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Rainwater Harvesting Power for Different Height of Building in Pasir Gudang

Nur Firdiuz Ibrahim[1], **Nordiana Azlin Othman**[1]*

[1]Department of Electric and Electronic Engineering,
University Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

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Abstract: Rainwater Harvesting system significantly with hydropower electric has a lot of benefits than the other renewable energy to apply in Malaysia due to weather in Malaysia hot and humid all over the year. This project is focusing analysis on the optimum parameter that could be produced by the Rainwater Harvesting system based on a parameter from the proposed building in Pasir Gudang using the simulation and neglecting the electricity storage. For this project, the data had been collected based on research will be used to further analysis of the parameter that crucial in the Rainwater Harvesting system in order to get the optimum output by using Matlab Simulink. Based on this project, the net head, bucket outlet angle and the number of nozzles were the crucial parameters that need to be analyzed using the parameter from the proposed buildings. The output of the Rainwater Harvesting system will affect if the crucial parameter changes either increase or decrease. The future project suggested including the penstock and generator since it also plays a big role in the output produced from the Rainwater Harvesting system.

Keywords: Rainwater Harvesting System, Pelton Turbine, Nozzle, Net Head.

1. Introduction

The European Commission described the primary theory of sustainable evolution in 2010 as "fulfilling the aspirations of current generations without affecting future generations' ability to satisfy their demands." To summarise, offer a higher level of living for everyone, including future generations [1]. The global society is watching with hope as a new focused sustainable agreement and agenda on climate change is implemented. This trend has sparked interest in low-carbon, flexible, and long-term technology. As a result, clean energy and renewable sources are given special attention [2].

Because of its tremendous advantages, hydropower has traditionally been the undisputed leader among renewable energy sources. An established technology, extremely cheap operating and maintenance costs, improved efficiency, resilience, increased degree of dependability, and massive storage capacity is among the most common advantages [3]. According to market data, the hydropower sector's operational energy storage capacity is above 97 percent globally [2].

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*Corresponding author: ndiana@uthm.edu.my

Due to its increasing capability in electricity generation, hydropower has been the clear leader among renewable energy sources since 2005. Hydropower meets one-sixth of the world's electrical consumption [3]. According to the IEA's Technology Roadmap from 2012 [3], hydropower is the most important renewable technology for worldwide energy production. Furthermore, according to the IEA's most recent research, the most promising places for hydropower technology are in Africa (cross-border and regional river basins, including the Nile, Congo, and Zambezi rivers), Asia (mostly in China), and Latin America (primarily in Brazil) [3].

1.1 Problem statement

Hydroelectric power, often known as hydroelectricity, is a renewable energy source (RES) that converts water held in a reservoir high up in the mountains into electricity. Hydropower is a predictable, dependable, proven, cost-competitive, and highly productive renewable energy source. Hydropower is a "green" form of energy because, unlike other power plants, it does not emit carbon dioxide. To put it another way, preserving fossil fuels and minimizing the environmental consequences of their use. Globally, there is a total of 1055 GW of installed hydroelectric capacity [4].

To accommodate significant amounts of energy, such as usage in factories and residential areas, hydropower generation is typically employed on a large scale. As a result, this project is being carried out to utilize this electric hydropower for daily purposes, where it will be scaled down by the requirements of the building used to collect rainwater for the catchment. The potential energy that will be produced from the rainwater collection will be turned into electricity through a ground-based turbine to meet the building's electrical needs. To analyse certain crucial elements that would impact the power output, this study focuses on the ideal parameters that must be attained.

This project’s work embarks on creating a simulation model of an RWH generation system that generates electricity by collecting the potential energy stored in a different height of building rainwater tank in Pasir Gudang. This project also aimed to investigate the relationship between the net head, and bucket outlet angle with the output power to get the optimum output power however the electricity storage is not covered in this research.

2. Materials and Methods

2.1 Phase of the project

Figure 1 shows a flow of the method that had been used to collect the data and run the simulation for analysis of the parameter that is crucial for the rainwater harvesting system to complete this project which is the Rainwater harvesting system to generate electricity.

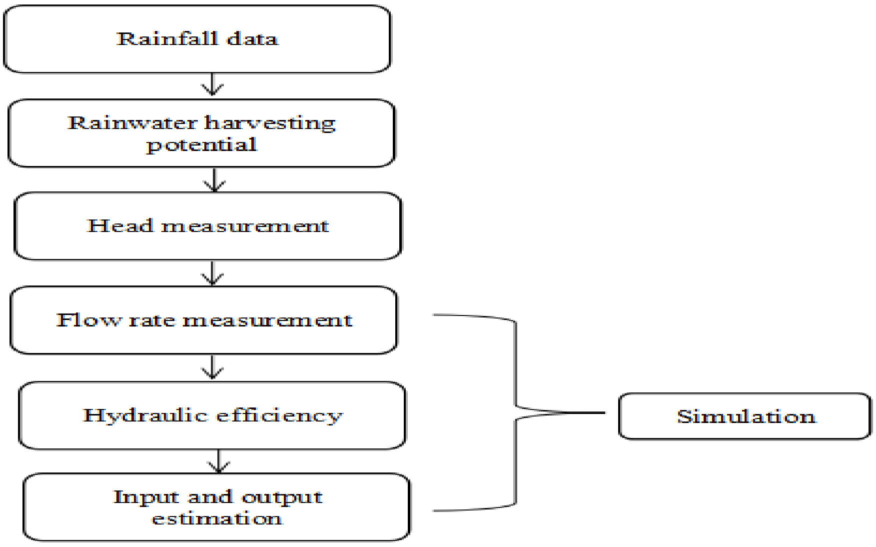

Figure 1: Flowchart of the project

2.2 Rainfall data

By studying the climate in Malaysia, it is possible to use renewable energy to power appliances and equipment within buildings. The weather in Pasir Gudang varies dramatically from month to month, as seen in Figure 2. The largest amount of rainfall (340 mm) was recorded in November, while the lowest amount of rainfall (135 mm) was recorded in February.

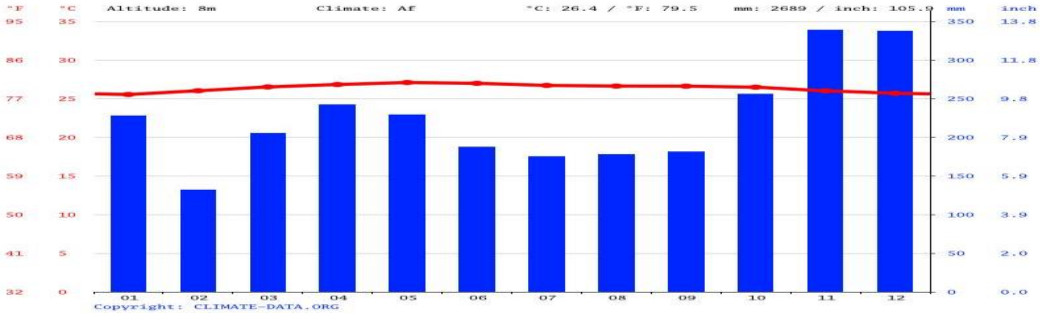

Figure 2: Rainfall data for Pasir Gudang [5]

2.3 The supply potential of rainwater

Three primary characteristics, such as run-off coefficient, catchment area, and rainfall data, will be used to assess rainwater collecting potential. The catchment efficiency on the surface is influenced by the run-off coefficient. The kind of catchment and region where precipitation falls, as well as surface qualities, all influence runoff. Table 1 lists the Runoff coefficient.

Table 1: Runoff coefficient

Type of roof	Runoff coefficient
Galvanized iron sheet	0.90
Asbestos sheet	0.80
Tiles roof	0.75
Concrete roof	0.70

A catchment area is a floor area where surface water from precipitation collects and drains toward the intake's entrance. The width and length gained from the roof in meters are multiplied to get in square meters, and the catchment area of the rooftop is estimated by simple multiplication in square meters. The picture of the catchment area is used to produce an estimate of the catchment area using Google Earth Pro. Figure 3 and Figure 4 show the catchment area of the proposed building.

Figure 3: Catchment area of Amansari Residence Resort

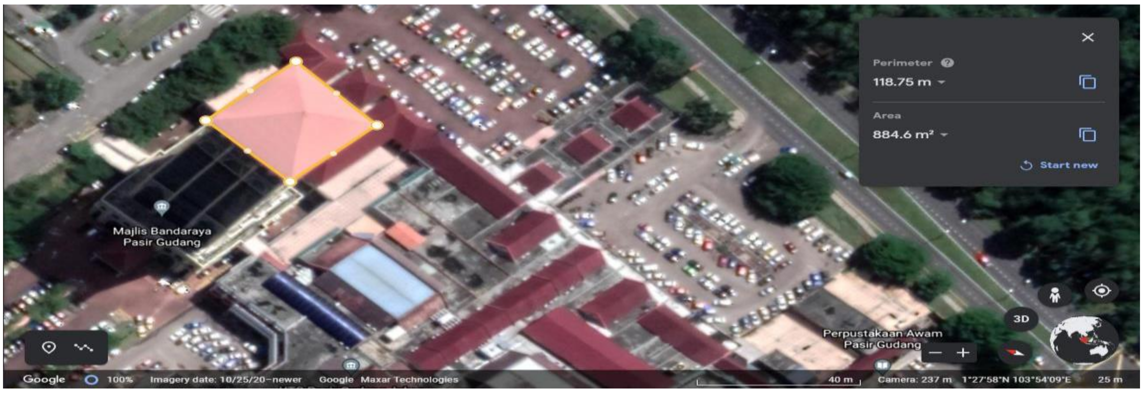

Figure 4: Catchment area for Aqabah tower

The formula of rainwater harvesting potential can be expressed as [6]:

$$RWHP\ (m^3) = \text{rainfall (m/month)} \times \text{catchment area}\ (m^2) \times \text{run} - \text{off coefficient} \qquad Eq.1$$

2.4 Head Measurement

The water flowing above the penstock will be measured all the way up to the ground-level turbine. The vertical distance between the water's surface and the turbine's intake is known as the gross head. The net head, on the other hand, is the distance removed from the gross head, which includes pressure and obstacles in the penstock that cause head losses.

The formula of head measurement can be expressed as;

$$H_n = H_g - H_l \qquad Eq.2$$

Where are the H_g gross head loss and H_l total head loss. The projected amount of these losses is 5% of the gross head [5]. By deducting the gross head from 5% of the gross head, the net head is obtained. As a result, while gross head may give you a decent estimate of the amount of energy available, the analysis is incomplete without the flow rate.

2.5 Measurement of water flow rate

The flow rate of the nozzle, Q, is the amount of rainwater discharged via the nozzle. It is calculated using the same formula as a pump system, except there is no pump. The following equation can be used to calculate the nozzle flow rate, Q [6].

$$\text{Flow rate of nozzles, } \mathrm{Q}(m^3/\mathrm{s}) = \text{Area of Nozzle } (m^2) \times V_1 \,(\mathrm{m/s}) \times n_{zz} \qquad Eq.3$$

Where the n_{zz} the number of nozzles used.

Based on $Eq.3$ the simulation had been done for flow rate measurement in the Matlab Simulink as shown In Figure 5.

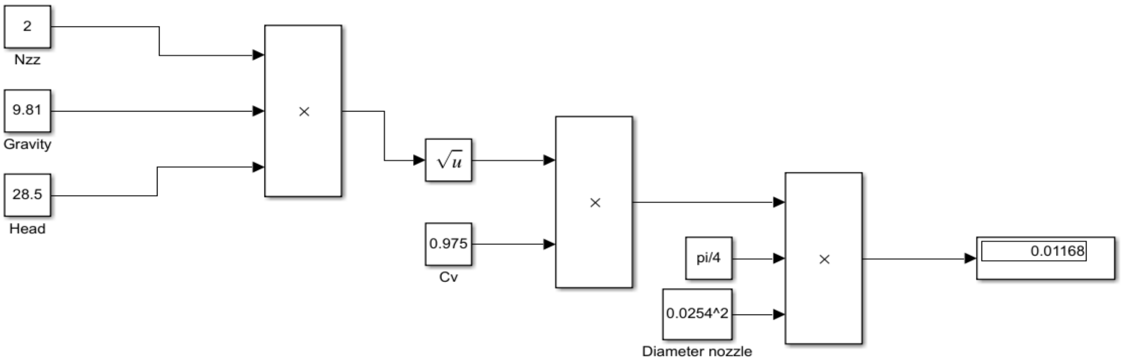

Figure 5: Simulation of flow rate measurement

2.6 Turbine Hydraulic efficiency

The deflection angle needs to be 180° in order to provide the best thrust on a revolving wheel. To prevent scenarios where water rebounding back from the bucket could miss the following bucket, the deflection angle has been restricted to 160°. The nozzle velocity coefficient of C_v =0.975 and the constant tangential velocity at intake and output is what determines u = 10 m/s for the proposed model. Figure 6 shows the triangle of velocity for the Pelton turbine. The estimation of hydraulic efficiency is created and developed using Matlab Simulink, as shown in Figure 7.

1. Angle of bucket outlet

$$\emptyset = 180^\circ - 160^\circ = 20^\circ$$

2. From (1.2), $V_1 = 0.975\sqrt{2 \times 28.5 \times 9.81}$

$$= 23.0556 \text{ m/s}$$

3. Figure 3.10 $V_1 = V_w$, v = u

$$V_w = u + V_r \rightarrow V_r = 13.0556 \text{ m/s}$$

4. For outlet, V_{r1}

$$\cos \emptyset = \frac{\mathrm{u}+\mathrm{V_{w1}}}{\mathrm{V_{r1}}}$$

Since $V_r = V_{r1} \rightarrow V_{w1}$ =2.2682 m/s

5. Hydraulic efficiency, ɳh

$$= \frac{2[\mathrm{V_w}+\mathrm{V_{w1}}]\mathrm{u}}{\mathrm{V_1}\times\mathrm{V_1}} = 0.9528 \rightarrow 95.28\%$$

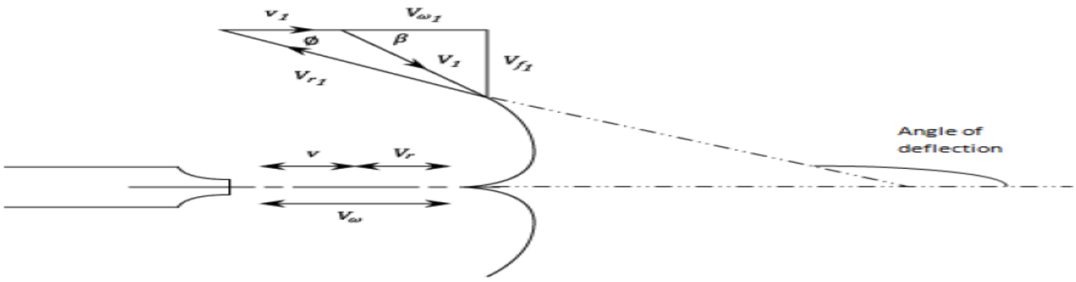

Figure 6: Triangle of velocity for Pelton turbine

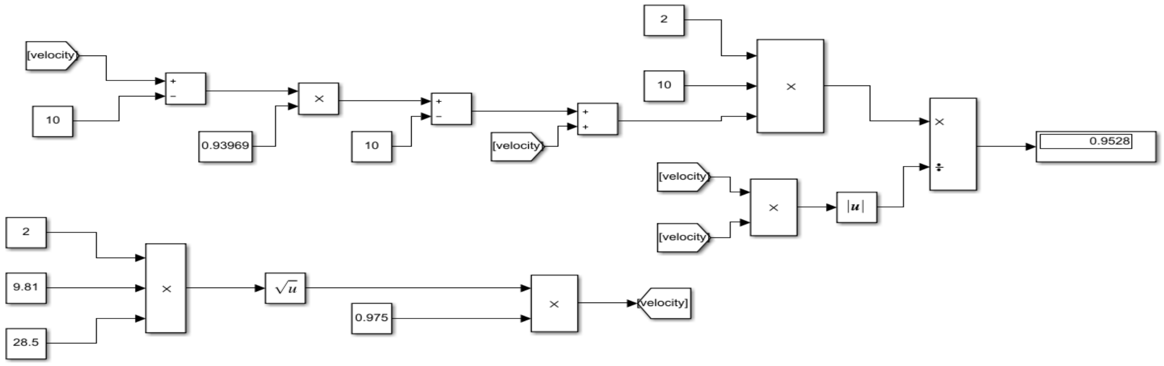

Figure 7: Simulation for hydraulic efficiency

2.7 Input and Output estimation

For this system, the proposed design is where only 90% of the effective generator is used, and the losses for electrical loss and mechanical loss are 5% and 1%, respectively [7]-[8]. Therefore, there is the formula for calculating the total power received by the hydroelectric system [9]. The simulation of output and input power using Matlab Simulink as shown in Figure 8 and Figure 9.

$$\eta_o = \frac{P_{out}}{P_{in}} \qquad Eq.5$$

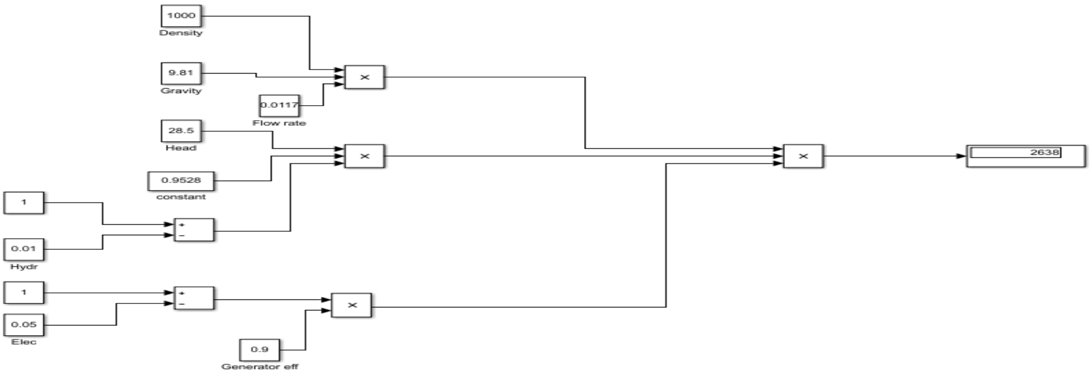

Figure 8: Simulation of output power

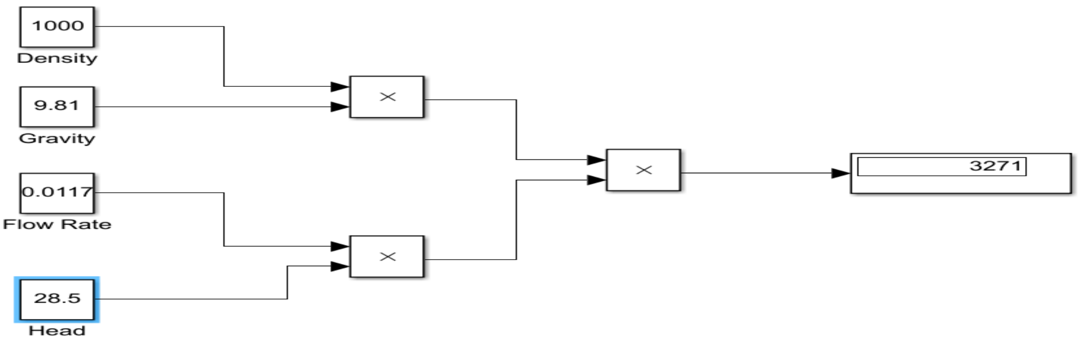

Figure 9: Simulation of input power

3. Results and Discussion

The rainwater harvesting system potential will be measured based on the proposed building in Pasir Gudang which is Aqabah tower and Amansari Residence Resort to show the Rainwater harvesting potential based on both building. Figure 10 shows the RWHP for proposed building.

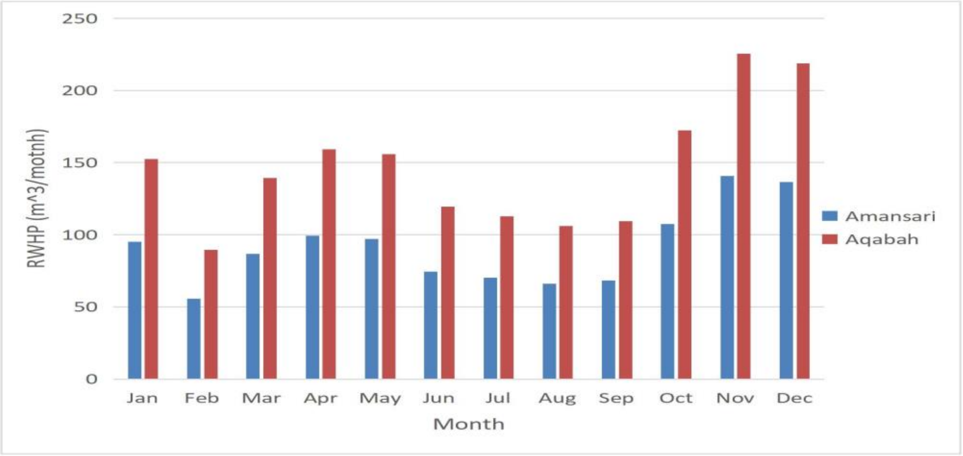

Figure 10: RWHP for the proposed building.

From Figure 10, the rainwater harvesting potential (RWHP) for the Aqabah tower was high compared to the Amansari Residence Resort. This is because the Aqabah tower has the higher of net head compared to the Amansari Residence Resort. Hence, the rainwater harvesting system is more suitable to be implement at the Aqabah tower rather than Amansari Residence Resort. Table 2 shows the parameters of the proposed building.

Table 2: Parameter of the proposed building

Amansari Residence Resort

Hn (m)	Uw (m/s)	N (rpm)	V1 (m/s)	Q (m^3/s)	ηh	Pin (W)	Pout (W)	η_0(%)
28.5	10.64	1333.39	23.0556	0.0117	0.9528	3271	2638	80.65

Aqabah Tower

Hn (m)	Uw (m/s)	N (rpm)	V1 (m/s)	Q (m^3/s)	ηh	Pin (W)	Pout (W)	η_0(%)
48.45	13.87	1738.70	30.0600	0.0152	0.8612	7224	5827	80.66

Based on this parameter, the Aqabah tower parameter will be taken to further analysis in order to get the optimum output for the rainwater harvesting system by varied the crucial parameter that affect the output value for this system. The parameter that will be varied in the further analysis is the net head, bucket outlet angle and the number of nozzles. Figure 11 shows the relationship of the net head against output power.

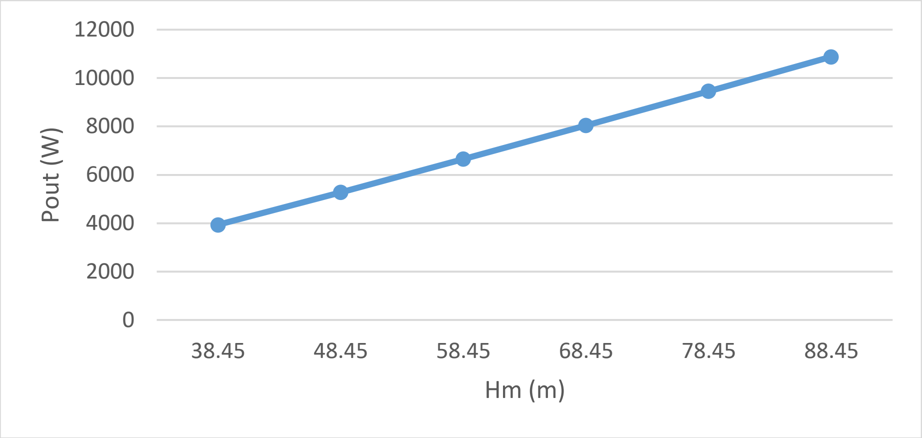

Figure 11: Relationship of net head against output power

Based on Figure 11 shows the result after varying the net head for the Aqabah tower, the output power always increases whenever the net head is increased. This can prove that a higher of the building will increase the output power of the rainwater harvesting system. This is because the potential energy will be increased if the rainwater harvesting applied in higher building because the gravity will play a big role to the increase of potential energy and the flow rate of the water.

Figure 12 shows the result after varied the bucket outlet angle with constant of net head. The output power will decrease accordingly whenever the bucket outlet angle is increase. This is because when a smaller angle at the bucket outlet is generated, the pushing power at the bucket is larger. As a result, the hydraulic losses of the turbine are minimized since the amount of water that flows back from the bucket is decreased.

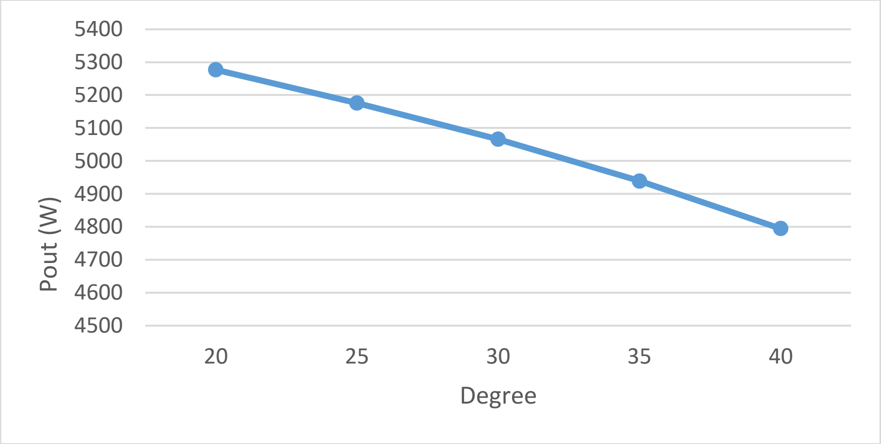

Figure 12: Relationship between output power and degree of the bucket outlet angle

Table 3 shows that the runner and nozzle diameter size for each number of nozzles use. This parameter helps on to determine the optimum number of nozzles use for the rainwater harvesting system based on certain height. Based on appendix A.3, the use of the number of nozzles can be varied through 1, 2, 4, and 6 based on their own speed range of 10 to 60.

Table 3: Turbine parameter based on number of nozzles

n_zz	1	2	4	6
Runner Diameter, D (m)	0.1524	0.1397	0.1270	0.1143
Nozzle Diameter, d (m)	0.0254	0.0233	0.0212	0.0191

Figure 13 shows that the number of nozzles use for certain height were determine by referring the specific speed which in range 10 to 60. The specific speed for each height which approaching to 60 will be taken to determine the number of nozzles use for this rainwater harvesting system.

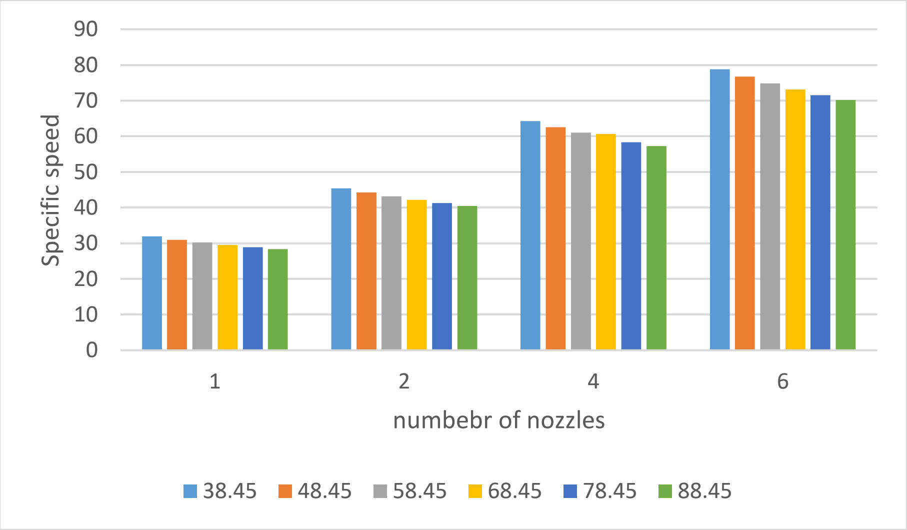

Figure 13: Relationship between specific speed and number of nozzles

All of the ideal parameters have been gathered and integrated in Table 4 based on the prior study. Based on these results, the turbine's maximum output power at 88.45 m net head and four nozzles is 30330 W. As seen in Figure 14, the output power generated increased dramatically from net head 68.75 m to 78.75 m. This is so that higher nozzles can work more effectively when the head is higher.

Table 4: Pelton turbine optimum parameters at maximum power output

Hm (m)	**N (rpm)**	**n_zz**	**Q (m^3/s)**	**ηh**	**Pin (W)**	**Pout (W)**	**η_o %**	**n_s**
38.45	1689.73	2	0.02284	0.9077	8615	6619	76.83	45.40
48.45	1896.76	2	0.02564	0.8612	12190	8884	72.90	44.23
58.45	2083.35	2	0.02816	0.8191	16150	11200	69.34	43.14
68.45	2254.51	2	0.03048	0.7819	20470	13550	66.17	42.15
78.45	2654.95	4	0.05400	0.7490	41560	26350	63.41	58.36
88.45	2819.09	4	0.05736	0.7200	49770	30330	60.92	57.24

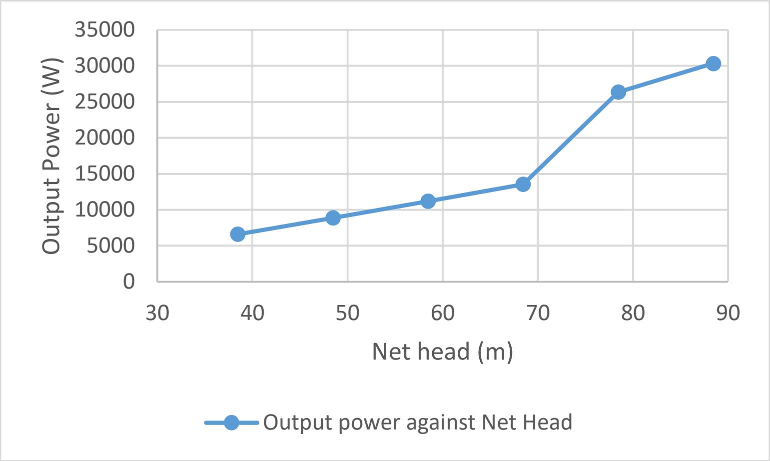

Figure 14: Plot of Output power against the Net head with optimum parameters

4. Conclusion

As a conclusion, a rainwater harvesting system is suitable to be implemented since the weather in Pasir Gudang is hot and humid all over the year based on rainfall data for Pasir Gudang that had been shown. Based on the analysis, the net head, the outlet of bucket angle and the number of nozzles had been varied in other to get the optimum parameter for this rainwater harvesting system. Then to increase the output power for further studies, a higher of building is required because it can increase the water potential energy at the nozzle before it hit the turbine to produce larger pushing power. For the bucket outlet angle, the 20 degree of deflection is the optimum parameter based on the analysis above. This statement is stated to avoid the water that hitting the bucket with velocity will flow out again due to the larger bucket outlet angle. Then, the higher of building is required the higher number of nozzles that need to be used in order to get the optimum output power for the system. The studies about the pen stock and generator were recommend for the further studies since both of them were the primary of components for the rainwater harvesting system.

Acknowledgement

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