraction due to the maintenance shutdown, station service and other activities was included in calculation.

The average import tariff of at 22 kV level from PEA that is approved by the government of Lao PDR, is the monetary concerns of project and is used for economic assessment.

6.4.1 Economic Criteria

Discount cash flow technique is adopted, considering the factor i.e. Benefit -Cost ratio (B/C), Net Present Value (NPV) and the Internal Rate of Return (IRR).

The criteria are following :

1) Economic life of hydropower project is 20 years,

2) Discount rate 10% recommended by the Study on Small hydropower plant in Northern Laos [10],

3) The electricity tariff is 0.0563 US$/kWh, referring and import tariff from PEA Thailand [6], and

4) Operation and Maintenance (O&M) cost is included the operation cost that is taken 1% of project cost and yearly inspection that taken by 0.5 % of civil work, 1.0 % of mechanical and electrical work of capital costs applied annually. The cost of spare parts is taken 1.5 % of mechanical equipment and electrical equipments applied in every five years [12]. They are summarized in table 6.3.

Table 6.3 Summary the Operation and Maintenance Costs.

No.	Work Items	Frequency (Year/ time)	Total Amount (US$)
I.	Operation cost 1.0 % of project cost	-	1,617
II.	Yearly inspection cost*	1	839
1)	0.5 % of Civil work and Piping work	-	532
2)	1.0 % of Mechanical and Electrical work	-	406
III.	Cost of Spare part (1.5 % of Mechanical and Electrical equipments)	5	609

Note: * Cost of O&M is increased as a shifted gradient at inflation rate 4.5% and applied annually.

The economic criteria of the project are summarized in table 6.4.

Table 6.4 Summary of the economic criteria for rehabilitation Nam Pha MHP.

No.	Items	Unit	Indexes
1)	Project life	Year (s)	20
2)	Electricity Tariff	US$/kWh	0.0563
3)	Operation and Maintenance cost	US$/year	2,555
4)	Inflation Rate**	%	4.5
5)	Discount rate	%	10

Note: ** Inflation rate 4.5% is the average rate for the last 3 years reported by Bank of Lao, 2007 [3].

6.4.2 Economic Cash Flow

The economic cash flow for rehabilitation Nam Pha MHP project is summarized by the overall cost estimation and economic criteria in table 6.4. It is shown in table 6.5.

Table 6.5 The economic cash flow for rehabilitation Nam Pha MHP Project.

Year	Cost of Project (C)			Benefit			Net Cash Flow (B+C) (US$)	Discount factor at discount rate 10%	NPV of Net Cash Flow (US$)
	Capital Cost (US$)	Cost of O&M		Energy generation potential					
		Yearly Inspection (US$)	Spare Parts (US$)	(kWh/year)	Price (US$/kWh)	Amount (US$)			
0	(161,781)						(161,781)		(161,781)
1	-	(2,555)		78,840	0.0563	4,439	1,884	0.909	1,712
2	-	(2,670)		78,840	0.0563	4,439	1,769	0.826	1,462
3	-	(2,790)		78,840	0.0563	4,439	1,649	0.751	1,239
4	-	(2,916)		78,840	0.0563	4,439	1,523	0.683	1,040
5		(3,047)	(609)	78,840	0.0563	4,439	783	0.621	486
6	-	(3,184)		78,840	0.0563	4,439	1,255	0.564	708
7	-	(3,327)		78,840	0.0563	4,439	1,111	0.513	570
8	-	(3,477)		78,840	0.0563	4,439	962	0.467	449
9	-	(3,633)		78,840	0.0563	4,439	805	0.424	341
10		(3,797)	(609)	78,840	0.0563	4,439	33	0.386	13
11	-	(3,968)		78,840	0.0563	4,439	471	0.350	165
12	-	(4,146)		78,840	0.0563	4,439	292	0.319	93
13	-	(4,333)		78,840	0.0563	4,439	106	0.290	31
14	-	(4,528)		78,840	0.0563	4,439	(89)	0.263	(24)
15		(4,732)	(609)	78,840	0.0563	4,439	(902)	0.239	(216)
16	-	(4,945)		78,840	0.0563	4,439	(506)	0.218	(110)
17	-	(5,167)		78,840	0.0563	4,439	(728)	0.198	(144)
18	-	(5,400)		78,840	0.0563	4,439	(961)	0.180	(173)
19	-	(5,643)		78,840	0.0563	4,439	(1,204)	0.164	(197)
20	-	(5,897)		78,840	0.0563	4,439	(1,458)	0.149	(217)
								Total	(154,552)

Results:

Discount Rate	10 %	NPV :	(154,552) US$
Electricity tariff	0.0563 US$/kWh	IRR :	- %
Energy generation	78,840 kWh/year	B/C Ratio :	0.19
	4,439 US$/year	Payback Period :	- Year(s)
Initial Investment	161,781 US$	Unit Energy Cost :	0.2866 US$/kWh

6.5 Results and Discussion

From the study section 6.2.3, for the selection the suitable pipe diameter and turbine type, it was found that there are no suitable turbine types for head lower than 5m and the maximum flow rate 0.58 m^3/s and pipe diameter 478 mm. Therefore, the project is technically infeasible. The further study was conducted to reduce the head loss by expansion pipe diameter. It was indicated that when the pipe diameter was expanded, the major cost of the project is a piping work (See table 6.2) while the power output is a minimal increment. The economic analysis results for rehabilitation Nam Pha MHP project was shown in table 6.6

Table 6.6 The economic analysis results for rehabilitation Nam Pham MHP project.

No.	Descriptions	Result	Unit
1)	Project cost	161,781	US$
2)	Energy production	78,840	kWh/year
3)	Net Present Value (NPV)	(154,552)	US$
4)	Benefit-Cost ratio (B/C)	0.19	
5)	Payback Period	-	Year (s)
6)	Internal Rate of Return (IRR)	-	%
7)	Unit Energy Cost	0.2866	US$/kWh

From the economic analysis results shown in table 6.6, it was indicated when the discount rate at 10%, an electricity tariff 0.0563 US$/kWh and the potential energy generation was 78,840 kWh/year .While the economic project life was 20 years period, the Net Present Value (NPV), the Benefit-Cost ratio (B/C), of this project equal to (166,499) US$, 0.14, respectively. The Unit Energy Cost that was 0.2866 US$/kWh, was greater than the internal tariff charge of EDL by six times. Therefore, the project was not economically acceptable.

6.6 Conclusion

The result of the feasibility study can be concluded as follows :

1) The rehabilitation of project is done by modifying the plant structures. It is not technically and economically feasible due to a very low elevation between the intake and the powerhouse that the effective head is only 4.56 m. It is therefore a very low energy production potential.

2) The installed capacity potential is 18 kW. The annual energy generation potential from the project is approximately 78,840 kWh/year,

3) The new 22kV distribution line will be 1.0 km long,

4) The total project costs is 161,781 US$/18 kW,

5) The results of economic analysis based on an average import rate form PEA Thailand electricity tariff of 0.0563 US$/kWh and discount rate 10%. It was indicated that, the project is economically unacceptable. The results are summarized as follows :

The Benefit-Cost ratio (B/C)	0.19
Net Present Value (NPV)	(154,552) US$
Unit Energy cost	0.2866 US$/kWh