CHAPTER 4
FEASIBILITY STUDY FOR THE IMPROVEMENT NAM MONG MICRO-HYDROPOWER PLANT

4.1 Introduction

Nam Mong micro-hydropower plant (70kW) was established in 2000 by New Energy Foundation (NEF), Japan and Ministry of Energy and Mining of Lao PDR. It locates in Nam Mong village, Nam Bak district, Luang Prabang province. It is an isolated system with dummy load governor function. Since commissioning in year 2000, its electricity generated has been directly sold to seven villages in Nam Bak district where the energy demand is only 65% of its generated energy. The surplus energy is released through dummy load by conversion to heat. However, the electricity demand gradually increases to the end of the year 2005 due to the EDL's grid line that passes through. This means those villages are electrified by both of EDL grid and Nam Mong MHP, and they are almost satisfied with the EDL grid which it is more reliable while electricity tariff is more expensive.

The objective of study is to demonstrate the feasibility study for installation the synchronous system to Nam Mong MHP for connecting to EDL's grid. The surplus of electricity energy was approximately 35 % of real energy generating and will be taken into account to estimate the benefit of the project. The economic key indicators such as NPV, B/C ratio and IRR will be used to evaluate the project viability.

4.1.1 Project Descriptions

Nam Mong MHP locates in the middle of Nam Mong river in the Northern part of Luang Prabang province. From Luang Prabang city center, Route No. 13 North and No.1 to Oudomxay province are available for access to the site, taking 2 hours by car. Nam Mong river is a relatively small river that is more of the tributaries of Nam Khan river. For more information is shown in appendix A, Section A.2.

NAM MONG MICROHYDROPOWER PLANT

Figure 4.1 The overview of Nam Mong MHP.

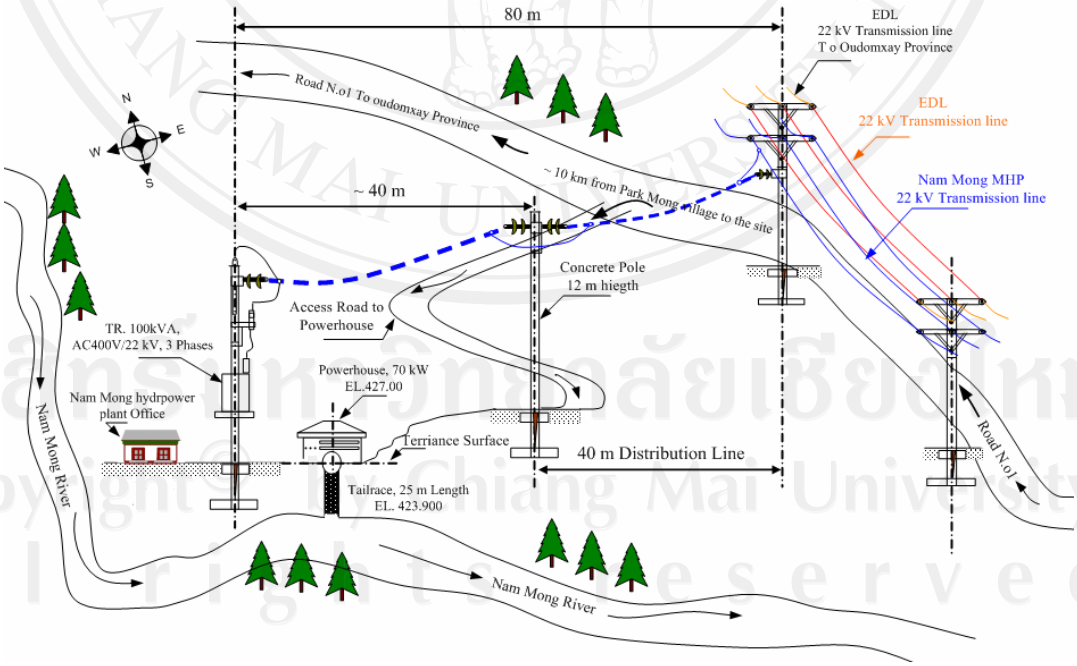

Figure 4.2 The electricity supply schematic of Nam Mong MHP.

4.1.2 The Energy Generation Status

From the data record of energy generating capacity of Nam Mong MHP, it was found that the surplus energy was released to dummy load by conversion to heat due to the energy demand that was only 65% of real energy generating. The situation of energy generation and energy demand is summarized in the table 4.1.

Table 4.1 Annual energy situation of Nam Mong MHP.

Year	Energy (kWh/year)		
	Generation	Demand	Surplus
2002	185,655	122,690	62,957
2003	176,250	111,653	63,976
2004	173,510	114,180	58,132
2005	217,830	148,461	69,223
2006	219,249	138,931	74,353
2007	152,893	95,189	65,385
Average	185,809	121,620	64,086

Source: Nam Mong MHP [15].

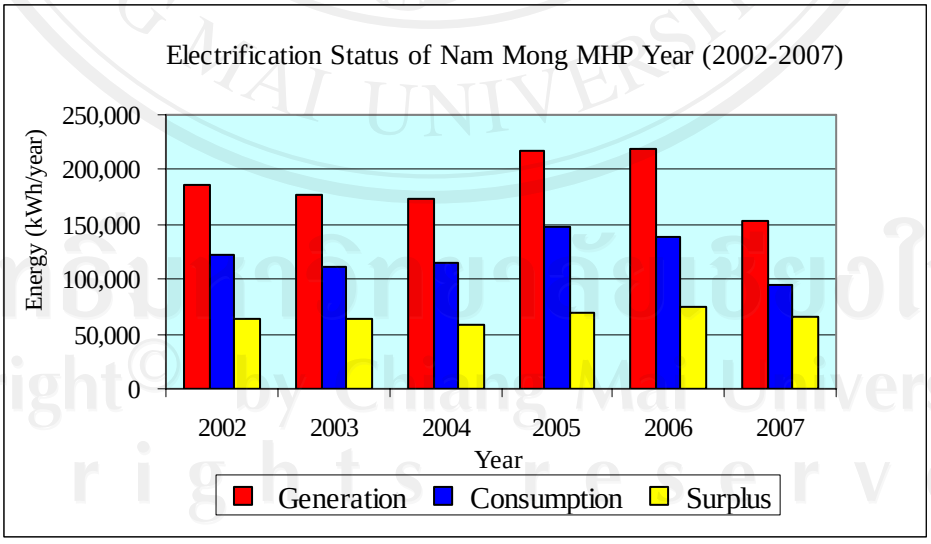

Figure 4.3 The electrification status of Nam Mong MHP.

1) Plant Factor of Nam Mong MPP

As seen in table 4.1, an average of real energy generation of Nam Mong MHP by the year (2001-2007) is very low comparison by the maximum energy generation capacity of (70 kW x 8760 hrs = 613,200 kWh/year). Plant factors of Nam Mong MHP by the (2001-2007) are shown in table 4.2.

Table 4.2 Plant Factor of Nam Mong MHP.

Year	Energy generation (kWh/year)	Plant Factor (%)
2001	175,274	29%
2002	185,655	30%
2003	176,250	29%
2004	173,510	28%
2005	217830	36%
2006	219,249	36%
2007	152,893	25%
Average	185,809	30.30%

Source: Nam Mong MHP [15].

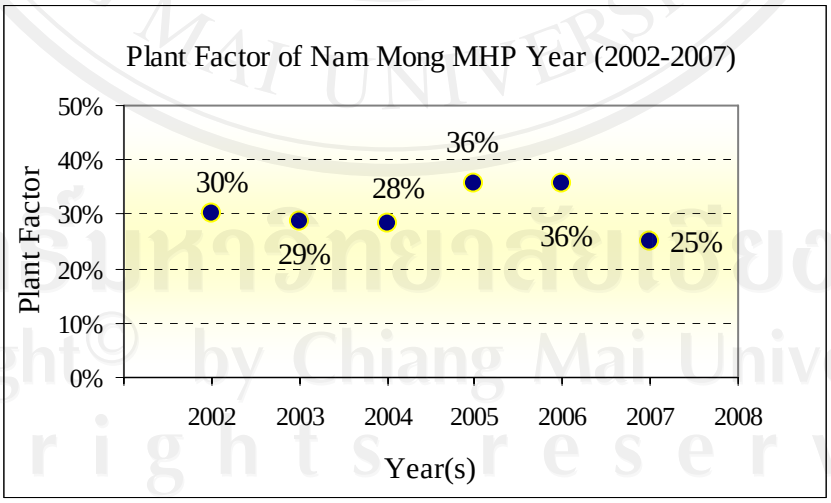

Figure 4.4 Plant Factor of Nam Mong MHP.

As a result, from the table 4.2, it was indicated that the plant factor was very low in comparison to the maximum energy generation capacity.

4.2 The Scope of Study

The study is separated into two particular parts, i.e., (i) it is a technical study and (ii) the economic feasibility study. They are conducted by the following:

4.2.1 Technical Study

The generating facilities and the operation process of Nam Mong MHP which is designed as an isolated grid system are not complicated. The generation plan is shown in the figure 4.5.

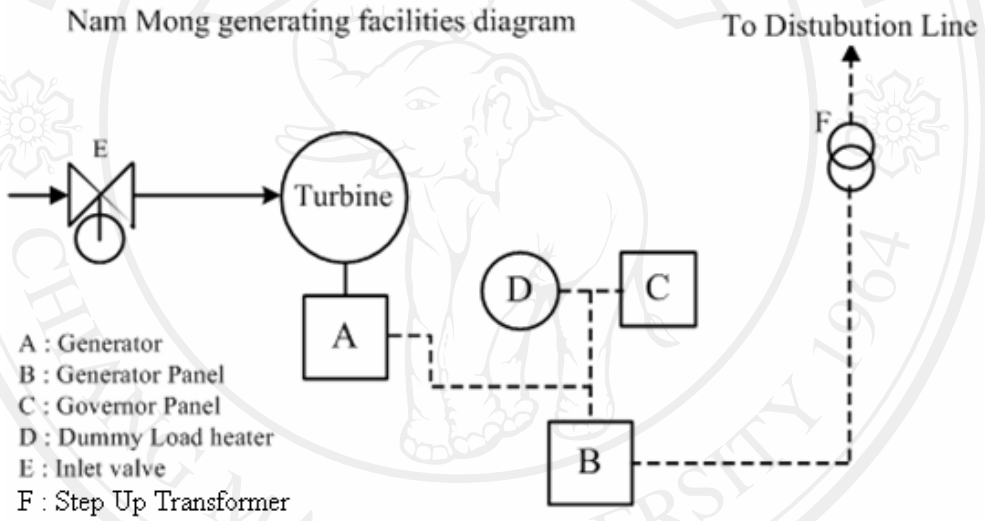

Figure 4.5 The generation plan schematic of Nam Mong MHP.

As seen from the figure 4.5, Nam Mong MHP is designed as an isolated grid system and the details of its plant facilities are shown in appendix A section A.2. The purpose of this study is to improve Nam Mong MHP's grid to connect to EDL's grid system at voltage level 22 kV. However, they have to be the same level voltage for interconnection between two grids known as synchronizing. The synchronizing procedure is explained in the chapter 2 section 2. The particular parts that have to be improved are the electro-mechanical control system such as (i) the synchronous control set with the semi-auto control system and (ii) the protection. However, the synchronous system is to be installed to the project. The electricity energy supply system diagram will be shown in the figure 4.6 and 4.7.

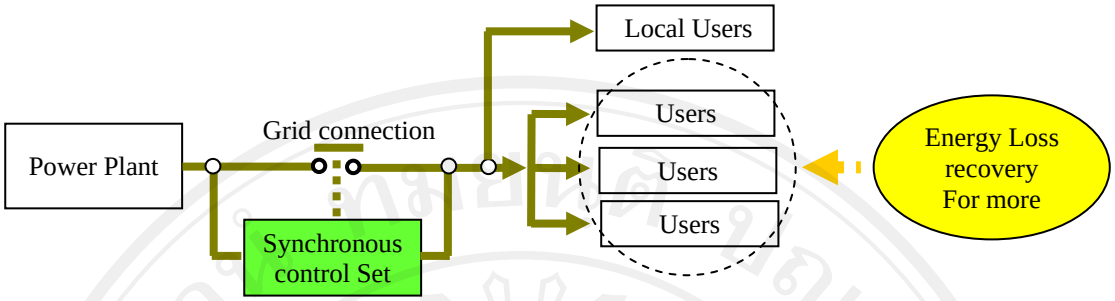

Figure 4.6 The concept of interconnection for Nam Mong MHP gird to EDL grid.

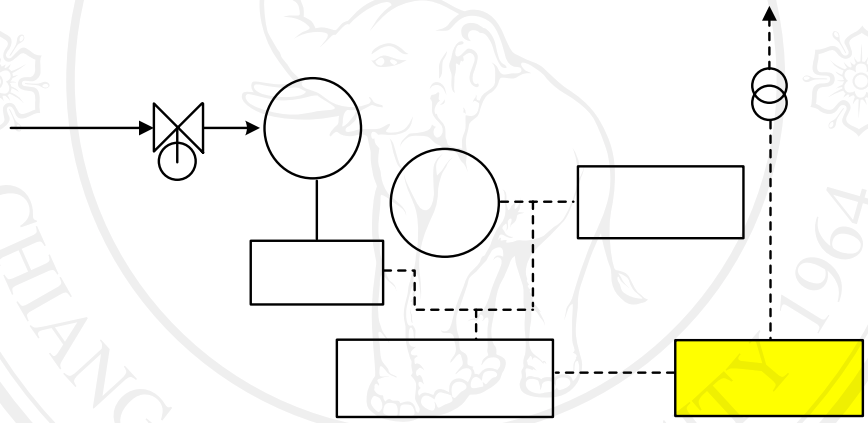

Figure 4.7 The generation plan schematic after Installation the synchronous system.

4.2.2 Estimation Costs of an Improvement for an Installation a Synchronous System

The estimated cost was based on the data from the Analysis of Cost Benefit of Synchronization for Mae Kampong Hydro Power Plant Project 3 to Provincial Electricity Authority (PEA) of Thailand Grid System [17], and from information received from with EGAT and EDL.

1) Cost Categories

The estimated cost has been broken down into major items as follows:

Nam Mong MHP generating facili

After improvement by installation th

system

Inlet Valve

Water Supply

Turbine

D

a) The costs of equipment consist of synchronous component and governor control unit. Theirs cost were estimated in term of lump sum cost.

b) The installation cost of this project is the cost of modification of the control system such as electrical and mechanical control system.

c) Miscellaneous/overhead cost was estimated by taking 10% of equipment cost and installation cost [10].

The overall costs estimation of equipment and installation of the project are summarized in the table 4.3. For the details sees appendix A, table A.10 and A.11, section B 3.2 and appendix D, table d.2

Table 4.3 Costs estimation of equipment and installation of an improvement Nam Mong MHP.

No	Items	Indexes (US$)
I. Equipment Costs		
1)	Synchronous System accessories set[1]	3,600
2)	Protection system[1]	1,800
3)	Distribution line (100 m Length)[2]	1,000
	Sub total	6,400
II. Installation Costs [1]		
1)	Electrical work	1,300
2)	Protection and control system	1,300
	Sub total	2,600
Total costs of Equipment and Installation		**9,000**
IV. Miscellaneous (10% of equipments and installation Costs)		900
Grand total		**9,900**

Note: [1] Estimated cost is based on cost reference [17].

[2] Estimated cost is based on cost reference [10].

4.2.3 Economic Study

As a result shown in the table 4.1, Nam Mong MHP produces the average of real energy of 185,809 kWh/year. An average energy surplus is 64,806 kWh/year and it is then directly used to estimate the benefit of the project.

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.

1) Economic Criteria

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

The adopted criteria o the project is following:

a) Economic life of the project is 20 years [16].

b) Discount rate of 10% is recommended by the Master plant Study on small hydropower plant in Northern Laos [10],

c) The electricity tariff of 0.0563 US$/kWh, referred to Import tariff rate from PEA Thailand at 22 kV [6],

d) Operation and Maintenance (O&M) cost is 2.5 % of equipment and installation cost [16]. The operation wage is excluded to calculation. The annual inspection cost is shown in table 4.4.

Table 4.4 Costs of Annual Inspection.

No.	Work Items	Total Amount (US$)
1)	Annual inspection (9,900 x 2.5% of project cost)*	250
	Total	250

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

The technical and economic criteria of the project are summarized in table 4.5.

Table 4.5 Technical and economic criteria of Nam Mong MHP.

No.	Item	Unit	Indexes
I.	Technical Assumption		
1)	Installed Capacity	kW	70
2)	Plant Factor	%	30
3)	Energy surplus	kWh	64,086
4.	Project life	Year (s)	20
II.	Economic Assumptions		
1)	Electricity Tariff	US$/kWh	0.0563
2)	Inflation Rate [1]	%	4.5
3)	Discount rate	%	10%

Note: [1] Inflation rate: 4.5% is the average rate for the last 3 years (Bank of Lao, 2007) [3].

2) Cash Flow of the Project

The economic cash flow of the project is summarized by the overall cost estimation and economic criteria. It is shown in table 4.6 and the details were shown in appendix A, section A.3.

Table 4.6 Net cash flow of Nam Mong MHP project.

Year	Cost		Benefit			Net Cash Flow (US$)	Discount factor at discount rate 10%	NVP of Net cash Flow (US$)
	Investment cost (US$)	Yearly inspection (US$)	Energy (kWh)	Electricity tariff (US$/kWh)	Amount US$			
0	(9,900)					(9,900)		(9,900)
1		(250)	64,086	0.0563	3,608	3,358	0.909	3053
2		(261)	64,086	0.0563	3,608	3,347	0.826	2766
3		(273)	64,086	0.0563	3,608	3,335	0.751	2506
4		(285)	64,086	0.0563	3,608	3,323	0.683	2269
5		(298)	64,086	0.0563	3,608	3,310	0.621	2055
6		(312)	64,086	0.0563	3,608	3,296	0.564	1861
7		(326)	64,086	0.0563	3,608	3,282	0.513	1684
8		(340)	64,086	0.0563	3,608	3,268	0.467	1524
9		(356)	64,086	0.0563	3,608	3,253	0.424	1379
10		(372)	64,086	0.0563	3,608	3,237	0.386	1248
11		(388)	64,086	0.0563	3,608	3,220	0.350	1129
12		(406)	64,086	0.0563	3,608	3,202	0.319	1020
13		(424)	64,086	0.0563	3,608	3,184	0.290	922
14		(443)	64,086	0.0563	3,608	3,165	0.263	833
15		(463)	64,086	0.0563	3,608	3,145	0.239	753
16		(484)	64,086	0.0563	3,608	3,124	0.218	680
17		(506)	64,086	0.0563	3,608	3,102	0.198	614
18		(528)	64,086	0.0563	3,608	3,080	0.180	554
19		(552)	64,086	0.0563	3,608	3,056	0.164	500
20		(577)	64,086	0.0563	3,608	3,031	0.149	451
							Total	17,901

Results:

Discount Rate	10 %	Plant factor (PF):	30 %
Electricity tariff	0.0563 US$/kWh	NPV :	17,901 US$
Energy	64,086 kWh/year	IRR :	33 %
	3,608 US$/year	B/C Ratio :	2.40
		Payback Period :	3.69 Year(s)

Initial Investment 9,900 US$ Unit Energy Cost : 0.0235 US$/kWh

4.3 Results and Discussion

The results of economic feasibility study in case of an installation of the synchronous system to Nam Mong MHP and based on the economic criteria (See table 4.5) were shown in table 4.7.

Table 4.7 The economic results of Nam Mong MH project.

No.	Descriptions	Results	Unit
1)	Project Cost	9,900	US$
2)	Net Present Value of Net cash flow	17,901	US$
3)	Benefit-Cost ratio	2.40	
4)	Payback Period	3.69	Year (s)
5)	Internal rate of return	33	%
6)	Unit Energy Cost	0.0235	US$/kWh

The project was economically acceptable. The economic key indicators such as Net Present Value (NPV), Benefit-Cost ratio (B/C), Internal Rate of Return (IRR) and Payback Period were 17,901 US$, 2.40, 33% US$ and 3.69 years respectively.

Follow the operation data (See table 4.2) when the synchronous system would be set up to Nam Mong MHP. It could be produced more electricity energy. Therefore, the plant factor should be increased. The undoubted result of B/C ratio, and IRR was increased while the Unit Energy Cost was decreased in proportion to the plant factor, and they were shown in the figure 4.8 and 4.9.

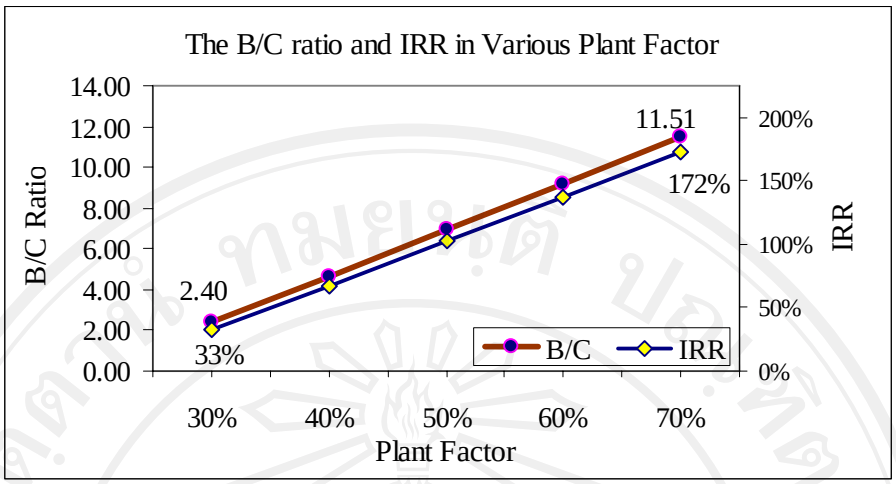

Figure 4.8 B/C ratio and IRR in various plant factors.

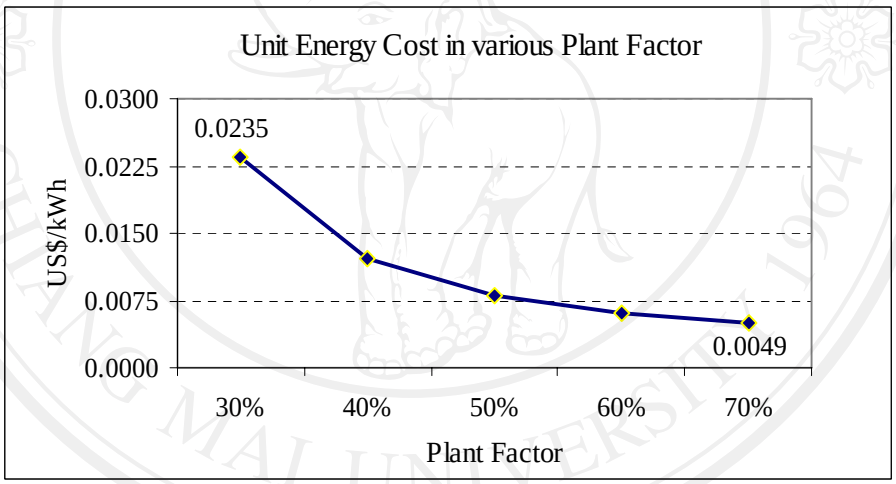

Figure 4.9 The Unit Energy Cost in various plant factors.

4.4 Evaluation of the Project

4.4.1 Economic Evaluation

In order analysis the project, it is based on the economic assumption in the year 2008. While the project might be implanted in the future, it is therefore the cost of the project might be increased because of the inflation rate and the others factor such as the cost of equipment, an installation cost and the expenditure during project implementation. Therefore, the sensitivity analysis is considered by the following:

1) Assumption

The sensitivity analysis, is base on with the following assumption :

- The electricity tariff is 0.0563 US$/ kWh,
- The average energy generation capacity is 64,086 kWh/Year,
- The project cost is 9,900 US$.

To evaluate the sensitivity of NPV, B/C and IRR by varying

a) The sensitivity NPV, B/C and IRR to discount rate variation

- The discount rate is the parameter of interest,
- Selected 8% 10% 12% and 15% increment.

The results of sensitivity of the project is shown in the figure 4.10 (The details see appendix A, Section A.4)

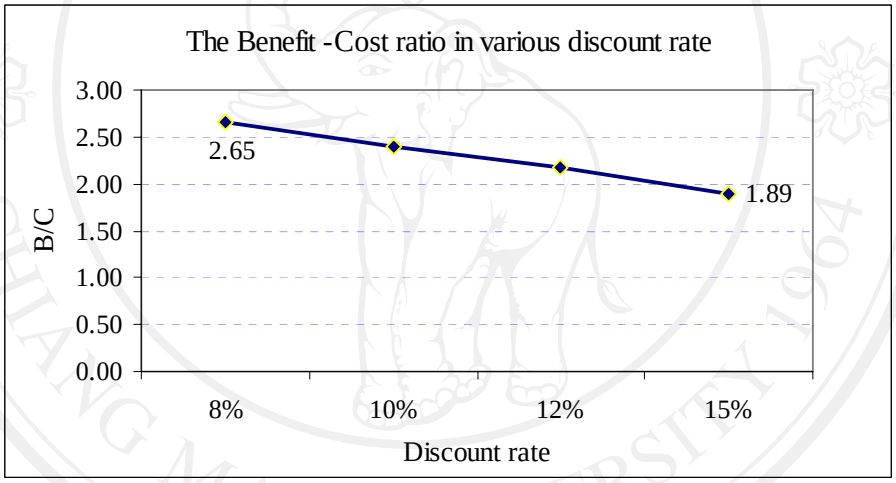

Figure 4.10 The Benefit-Cost ratio in various discount rate.

As seen in figure 4.10, the discount rate of this project was increased (8%, 10%, 12% and 15%), the B/C ratio was reduced but it was greater than 1, and also the units energy cost was lower than 0.0563 US$/kWh. Therefore, the sensitivity analysis in term of variation of discount rate in range (8%-15%) indicated that the project was economically acceptable.

b) The sensitivity of NPV, B/C and IRR to project cost variation.

- The project cost is the parameter of interest,
- Selected 10% increment to evaluate sensitivity to the range is 10% to 50% of project cost 9,900 US$,
- Set up discount rate (*r*) at 10%.

The results of sensitivity of the project by increment the project cost is shown in the table 4.8 (The details see appendix A, Section A.4)

Table 4.8 Results of economic evaluation by increment the project cost.

Cases	Project Cost (US$)	Net Present value (US$)	B/C ratio	IRR (%)	Unit Energy Cost (US$/kWh)
Base case	9,900	17,901	2.40	33%	0.0235
10%	10,890	16,911	2.22	30%	0.0253
20%	11,880	15,921	2.08	28%	0.0271
30%	12,870	14,931	1.95	25%	0.0289
40%	13,860	13,941	1.83	23%	0.0307
50%	14,850	12,951	1.73	22%	0.0326

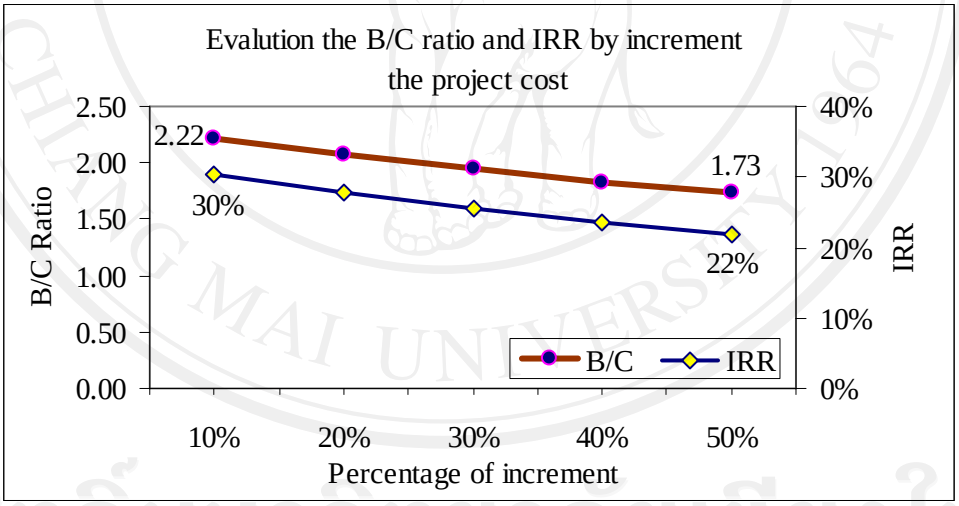

Figure 4.11 Evaluation the B/C ratio and IRR by increment the project cost.

As seen in table 4.8 and figure 4.11, it indicated that although the project cost was increased 10%, 30%, 40%, and 50% respectively, based on the base case at discount rate of 10% and electricity tariff of 0.0563 US$/kWh, the B/C ratio was greater than 1 and the minimum of IRR was 22% and unit energy cost was 0.0326 US$/kWh when the project cost was increased to 50%. Therefore, it was justified that the project was also economically acceptable.

4.4.2 The Recovery of Energy Generation Potential of the Project

As the results shown in figure 4.8 (See details in table A.6), Plant factor is influence to the benefit of the project. However, this project could entirely produce the average energy of 185,533 kWh/year from its maximum energy generation potential of 613,200 kWh/year. The plant factor seems to be very low. To improve the plant factor of project, the major and minor categories that effects to plant factor such as the trouble plant facilities, demand, water supply and other activities was considered by using the Cause-Effect analysis technique shown in the figure 4.12.

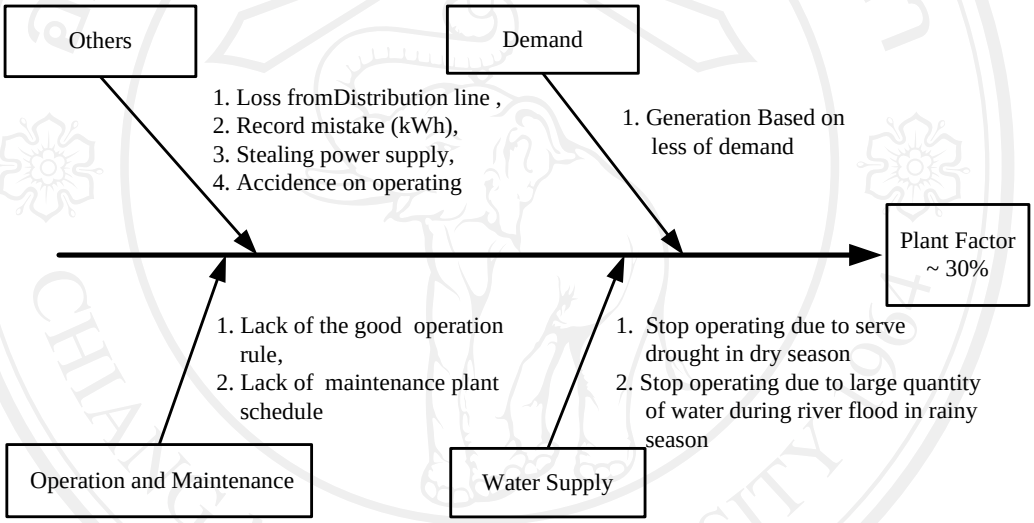

Figure 4.12 Cause-Effect analysis.

From figure 4.12 and the operation data recorded by the years 2006 and 2007, it was a similar pattern since commissioning 2000. The causes that effects plant factor (in comparison to the maximum energy generation capacity 70 kW x 24 hours x 365 days = 613,200 kWh/year) were summarized in table 4.9 (details sees appendix A, table A.7).

Table 4.9 Summary of annual energy generation capacity.

No.	Cause-Effect	Energy Capacity	
		(kWh)	(%)
1)	Reality annual energy generating	185,553	30.26%
2)	Energy Loss due to low Generated capacity in the condition of demand less than Supply	416,093	67.86%
3)	Maintenance	1,750	0.29%
4)	Water supply trouble	7,632	1.24%
5)	Others	2,172	0.35%
Total		613,200	100%

Source: Nam Mong MHP energy record (2006 and 2007).

Form the table 4.9 it was found that, the potential loss was 67.86 % or 416,093 kWh/year can be recovered. The loss was due to the low generated capacity in the condition by which the demand is less than supply. Minor loss extraction due to maintenance shut down water supply trouble and others activities are excluded for further calculation the energy recovery.

From the recommendation of the hydropower plant theory, the small and micro-hydropower plant that was a Run-of-River type could entirely gain the maximum generation capacity at plant factor of 70% of installed capacity (See chapter 2, table 2.5).

1) The potential annual energy generation is shown in table 4.9

(416,093 kWh/year + 185,553 kWh/year) = 601,606 kWh/year.

2) The annual energy generation at plant factor 70% is

70 kW x 24 hours x 365 days x 70 % = 429,240kWh/year.

As a result, the potential energy generation of 601,606 kWh/year is greater than the energy generation of 429,240 kWh/year at plant factor 70%. Therefore, energy potential recovery of 307,887 kWh/year is available. (Taken from the energy production potential of 429,240 kWh/year minus the energy demand of 121,353 kWh/year, See table 4.1) is shown in figure 4.12.

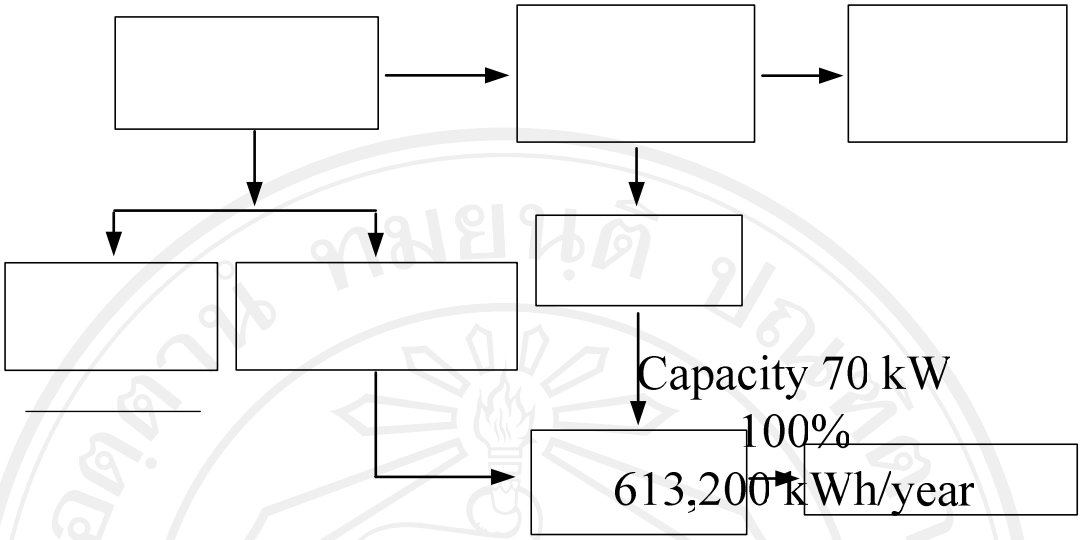

Figure 4.13 The energy recovery potential of Nam Mong MHP.

Similar to the previous economic analysis criteria were used such as the project life is 20 years, discount rate was10% and electricity tariff is at 0.0563 US$/kWh. The results of economic viability were expressed in the table 4.10 (See details in appendix A table A.9)

Table 4.10 Results of economic analysis with the maximum of energy recovery potential of Nam Mong MHP Project.

No.	Descriptions	Results	Unit
1)	Project Cost	9,900	US$
2)	Net Energy Recovery	17,354	US$
3)	Net Present Value	134,758	US$
4)	Benefit-Cost ratio	11.51	
5)	Payback Period	0.64	Year (s)
6)	Internal rate of return (IRR)	172%	%
7)	Unit Energy Cost	0.0049	US$/kWh

As seen in table 4.10 the results of B/C ratio was double increased compared to the first results. The IRR is greater than 100% while Unit Energy Cost was at 0.0049 US$ /kWh. It was lower than the import tariff rate at 22 kV from PEA Thailand which means the project could get more profit when the synchronous system would be

installed to Nam Monh MHP. The payback period was less than a year. It takes short period to recover the initial investment at discount rate 10%.

4.5 Conclusion

The results of feasibility study for installation the synchronous system to Nam Mong MHP can be concluded as follows:

1) Connection of Nam Mong 22 kV grid to the EDL grid is technically and economically feasible,

2) The install capacity of 70 kW and an average of the reality energy generation of 185,809 kWh/year, energy surplus that of 64.086 kWh/year directly concerns to assess the economic of the project,

3) The total project cost is 9,900 US$,

4) The results of economic analysis indicated that the project is economically attractive with an average import rate form PEA Thailand electricity tariff of 0.0536 US$/kWh and is summarized as follows :

Internal Rate of Return (IRR)	33%
Benefit-Cost ratio (B/C)	2.40
Net Present Value (NPV)	17,901 US$
Payback period	3.69 years
Unit Energy Cost	0.0235 US$/kWh.

The synchronous system with the Semi-Auto control system is necessary for Nam Mong micro-hydropower plant with the installed capacity of 70 kW to connect to the EDL's grid region.