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Investment cost analysis for electricity generation with renewable energy and measurement of water pressure from weir to water conservation of small hydropower project

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Abstract

This research paper presents to study and analyzed the cost economics, for an investment to produce electricity with renewable energy of water from weir, and measurement of water pressure due to water conservation of community village area. In case study of the hydropower plant project, amphoe Makham, Chanthaburi province in Thailand, which this research will be design and test for electricity generation from hydropower, will be the real testing weir and considering based on the economics cost estimation. Analysis of economic and financial with selective approach to research and development projects that is appropriate to the economy. Thus, evaluation of economics cost indicators including the calculation of net present value, internal rate of return of this project (IRR), analysis of return on investment, benefit-cost ratio (B/C), average incremental costs or cost of energy, pay- back period time and cash flow value, etc. The results of measurement from water pressure and analyze the cost economics are will enough to bring to produce the electricity. The hydropower turbine size 7 MW have potential in electricity production is 38.45 GWh/year for economics evaluation meets that can payback get in period time is 12 year 5 month, the benefit-cost ratio on the investment is 1.34 and yield of the project or internal rate return to 13.28 %.

Keywords: Renewable energy; investment; electricity generation; water conservation; hydropower

1. Introduction

Hydropower is a renewable energy source to very important for the electricity production. This method of energy used to produce electricity. The dam will create a reservoir off the river bottom and the level is so high that the water content, and a pressure sufficient to bring the water to spin a turbine and generator to produce electricity next. There are also areas which are suitable for the development and potential use of hydropower also include hydropower project of community. The study area has a hydropower potential of small countries. It was found that the potential areas which can be developed as hydropower projects smaller than 25,500 MW and a hydropower plant project from a reservoir of approximately 115 MW [1].

The purpose of this paper is to investment cost analysis and to measure the pressure of water from a weir in the area of hydropower plant project. The need to assess the environmental impact will be include social, economic, cultural and quality indicators of the community, etc. The participation person of the community area and efficient management of the community together in the event of a hydropower plant project, the opportunity for people in the community involved from the beginning of the project informed.

2. The Development of Hydropower

Thailand is policy on small hydropower projects to help people in remote areas. Because of potential

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small hydropower community can be nurtured as well, the supply of electricity in the village itself. It is a path of self-reliance is literally. However, the water energy is the energy source with great potential to reduce the amount of carbon dioxide from electricity generation, and reduce losses of the transmission system. Because will not have to buy fuel to run electricity, reduces the risk of an oil crisis effectively.

3. The Main Components of Small Hydropower Projects

It consists of the following

3.1. Weir or dam catchment

The structure was built weir the river. Serves to irrigate or water in the river to rise and the diversion of water control into the catchment area of the building. The excess water will overflow the weir spillway.

3.2. Intake structure

The concrete structure, which can be do - turn off the water and control water used. It is built along the banks of the river adjacent to the weir water and usually placed in a line perpendicular to the direction of flow of the river, a door to adjust the flow of water to flow to the irrigation system [2]-[4].

3.3. Headrace system

The water is delivered from the mouthpiece to a basin or head tank. Headrace system may include a canal or pipeline. There is usually a slope less stable.

3.4. Fore bay or head tank

Is to control and adjust the amount of water flow with scum removal and sand. Before being sent to pipeline pressure (Penstock), and also help prevent high pressure to cause damage to the water pressure.

3.5. Penstock

Made of steel and can withstand high pressure. Usually placed above ground, but buried in the ground and designed to withstand water pressure and stress, this water pipe to bring water into spin of turbine.

3.6. Hydro turbine

The device serves to receive water from a penstock, is converted into mechanical energy and drive a turbine, which is connected to the generator turbines.

4. An Analysis of Electricity Generation from Hydropower

(a) (b)

Fig. 1. (a) Hydropower generator of the Tapnakorn hydropower plant project, Chanthaburi province in Thailand to power set up 35 kW, speed 1,500 rpm, efficiency 94 %, (b) weir due to water conservation in community village area.

The principle of electricity generation from hydropower is to change the status of the water energy into electrical energy by the difference in the water level above the dam and downstream to the hydro turbine and generator, to generate electricity in during the process of energy transformation. There will be losses of energy occurs, such as the height of the water level, speed of the water flow, stiffness, leakage of water, vibration, friction between the shafts and bearings, etc [5]-[7]. For in Fig, 1 (a) shows devices such as hydro turbine and electricity generator, which can be control of the switch board except the transformer is located outside the building. The optimization of these turbines has enabled the modern axial-flow hydro turbines to reach operating efficiencies of over to 90 %, and in Fig. 1 (b) shows a small dam or weir dam dammed river by the diversion of water from the weir to irrigate the plants with water to produce electricity. The water pressure is enough to rotate the turbine and generator, the downstream with lower levels. Thus, cause is energy and can produce electrical energy.

4.1. Calculate the electric power from the flow rate with hydro turbine

The transition from a hydropower to electric energy by using hydro turbine and generator according to a formula showing the relationship of the potential energy is converted to electrical energy are as follows.

$$P = 9.81 Q_d H_d N_g N_t \tag{1}$$

and

$$E_i = Pt\eta f \tag{2}$$

where P is the electric power (kW), t is the production period (hours), E_i is electrical energy is produced (kWh/year), Q_d is the flow rate of water through the turbine (m^3/s), N_g is the efficiency of the hydro turbine is 0.9, N_t is the efficiency of the generator is 0.97, f is the coefficient for fluctuations in water flow in the river, H_d is the height of water heads were designed or water potential (m) and η is the efficiency of the hydro turbine will be between is 0.5 to 0.9

4.2. Calculate the flow rate of the location project

The calculated flow rate by the average monthly this location of the project is the position of intake for procedure, the ratio of water volume by average per yearly and water volume of the station as follows:

$$Q = \frac{Q_{m}}{Q_{mi}} Q_i \tag{3}$$

where Q is the flow rate by the average monthly at the project site, Q_m is the water volume by average per yearly of the project, Q_{mi} is the water volume by average per yearly of the selected station and Q_i is the flow rate by the average monthly of the selected station [8].

5. Analysis of Economics Cost to Energy Produces

5.1. Electricity cost analysis

The possible economic costs evaluation of to determine the cost of electricity production, as follows:

$$C_e = \frac{C + M - S}{E_i} \tag{4}$$

where C_e is the cost of electricity (USD/kWh), C is the cost of annual investment (USD/year), E_i is electrical energy is produced (kWh/year), M is the economic costs of operations and maintenance hydro machines (USD/year) and S is the investment cost per year (USD/year) at the end of the useful life 10 %.

5.2. Calculate the present worth value

Present worth value analysis over the life of the project. There will be costs incurred during a different time. It must be adjusted to the time difference of the revenue values, consider are given by

1. The money value for present and the money value of the future, when event is paid only once.
2. Find the money value for present revenue or expenses that occur each year.

$$P_m = \frac{F}{(1+i)^n} \tag{5}$$

and

$$P_m = A\left[\frac{(1+i)^n - 1)}{i(1+i)^n}\right] \tag{6}$$

where P_m is the money value of the present, F is the money value of the future, i is the interest rate per year, n is the life of the project for investment is year at n (years), A is the value of money is equal every year and $(1+i)^n$ is interest factor of the project in the adjustment period: n.

5.3. Calculate the payback period

The payback period is to measure the return on investment in a few years it will be paid back [9]. If the payback period is less to projects that fit the investment can be obtained as follows:

$$\text{Payback period time} = \frac{\text{Initialinvestment}}{\text{Theaverage annual net return}} \tag{7}$$

5.4. Calculate the net present value

The net present value (NPV) is the difference between of the revenue and cost expenditure throughout the project. If the NPV value is greater than 0 means the benefits over the life of the project is more than the cost of the project, the average energy efficiency. The principle is that there should be an investment decision. The net present value is positive. Do not invest if the present value is negative, as the following:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t} \tag{8}$$

where B_t is the return value of the project in the year: *t*, C_t is the cost or the investment of the project in the year: *t*, *r* is the discount rate or the interest rate (% per year), *t* is an annual project of the year at 0, 1, 2, …n and $(1+r)^t$ is discount factor of the project in the year: *t*.

5.5. Return on total costs (Benefit cost ratio: B/C ratio)

The ratio of benefits to costs are ratio of the present value of lifetime income and the present value of the project cost throughout the project or are comparison between the present value of the return on the value of present investments and the costs for the following [10]:

$$\text{B/C} = \frac{\sum_{t=0}^{n} B_t (1+r)^{-t}}{\sum_{t=0}^{n} C_t (1+r)^{-t}} \tag{9}$$

In this project, if the B/C ratio greater than 1 means of the return worth the investment that should be invested, if B/C ratio will be less than 1 means the return of project is not worth with an investment loss.

5.6. The yield of the project (Internal Rate Return: IRR)

The yield of the project is the rate of returns on investment, which is the rate that makes the present value of the net revenues of the initial investment amount this of the hydropower plant project as follows:

$$\sum_{t=0}^{n}\frac{B_t - C_t}{(1+r)^t} = 0 \tag{10}$$

and

$$\text{Investment} = \sum_{t=1}^{n}\frac{F}{(1+IRR)^t} \tag{11}$$

The conditions:

IRR > interest rate financing, It also shows that investment of the project is worth the investment.
IRR = interest rate financing, It also shows that investment of the project is possible.
IRR < interest rate financing, It also shows that investment of the project is not worth the investment.

6. Operating Research Methodology

This research analyzed the economics investment of electricity generation using renewable energy of water from weir within the community village area, to study and development for hydropower energy of small hydropower plant project. This project uses the water in the river, which the water level recorded by the station. Data storage of flow between the years 2012-2016, can be explained the process as follows:

6.1. Data collection and operating test

Data is used to conduct this research came from the inquiry and a survey, the quantitative study on the use of energy, performance generator, maintenance and generator installation, operation as follows:

- Study and surveys by the weir water. Initial surveys of water sources and storage weir water in Chanthaburi province, which into the area in several communities, to be a part of the information used in the evaluation of small hydropower [11]-[13].
- Design builds a hydro turbine and hydro generator. Design and test water turbine using a turbine at the lower level of the water. The hydro generator uses permanent magnetic. The design created using wind energy to solve water pressure not consistent.
- Testing and assembly equipment in each section. Modify and make changes to improve, when assembled test kits can be used for the purposes set. Using generators to test the water weir overflow to compare the results obtained with the calculated values in theory.
- Measurement of water pressure due to water leakage, when the concrete lining resulting from above seepage analysis for water conservation of community village area [14].

6.2. Quantitative data analysis

An analysis to determine the suitability of investment projects on the basis of cost and benefit. By the costs and benefits compared to an adjustment of the time. The sensitivity analysis of this project, because the next future is uncertain forecasting the economic costs and benefits of future projects often take place during uncertainty. It has many causes, such as the cost of inputs and benefit changes. This research paper using of hydro turbine test is 2 units [15]. It was given four choices are 5, 7, 9 and 12 MW that would be the most appropriate choice, can be as shown in Table 1. Thus, consider diagram to concept idea structure of operating renewable energy from water for electricity power generation as shown in Fig. 2, which this diagram structure of operating renewable energy from water. Weir serves to irrigate water in the river to a higher level and water level control. Water that has been classified as a separate debris from the weir, this water pipe or penstock to bring water to spin turbines in the next. The hydropower generator is device serves to receive water from a penstock, is converted into mechanical energy and drive a water turbine, which is connected to the generator turbines to produce electricity with power distribution control panel. And transformer to convert the voltage level with distribution power system for the transmission lines to electricity user, building, home and the community village area [16]-[18].

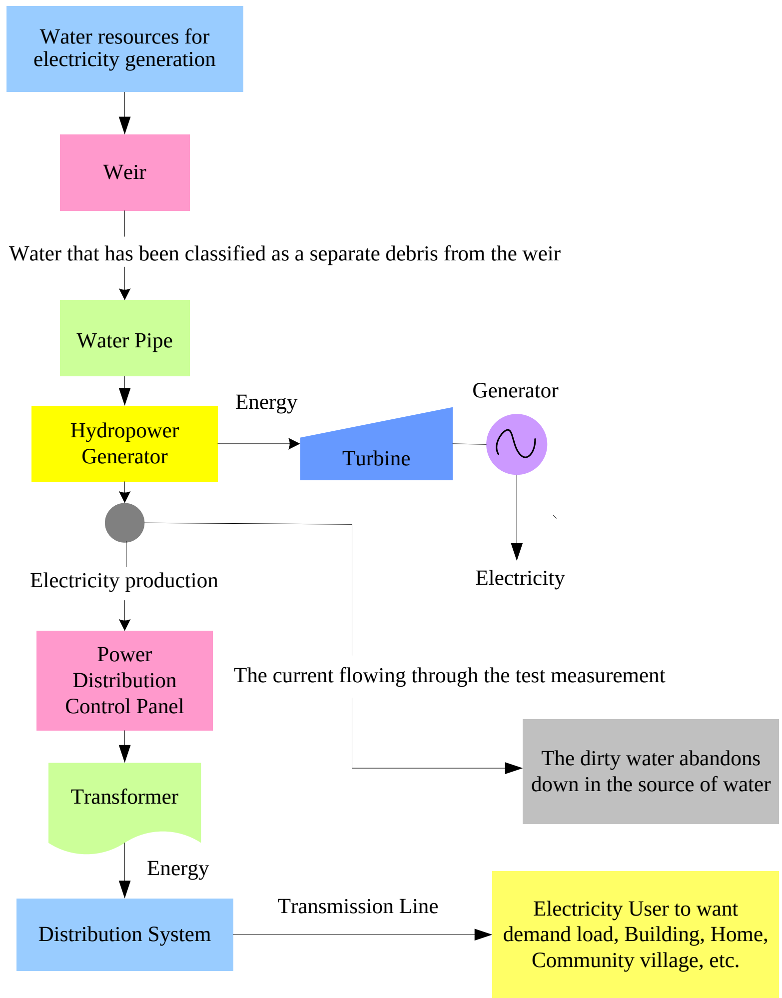


Fig. 2. Diagram to concept idea structure of operating renewable energy for electricity generation to the community.

7. Research Result

The result of hydro turbine and hydropower generator testing of this project, to measuring the speed of rotation of the turbine, can be increase the efficiency of the turbine and generator sets, calculate the flow rate of water, calculate the net head of intake to 2-4 m and calculate the potential of electricity generation. Results of cost and benefit analysis of electricity generation. Considering the electrical energy result in Table 3 shows that in month January to December, years 2012-2016. The electrical energy will have that different very. Because the rainfall that agree to come to in each month have rough amount. In this study the efficiency of the turbine is constant at around to 94 %, the discharge of water from the weir more. The percentage the flow rate is very valuable, this more efficient hydro turbines as well. The study reveals that the four choice between will be 7 MW is the best choice. Because of lower costs to 28,346.40 USD/year as shown in Table 2, the return of this project was most appropriate. For in Table 1 shows the result of payback period of the lowest is 12 year, 5 month. The net present value to 9,534.82 USD, and the ratio of benefits to costs by approximately 1.34, the yield of the project or internal rate return to about 13.28 %, the hydropower generator can be electricity generation is 38.45 GWh/year as shown in Fig. 3 and Fig. 4.

For in Fig. 5 shows result of distribution measurement for water pressure head around tunnel due to water leakage, (a) the result from measurements made with the water pressure is very high, (b) the result from measurements made with lower water pressure as well, due to water conservation of community village area for small hydropower project. Because water pressure drop due to the more or less pervious lining. The eventually grouted zone around the tunnel is beneficial in reducing the permeability of the rock and producing an additional water pressure drop at distance tunnel from 5 m to 47 m.

Table 1. The result of financial return of an investment in the choice of projects from hydro turbines

Return value of an Investment	5 MW	7 MW	9 MW	12 MW
Net present value: NPV (USD)	2,680.45	9,534.82	-5,342.31	5846.20
Internal rate return: IRR (%)	6.36	13.28	-1.26	9.45
Ratio of benefits to costs: B/C	1.02	1.34	0.36	1.25
Payback period time (year)	18.7	12.5	20.9	23.4

Table 2. The result of investment cost analysis of small hydropower project, Chanthaburi province in Thailand

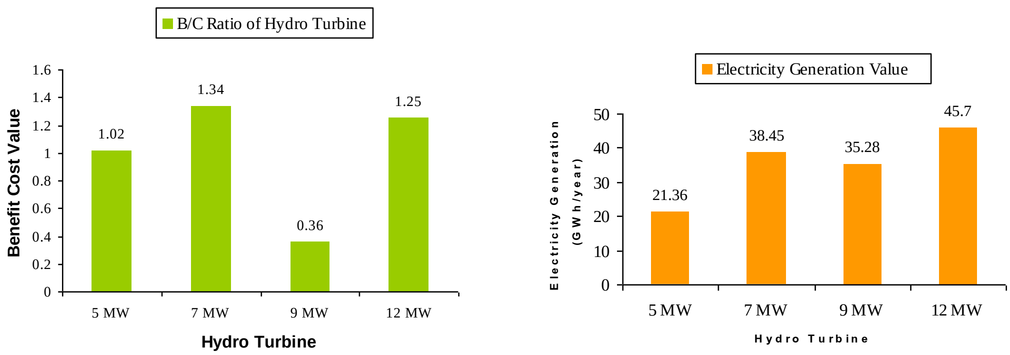
Investment Cost	5 MW	7 MW	9 MW	12 MW
1. The cost of civil work	6,437.52	5,368.26	6,936.84	7,439.32
2. Electrical material prices	5,836.90	3,120.85	6,851.62	6,980.54
3. The cost of project management	9,135.46	4,513.54	7,645.35	8,456.37
4. Staff engineer wages	8,956.38	8,956.38	8,956.38	8,956.38
5. Staff control and Lab test	3,421.50	3,421.50	3,421.50	3,421.50
6. The cost repair and maintenance machines	4,953.74	2,965.87	5,163.91	6,543.26
Total	38,741.50	28,346.40	38,975.60	41,796.37

Note: Unit is USD/year

Table 3. The results of the analysis for hydro generator to electrical energy generation have calculated monthly

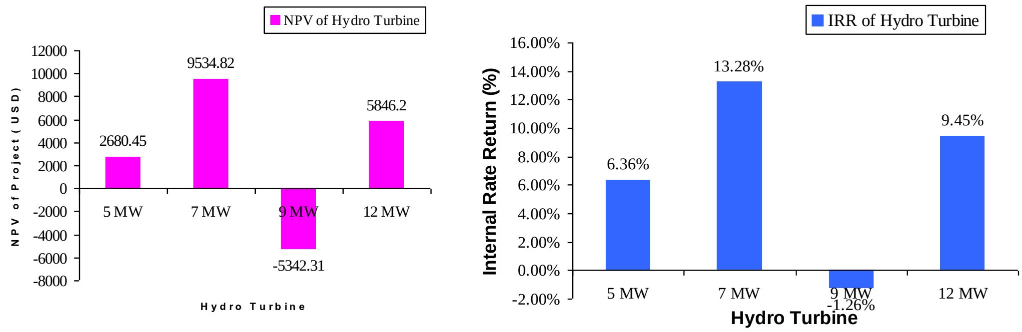
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2012	0.356	0.192	0.187	0.253	0.534	0.728	3.109	5.426	3.872	2.21	1.28	0.64	18.79
2013	0.452	0.297	0.263	0.354	0.823	1.542	2.374	3.580	4.850	1.97	0.85	0.49	17.85
2014	0.328	0.331	0.196	0.257	0.641	1.289	1.862	2.918	2.267	1.02	0.74	0.37	12.23
2015	0.254	0.159	0.162	0.216	0.412	0.356	2.419	6.203	5.123	1.95	1.03	0.56	18.84
2016	0.346	0.282	0.275	0.426	0.825	0.974	1.280	1.536	1.302	0.94	0.98	0.87	10.05

Note: Unit is GWh/month



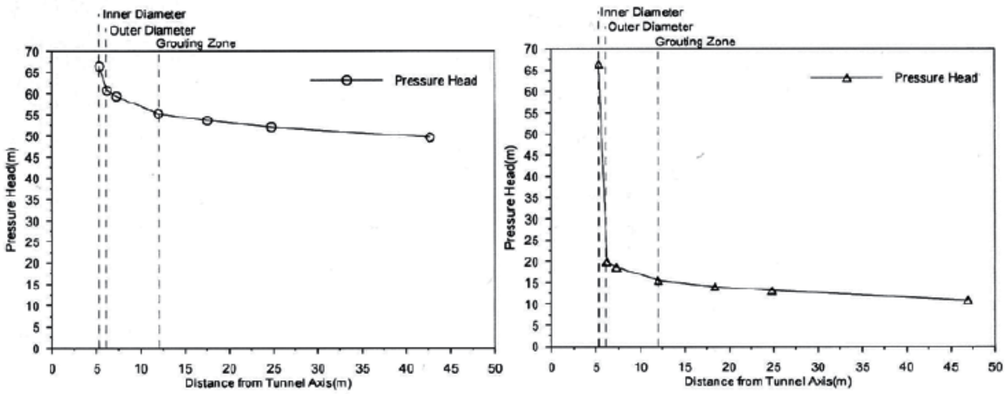
(a) (b)

Fig. 3. (a) Results of the benefit cost ratio (B/C Ratio) due to investment cost analysis, (b) the results of electricity generation from hydro turbine of the hydropower plant project.



(a) (b)

Fig. 4. (a) Results of the net present value (NPV) from hydro turbine due to investment cost analysis, (b) the results of the internal rate return value (IRR) from study of the hydropower plant project.



(a) the water pressure is very high (b) the water pressure is lower

Fig. 5. Results of distribution measurement for water pressure head around tunnel due to water leakage.

8. Conclusion

The result from investment cost analysis, when consider of this project to electricity generation using the hydropower generator and hydro turbine with renewable energy of water from weir, found that the economic value worth, for the positive impact on society is include the benefits to the environment. An investment cost analysis is a comparison between revenues and expenditures that. If revenues exceed is higher than expenditure, show that the investment is worth it. If the rate of return higher than the interest rate of its investments is to invest otherwise. And higher interest rates will mean that investment returns at a rate incentive measure. For seepage analysis is conducted for both permeability of cracked concrete, in order to predict the water losses through the lining taking account of the cracked concrete lining, grouted zone on water pressure in surrounding rock mass, which overburden above the headrace tunnel due to water leakage from the concrete lining result from above seepage analysis. The permeability of the rock mass defines the further drop in pressure. It is immediately cleared that the ratio of the permeability of the lining to that of the rock mass plays a determinant role in the distribution of the water pressures around tunnel. The results of the distribution measurements for water pressure head that cause water leakage was a little tube tunnel at slope is 7 m to 12 m.

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