Feasibility Evaluation of Micro-Hydropower System Generation for Different Types of Sewage Treatment Plants

Ahmad Firdaus Abdul Jalil, Jagadeesh Pasupuleti, M. Reyasudin Basir Khan

Abstract: ***Small scale hydropower is among the most attractive and cost-effective sustainable energy technologies available, by harnessing electricity through moving water. Naturally, moving water can be found in rivers and also man-man conduits where there is a continuous water flow. The sewage treatment facility has continuous water flow at the effluent pipe that can generate electricity by means of small-hydropower system. However, there are no sewage treatment plants (STP) in Malaysia that reclaim the energy through the usage of water turbines. This study is conducted to evaluate the feasibility of a micro-hydropower (MHP) system at the continuous flow of effluent discharge point of domestic STP that comprises of a low head with high flow fluctuations. This work comprises of evaluation of the potential power output of MHP generator which attached to different type of STP. The work starts with selection of a five STP which have maximum current population equivalent (PE) over design PE loading ratio. Next, the effluent discharge flow rate & outfall head are collected and recorded. Finally the potential output power for all selected STPs is calculated. The highest continuous effluent discharge flow rate contributing in high potential power and will be identified as the feasible STP for the MHP system installation.***

Keywords: ***Effluent, Hydropower, Population Equivalent, Sewage Treatment***

I. INTRODUCTION

The Renewable Energy Network for the 21st Century (REN21) Global Status Report 2016 has shown that fossil fuels currently contribute 78.3% of the world energy consumption, while 19.2 % comes from renewable resources and the remaining comes from nuclear energy [1]. The report indicates that renewable energy (RE) progresses robustly in all end user sectors, its capacity continuously growing, while globally its price continues to decrease. In order to reduce fossil fuel dependency, governments and private sectors worldwide are pursuing research and supporting the development of sustainable energy. Malaysia is among the countries that mainly rely on fossil fuels for electricity generation. Malaysia's current electricity generation is largely supplied by five different sources: coal, oil, natural gas, hydro, and others (solar, biogas and biomass).

In order to mitigate the dependency on fossil fuels, the government has initiated several renewable energy policies over the years. The policies are designed to accomplish the nation's aim to satisfy the growing need for energy and reduce issues of energy efficiency, security, and adverse effects on the environment [2]. Currently, the annual power generation of commissioned RE installations of Malaysia in 2016 was 234,864.9 MWh where 55.42% contributed by biomass, followed by solar PV (30.89%), biogas (8.98%) and small hydro (4.71%) [3]. Small-scale hydro, which is a run-of-river scheme with no water storage, is among the most cost-effective and environmental friendly energy technologies available [4]. There are no agreements on the classification of small-scale hydropower but in this research work, a small hydro is considered as any hydro scheme below 10 MW. A hydropower scheme below 1 MW is referred to as a mini-hydro, below 100 kW is micro-hydro, and pico-hydro is for any scheme below 10 kW [5]–[7]. This type of hydropower system produces electricity from stream flow directed through turbine which drives an AC generator. Normally, the power output from this type of hydropower system is intermittent due to no water storage or sometimes faced with flow fluctuations [8]. Sewage treatment uses a lot of energy. Recently, the rising of energy cost and stricter environmental regulations, has forces the municipality to mitigate the energy usage in the water treatment plant. RE technologies such as micro-hydopower system able to transform the STP into RE energy producers by reclaiming the energy through the usage of water turbine. In literature, the sewage treatment facility has shown to have continuous water flow at the final effluent that can a generate electricity by means of small hydropower system [9], [10]. According to the National Water Services Commission's Malaysia Sewage Industries guideline 2009, the estimated volume of wastewater generated by municipal and industries sectors is 2.9 Billion cubic meters per year [11].

There has been many successful installation of micro hydropower system (MHP) in a sewage treatment plant (STP). For instance, Kyu-Jung Chae et al. has successfully installed a MHP with 13.4 kWp rated capacity for Kiheung Respia STP in South Korea [12]. The system is economically feasible with rate of return of 6.1% and capable of generating an approximate of 2.1% of the STP energy demand. Moreover, the small hydropower system that has been installed at sewage treatment plant in Deer Island, Boston able to generate 5.1% of the annual energy demand on the island [13].

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Although implementation of MHP in STP is still in the developmental stage due to low head constraint, the water-energy extant in those facilities has been receiving more attention as new low-head turbine system technologies have emerged. Recent investigation by seven states in the United States (i.e., California, Texas, Florida, Pennsylvania, New Jersey, New York, and Massachusetts), Torrey [14] has identified both high energy prices and an abundance of STP that would make these sites attractive candidates for wastewater hydropower installations.

The other research study related to MHP with low head constraint was done in Vilareal Spain where the measured head are about 1.5m & 3m and the potential energy which can be produced from wastewater treatment facilities were about 1.67 kW & 3.1 kW respectively [15]. Moreover, another study which is focusing on the potential hydro flow capacity by PE volume was done in Malaysia by proposing a micro hydroelectric generator which is embedded at the continuous flow of effluent discharge point domestic Sewerage Treatment Plant (STP). This study evaluated the potential of electricity generation from micro hydroelectric generator attached to a 100,000PE STP based on the power output obtained from calculation of electrical power [16].

In this research work, five selected STP under Indah Water Konsortium (IWK) will be selected as based on their maximum Current PE over Design PE ratio and discharge effluent outfall head. Generally, IWK is operating based on three major types of STP; Sequent Batch Aerator (SBR), Oxidation Ditch (OD), Extended Aeration (EA). Currently, SBR is the most used by IWK as its space of building structure is smaller and has higher flow rate of 300,000 PE to 500,000 PE. However, SBR do not have the continuous final effluent as it is designed to discharge the final effluent only during the decanting process cycles (a SBR tank typically has 4 decanting cycles per day). For the purpose of this study, the SBR flow rate will be measured exactly before the SBR tank flow incoming.

II. METHODOLOGY

STP Selection for MHP System

In this feasibility study, five out of 340 IWK Unit Office Subang Jaya STP with three different types (Sequent Batch Aerator (SBR), Oxidation Ditch (OD), Extended Aeration (EA) have been selected according to their maximum DPE and Current PE over Design PE loading ratio. The related STPs are shown in Table 1:

Table. 1 Selected location

No	Location	Type	Loading ratio
1	PTG 239 (Subang Jaya)	Sequent Batch Aerator (SBR	125,219 CPE / 150,000 DPE; 83.48%
2	PTG 118 (Subang Jaya)	Oxidation Ditch (OD)	34,473 CPE / 134,473 DPE; 100%
3	PTG 117 (Subang Jaya)	Oxidation Ditch (OD)	37,337 CPE / 37,337 DPE; 100%
4	PTG 231 (Subang Jaya)	Extended Aeration (EA	22,500 CPE / 22,500 DPE; 100%
5	PTG 153 (Subang Jaya)	Oxidation Ditch (OD	48,000 CPE / 75,000 DPE; 64%

CPE over DPE loading ratio, the highest percentage loading ratio will have the highest effluent discharge flow rate. This study starts with selection of STP followed by data collection of flow rate and head. Then, potential power at each site is calculated based on general hydropower equation.

Data Collection

The data collection for this research work is flow rate and available head for the selected sites. The flow rate was collected manually using a HACH FL900 Portable Ultrasonic Water Flow Sensor with Data Logger. Figure 1 shows the flow sensor setup for collecting the effluent discharge flow rate for this research work. The sensor data setting is set by putting the effluent discharge path area and the sensor level through the FSDATA software. Figure 2 shows data collection activity at selected STP.

Fig. 1 HACH FL900 portable ultrasonic water flow sensor with data logger

Fig. 2 PTG 239 flow rate measurement activities

Figure 3 until Figure 7 show the different pattern of effluent discharge flow rate which is obtained from different type of STP and flow rate. Figure 3, 4 & 7 show extreme variable effluent discharge flow rate which is not feasible for the MHP system requirement. Figure 6 shows the consistent effluent flow rate pattern but its flow rate is quite low.

The most consistent and high effluent discharge flow rate can be seen in Figure 5: PTG 118 where the flow rate is stable compared other locations. However the sudden increase in flow rate at 23:00 hour needs to be given extra attention during MHP system design stage.

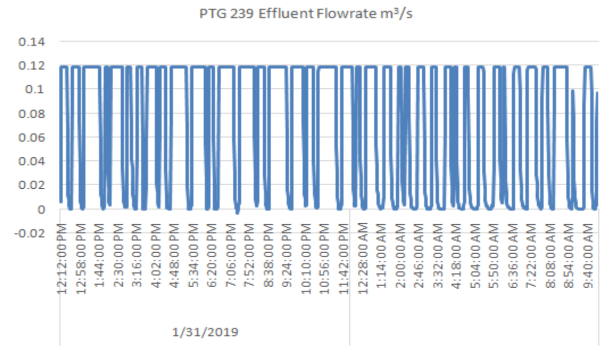

Fig. 3 PTG239 effluent flow rate data (1317 data)

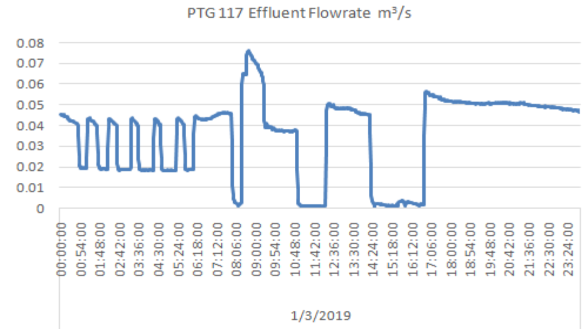

Fig. 4 PTG117 effluent flow rate data (1442 data)

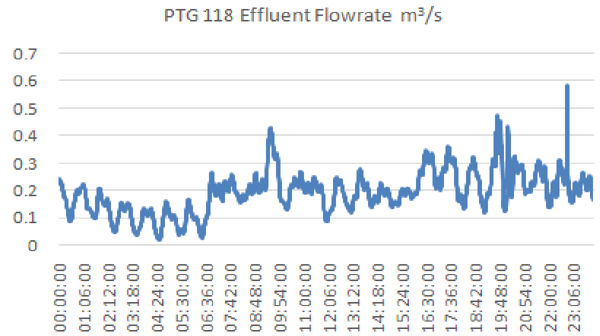

Fig. 5 PTG118 effluent flow rate data

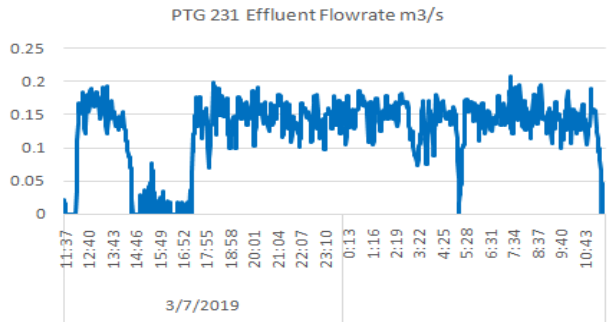

Fig. 6 PTG231 effluent flow rate

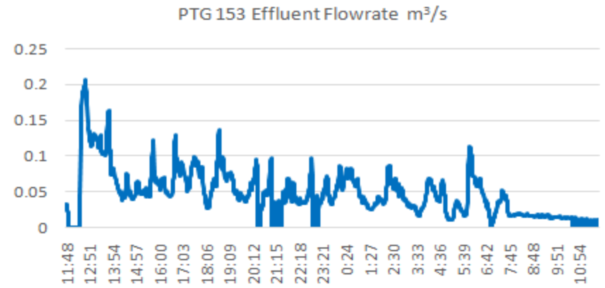

Fig. 7 PTG153 effluent flow rate

Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12 show the effluent outfall head condition in IWK. The head dimension has been taken between the effluent outfall and river or drainage bed.

III. RESULTS

The potential power from the turbine at selected STPs locations were determined based on general hydropower equation based on head, flow, gravitational acceleration, and efficiency as shown in Equation (1) [17].

$$P_e = QHg\rho\eta \tag{1}$$

Where, P is potential electrical 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) and ρ is the density of the water (kg/m^3).

Table 2 demonstrates the potential power for each STP based on the head availability and average flow rate. The highest average potential power is from PTG118 with power output of 4.75 kW with an effluent discharge outfall head of 2.50 meter high.

Table. 2 Potential power output for selected STPs

Location	Flow rate (m^3/s)	Head (m)	Potential Power (kW)
PTG239 SBR	0.073	0.50	0.356
PTG118 OD	0.194	2.50	4.750
PTG117 OD	0.036	0.50	0.175
PTG231 EA	0.125	0.50	0.611
PTG153 OD	0.048	0.50	0.234

IV. CONCLUSIONS

In conclusion, it is not practical to harness the energy at SBR effluent discharge point as flow rate is not continuous and stable (please refer to FIGURE 3). To mitigate this issue for SBR, a high capacity energy storage need to be used as a buffer tank and this definitely will consume high installation cost later. Other types of STP such as OD and EA have higher potential for MHP as the effluent discharge flow is continuous and stable compared to SBR. In this research work, three types of STP have been assessed for potential installation of MHP system. The OD in PTG118 shows the highest potential power output with 4.750 kW followed by EA with 0.611 kW, while other STPs have potential power output less than 1 kW. However, with the implementation of ETOU tariff system recently by TNB, the monthly STP max kWh needs to be minimized, thus leading to the Raw Sewage Pumps temporary shutdown during the particular of ETOU period. As a consequence, this will reduce the effluent discharge pressure and flow rate. Hence, MHP energy recovery will be reduced. Therefore, design of MHP at STP needs to consider this issue to maximize power generation from installed MHP system.

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