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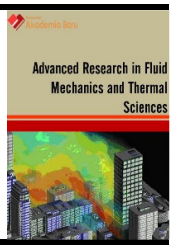

The Potential of Micro Hydro Generator Embedded at 100,000PE Sewerage Treatment Plant

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ABSTRACT

A micro hydro generator is a hydroelectric generator which generates electricity from 5kW to 100kW by using the natural water flow. Micro hydro generator altered the potential energy to an electrical energy. This research desired to be implemented by using a micro hydroelectric generator which is embedded at the continuous flow of effluent discharge point domestic Sewerage Treatment Plant (STP). This research evaluates the potential of electricity generation from micro hydroelectric generator attached to a 100,000PE Sewerage Treatment Plant based on the power output obtained from calculation of electrical power. Other than that, this research also focused on the relative range in measurement of head of the micro hydroelectric generator and average flow rate that can be suited to install in STP and the overview of micro hydroelectric generator on the actual application with the consideration of payback period is summarized. The ultimate aim of the whole application is to have a self-ecosystem electrical power generated for the internal use of STP by using its own flowing water in supporting the sustainable engineering towards renewable energy and energy efficient approach.

Keywords:
Micro Hydro Generator, Sewerage Treatment Plant, Electrical Energy, Effluent, Energy Efficient

1. Introduction

Hydropower is one of the renewable energy sources that can be derived from the falling water which may be harnessed to generate electricity [1]. Application of hydropower in the waste water starts with the treating of waste water in the Sewerage Treatment Plant (STP). Micro hydro power is one of the simple renewable energy sources and able to generate electricity from 5 kW to 100 kW by natural water flow. There is also a common practice to compliment the micro hydro systems with solar photovoltaic power as a hybrid system to optimize the generation.

Sewerage water is a liquid waste from domestic use and need to be treated before been discharged to the environment. Sewerage water contains inimical materials. It is a complicated mix

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of organic and inorganic nutrients, impurities, disease that cause bacteria and other microorganism and suspended solids that require us to treat the sewerage water before discharge to the rivers or seas [2].

Micro hydropower system in sewerage treatment plant can be dependable and does not require a large dam or a land flooded, it can provide constant electrical energy through waste water treatment process [3]. Eslamian [4] stated that generating power need only waste water from different parts of the city so there has almost zero environment impact. It is hoped that by using this renewable energy, micro hydro plants can provide power for a small domestic use or at least, to the STP plant itself.

The purpose of this research is to determine the possible electrical power generated by the micro hydroelectric generator in kilowatts, to identify the Return on Investment (ROI) in terms of years or payback period based on saving on monthly electrical fees for application of micro hydro system in the operation of STP and to identify the relative range in measurement of head of the micro hydroelectric generator and average of flow rate that can be suited to install in STP.

2. Material and Methods

This research focusing on identifying the potential of micro hydro generator embedded at 100,000 PE sewerage treatment plant. Possible electrical power generated by micro hydro generator and payback period or return on investment (ROI) based on saving monthly electrical cost for application of micro hydro generator in sewerage treatment plant and also identify requirements include optimum head and minimum flow rate to allocate the micro hydro generator in the effluent discharge of sewerage treatment plant (STP). Juru Regional Sewage Treatment Plant (RSTP) was chosen for this research which is located at Jalan Kota Permai, Bukit Mertajam, Seberang Perai, Penang. This STP has design capacity of 150,000 PE.

2.1 Preliminary Data

The preliminaries data that obtained from the Juru STP is shown in Table 1. These data are used to calculated the estimated power output that can be generated by micro hydro generator in Juru STP.

Table 1
Preliminaries Data from Juru Regional Sewerage Treatment Plant

Preliminary Data	Values
Population Equivalent, PE	100,000
Average Flow Rate of Effluent, Q	0.261 m^3/s
Head of Effluent, H	1.0 m
Gravitational Acceleration, g	9.81 m^2/s
Efficiency of Turbine, η	0.85
Density of Effluent, ρ	1000 kg/m^3

The average rate of electrical bill per kWh usage of Juru Regional Sewerage Treatment Plant is shown in Table 2.

Table 2
Details of average values for electrical bill per kWh usage of Juru Regional Sewerage Treatment Plant

Details of Average	Values
Average total monthly electrical energy consumption	205,692 kWh
Average total monthly electrical bill	RM 81,533.47
Average rate of electrical bill per kWh usage	RM 0.3964/kWh

2.2 Calculation of Electrical Power Output

The electrical power can be generated from the turbine at Juru STP was determined based on the head, flow, and constants related to the water density, gravitational acceleration, and efficiency by using Equation (1).

$$Pe = Ph \times \eta = Q \times H \times g \times \rho \times \eta \quad (1)$$

where,
Pe is electrical power (kW)
Ph is hydraulic power (kW)
η is the efficiency of the turbine
Q is the flow of the water through the generator (m^3/s)
H is the head (m)
g is the acceleration due to gravity (m/s^2)
ρ is the density of the water (kg/m^3)

2.3 Estimation of Return on Investment (ROI) /Payback Period

The payback period is used to evaluate the viability of an investment or to think about the effectiveness of various investments. The monthly electrical bill saving by application of micro hydro generator in Juru STP is compared with the monthly electrical bill using for the plant operation in Juru STP to obtain the practical payback period by implementation of micro hydro generator.

2.4 Operation of Micro Hydro Generator on Pumping System of Aeration Tank in the Sewerage Treatment Plant

The aeration system for the operation of typical activated sludge wastewater treatment plant consumes 50 percent until 65 percent of the electrical power of the system as reported by Sandhu and Pandey, 2014 [5]. That why aeration system consumed a large quantity of electrical power that is more than half of the power of all the operation of treatment plant. In this research, possible saving of electrical bill payment contributing to the operation of aeration system is discussed.

2.5 Practicality of Speculative Micro Hydropower Situations

There were three steps needed to define the practicality of installing the micro hydro generator for the speculative cases of head and flow that were set up. Firstly, potential of electrical power

output generation in kWh was calculated in consideration of the possible combinations of head and flow in the ranges by using Equation 1. Secondly, savings is calculated by converting the values of the potential power generation values using an average rate of RM 0.3964/kWh usage. Annual saving for every speculative case is shown in Malaysia Ringgit. Finally, payback period is calculated by comparing the investment capital estimated at RM 70,000 and the annual savings.

3. Results and Discussion

3.1 Electrical Power Output

The power output possibly obtained through calculation from this research is 2.176 kW as shown in Table 3, which is considered low. So, from this result, the installation of micro hydro at Juru sewerage treatment plant is not recommended since the power output is not satisfied. Besides, in order to get the target power output which is 12 kW in Juru STP, the minimum flow rate can be determined by using the electrical power Equation (2).

$$Qreq = \frac{Preq}{H \times g \times \rho \times \eta} \quad (2)$$

Table 3
Power output calculated

Power Output	Values (kW)
Hydraulic Power available in the system, Ph	2.56
Electrical power converted from hydraulic power, Pe	2.176

Based on the Table 4, the required flow rate is 1.44 m^3/s to get the target power output. Juru STP plant has a flow rate of 0.261 m^3/s which is more than required flow rate. Though Juru STP has a reasonable required flow rate, this plant cannot generate target power output because of the low head.

Table 4
The flow rate required based on electrical power required

Electrical Power Required, Preq (kW)	Head, H (m)	Gravitational Constant, g (m^2/s)	Density of Water, ρ (kg/m^3)	Turbine Efficiency, η	Flow Rate Required, Qreq (m^3/s)
12.0	1.0	9.81	1000	0.85	1.44

The flow rate of Juru STP is 0.261 m^3/s which is smaller than the flow rate of the sewerage treatment plant in Emmerich of Germany which is 0.4 m^3/s and it can generate output power up to 13 kW. But according to Tamrakar *et al.,* 2015 [6], a low power flow rate of 0.06m^3/s and a maximum head up to 30m of height can generate the power output up to 12 kW. But the possible power output of Juru STP is 2.176 kW and it cannot achieve the target power of 12 kW which means Juru STP can generate only 18.13% from the targeted power output. As shown in Table 5 Poggio Cuculo of Italy, Armary of Switzerland, Marchfeldkanal of Austria, Llys y Fran of Scotland, Sangüesa of Spain sewage treatment facilities generated acceptable power output which is under 100 kW (micro hydro power) by either in high in flow rate (m^3/s) or high in gross head (m). Since Juru STP has low head and low flow rate, there has small power output than target power output.

Table 5
Comparison of power output generated by micro hydro generator on different elevation and flow rate

Facility	Gross Head (m)	Flow Rate (m^3/s)	Power output (kW)	Reference
Emmerich, Germany	3.6 - 3.8	0.40	13	Lau, [7]
Puan Hydro, Korea	19.6	1.18	200	Lau, [7]
Poggio Cuculo, Italy	28.0	0.38	44	Denis *et al.,* [8]
Armary, Switzerland	105.0	0.09	68	Denis *et al.,* [8]
Marchfeldkanal, Austria	2.0	6.00	70	Denis *et al.,* [8]
Llys y Fran, Scotland	25.0	0.16	29	Denis *et al.,* [8]
Sangüesa, Spain	11.0	1.16	75	Denis *et al.,* [8]
Juru Regional Sewerage Treatment Plant, Penang	1.0	0.261	2.176	Current research

3.2 Return on Investment (ROI) /Payback Period

The profit to a shareholder that is obtained from an investment of certain resource is known as Return on Investment (ROI). It is proposed that one generator will run by 24 hours per day in this research. Table 6 shown the estimated total power generated by micro hydro generator and also estimated cost saving in electrical bill by applying micro hydro generator in Juru Regional Sewerage Treatment Plant. From the result, Juru STP potentially saves RM 621.05 monthly or RM 7,452.60 per year. Comparing the electrical bill usage in Juru STP without applying micro hydro generator, it was estimated that 0.762% opportunity in saving for electrical bill per month by introducing micro hydro generator in the system.

Table 6
Estimated power output for application of micro hydro generator in Juru Regional Sewerage Treatment Plant

Operation Category	Total Generated Power (kWh)	Saving in Electrical Bill (RM)
Monthly	1,566.72	RM 621.05
Yearly	18,800.64	RM 7,452.60

In this research, RM 70,000 was estimated as a total investment cost for this system including other construction cost. The Juru STP will require at least 10 years before getting the benefit from the initial investment from the calculation of Return on Investment (ROI). Juru STP will save in electrical bill approximately RM 7,452.60 per year and the total investment cost is RM 70,000. As a result, the payback period is around 10 years so that is likely probable according to the payback period. This will not include the maintenance cost of the micro hydro.

Since the operation of micro hydro requires preventive maintenance, the ROI will definitely become longer if been added to this estimation.

3.3 Contribution of The Operation of Micro Hydro Generator on Pumping System of Aeration Tank in The Sewerage Treatment Plant

From the calculation, the average minimum estimated net power consumption of aeration system is 102,846 kWh and the average maximum estimated net power consumption of aeration system is 133,699.8 kWh. Monthly electrical bill for this system can cost from RM 40,768.15 to RM 52,998.6. Applying the micro hydro generator in the STP, this system is able to save the electrical bill from 1.17% to 1.52% only. This range is not a significant for this aeration system.

3.4 Practicality of Speculative Micro Hydropower Situations

Total of 126 speculative micro hydropower cases are analyzed in Table 7. Those cases that have a payback period of 5 years or less than 5 years are assumed to be possible and cases that have 6 years or 7 years are likely possible and more than 7 years are impossible. As a result, 96.83% are possible, 1.59% are likely possible and 1.59% are impossible by changing in flow (m^3/s) or head (m). Most of the cases are possible for 0.3 m^3/s of flow rate with head of 1 m and above.

Table 7
The viability of the different combinations of hypothetical flow and head cases

Flow (m^3/s) \ Head (m)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
0.03	>15	>15	>15	>15	11-15	11-15	9-10	9-10	8
0.04	>15	>15	>15	11-15	9-10	8	7	6	6
0.05	>15	>15	11-15	9-10	8	7	6	5	5
0.10	>15	8	6	5	5	4	4	3	3
0.20	6	5	4	3	3	2	2	2	2
0.30	5	3	3	2	2	2	2	1	1
0.40	4	3	2	2	2	1	1	1	1
0.50	3	2	2	2	1	1	1	1	1
0.60	3	2	2	1	1	1	1	1	1
0.70	2	2	1	1	1	1	1	1	1
0.80	2	2	1	1	1	1	1	1	1
0.90	2	1	1	1	1	1	1	1	1
1.00	2	1	1	1	1	1	1	1	1
2.00	1	1	1	1	1	1	1	1	1
3.00	1	1	1	1	1	1	1	1	1
4.00	1	1	1	1	1	1	1	1	1

>15	11-15	9-10	8	7	6	5	4	3	2	1	<1

Not Viable | Potential Viable | Viable

4. Conclusions

From the result of power output, it is decently lower than the target power output which is 12 kW. Since the micro hydro power range is from 5 kW to 100 kW, the power output of this research which is 2.176 kW is not in the range of micro hydro power. Besides, payback period for this research is estimated 10 years without considering the maintenance cost. The obtained power is low below than targeted due to the low head of Juru Regional Sewerage Treatment Plant. According to the application of micro hydro in actual, flow rate of 0.261 should have at least the head of 2.5 m that feasible to the investment. Even though the low head and low flow rate in the system, the total estimated monthly saving in electrical bill is calculated at RM 621.05 which is 0.762% saving for electrical cost monthly. However, the power output is not in the range of micro hydro power and not achieved the target power, this research found that suitable power output generating by micro hydro

generator is able to provide sufficient electrical power for the internal use of sewerage treatment plant and it will help to save the electrical bill for the plant operations.

Application of micro hydro generator embedded at the effluent discharge point of the sewerage treatment plant is eminently prescribed to explore more researches and configuration works. The micro hydro is renewable energy and supports the generation of sustainable power source and energy efficient approach hence the implementation of generating electricity using micro hydro generator is highly recommended. There are some researches that proved that the possibility of generating the electrical power using micro hydro generator in sewerage treatment plant like sewerage treatment facilities in Korea, Italy, Austria, Spain, Germany, Switzerland and Scotland according to the Lam [9] and Denis *et al.,* [8].

From the result of this research, the implementation of micro hydroelectric generator for constructing a business around utilizing energy in streams of waste water effluent is considered as a possible attempt, however, the detailed work in terms of design and application is highly required. Most of the industries are substantially used the water for the processes so they are one of the most possible candidates for applying micro hydroelectric system in their water treatment facility.

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