Potential power generated from rainfall in DKI Jakarta area

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Abstract. By looking at the potential of this rainwater, Indonesia is part of an area with high rainfall intensity. In several regions in Indonesia, a natural phenomenon often appears, namely when the rainy season arrives, a large amount of water occurs, based on annual data from the BMKG (Meteorology, Climatology and Geophysics Agency). In this work, the potential of power generated from rainfall is overlook based on the precipitation of rainfall, total days of rainfall and typical house design. It is found that the potential of electric power that can be generated from rainfall at least 1000 watts per month of January, February, March, April, November, and December.

Keyword: potential, electric, power, rainfall

1. Introduction

Energy demand is a basic human need, which continues to increase in line with the level of life [1]. Energy demand is increasing day by day due to the increasing population and industrialization. However, excessive use of electrical energy can cause an electricity crisis. Therefore, it is necessary to develop optimal utilization methods that can reduce excessive energy use and try to work as a positive catalyst in a stable environment.

World energy consumption data published by the U.S. Energy Information Administration in the World Energy Demand and Economic Outlook EIA’s Handling of Non-U.S. Policies in The International Energy Outlook 2016 noted that total world energy consumption increased by 48% from 2012 to 2040 [2]. Most energy consumption is used in the building sector, including not only commercial buildings but also residential buildings [3]. Especially in Indonesia, the need for electrical energy has increased every year. The total demand for electricity in Indonesia is estimated to reach 172.34 TWh in 2020. The increase in electricity demand per year is around 6.5% per year [4].

The availability of energy sources from fossil and petroleum will decrease over time, while the need for energy continues to increase. Renewable energy is an alternative energy source that is used as a substitute for fossil energy sources and petroleum [5]. One example of a renewable energy source is rainwater. Rainwater can be utilized to generate power through the proper water turbines. Water turbines are the ideal solution to generate power that can be transformed into modern technology to solve the energy needs of people, who lack electricity. Which leads to clean electricity generation that is environmentally friendly. Many works regarding the rain water such as investigation the relation between the rainwater harvesting simulation results and the rainfall characteristics of various time
series lengths [6], studying in order to establish a methodology to construct a Markov chain model for
time series of rainfall in temperate climates that optimal operation of rainwater harvesting systems,
which is cast in the framework of stochastic dynamic programming [7], and studying a method that
can be used to identify representative length of short-term rainfall data for rainwater harvesting system
modelling for 12 cities located in different climatic zones [8].

By looking at the potential of this rainwater, Indonesia is part of an area with high rainfall intensity.
In several regions in Indonesia, a natural phenomenon often appears, namely when the rainy season
arrives, a large amount of water occurs, based on annual data from the BMKG (Meteorology,
Climatology and Geophysics Agency) [9].

Rainfall is a sediment or water deposit in liquid or solid form, which comes from the atmosphere.
Rain characteristics of an area need to be known to determine the availability of water and the
possibility of problems and disasters related to water resources. Rainfall in Indonesia has a very high
level of diversity in space and time. The existence of weather and climate has a major influence on
the life of Indonesian people [10].

Based on the dynamics of the hydrological cycle, one of the main water sources is rain. Naturally,
rain occurs from the condensation of water vapor in the air which then forms a cloud. If the physical
conditions both inside and outside the cloud are supportive, the rain process will take place. Therefore,
the nature and conditions of a rainy or rainy season are very dependent on the prevailing weather /
climatic conditions. Natural water availability on a global scale is constant, only occurs, variations
both over time and space on a regional scale [11].

Various technologies have been applied to optimize and utilize rainwater so that it can be used as
renewable energy that can generate electrical energy so that dependence on the resources generated
from the PLN network can be reduced.

At present, almost all residential houses use energy sources from the PLN network. The source of
electrical energy provided by PLN will save as much as possible in the use of electricity [5]. Based on
this, it is necessary to study the potential of rainfall to generate electrical power, where this method is
commonly used because it is very simple and easy to use [12].

Even so, efforts to utilize water often experience obstacles due to the uneven distribution of rain.
Facing this condition, in addition to optimizing the utilization of water that reaches the ground
naturally.
Since there is no literature that shows the potential rainfall harvesting for generating power by
converting using water turbine, therefore, it is interesting to conduct this research.

2. Methodology

2.1. Rainfall data
Rainfall data is an important factor to observe the areas that have a high potential for rainfall. The data
used in this study are obtained from the Badan Meteorologi, Klimatologi, dan Geofisika (BMKG),
which the selected area is DKI Jakarta and the Station is at Halim Perdana Kusuma Jakarta Station.
The rainfall data is in mm of unit per day from January 2015 to October 2020. From this data, the
amount of rainwater discharge would be determined, then was being used to estimate the power
(watts) generated for each month.

2.2. Water discharge of rainfall
The rainfall data from year of 2015 up to 2020 was carried out to calculate the water discharge. However, there are several parameters need to be defined in order to determine water discharge using
rational equations [13], as follows:

\[ Q = 0.002778 \times C \times I \times A \]

Where:

Q = peak flow (discharge) rate (m³ / sec)
C = runoff coefficient (0 ≤ C ≤ 1)
I = rainfall intensity (mm / hour)
A = area (m²)
The runoff coefficient (C) is defined as the ratio between the peaks of runoff and the intensity of rain. The value of C is determined by the method of Hassing[14] as summarized in Table 1.

**Table 1.** The runoff coefficients for the rational method.

| Topography, Ct | Land, Cs     | Vegetation, Cv |
|---------------|--------------|----------------|
| Flat (1%)     | 0.03 Sand and Gravel 0.04 Forest 0.04 |
| Wavy (1-10%)  | 0.08 Sandy loam 0.08 Agriculture 0.11 |
| Hills (10-20%)| 0.16 Clay and silt 0.16 Meadow 0.21 |
| Mountains (>20%)| 0.26 Rocky land 0.26 No plants 0.28 |

In DKI Jakarta area is flat and has a type of rocky land, with vegetation without plants. Therefore, the runoff coefficient (C) is as follows:

\[
C = Ct + Cs + Cv \\
= 0.03 + 0.26 + 0.28 \text{ (flat <1%), rock layers without plants)}
= 0.57
\]

By using the formula for rational equation, the amount of water discharge for each 1 m\(^2\) of area can be calculated as:

\[
Q = 0.002778 \times C \times I \times A \\
= 0.002778 \times 0.57 \times I \\
= 0.00158 \times \text{m}^3/\text{s.m}^2 \\
= 1.58 \times \text{ltr/s.m}^2.
\]

2.3. Power generated from rainfall

To estimate the power generated from the rainfall, the design of typical house is needed in order to simulate the area where the rain water is falling as a roof. From this design, the potential and kinetic energy also can be determined. Figure 1 shows the typical house with the base area of 6 x 10 m\(^2\) and height of 3.5 m. The purpose of determine roof area is to get the water discharge in unit of ltr/s. The area of the roof can be calculated using the equation as:

Area of roof = base area + 1 m of eaves stick out + 30° of roof angle.  
= 60 + 1 m of eaves stick out + 30° of roof angle = 113.7 m\(^2\).

**Figure 1.** Simulated typical house.
The power generated from rainfall is adapted the hydroelectric equation to determine the power. This equation is based on the energy laws of thermodynamics that consist of potential energy and kinetic energy of water. The equation is as follows:

\[ P = \text{Eff.} \times Q \times h \times g \]  

Where:
- \( \text{Eff.} \) = efficiency of the system (60%)
- \( Q \) = water discharge (ltr/s)
- \( h \) = height (3.5 m)
- \( g \) = gravitation (9.8 m/s\(^2\)),

3. Results and Discussion

Figure 2 shows the results of the average rainfall per month from 2015 to 2020 in the Total of Precipitation of Rainfall (mm) graph, as follows:

![Figure 2. Total precipitation of rainfall (mm) each month from 2015 to 2020](image)

From Figure 2, the precipitation of rainfall (mm) shows that in 2020, February has the highest average rainfall value compared to other months, while in certain months the average value of rainfall has decreased starting from March, April, May, June, July, and August for each year.

Figure 3 shows the total days of rainfall in DKI Jakarta from 2015 up to 2020. From Figure 3, total days of rainfall can be seen that the occurrence of rain every month from 2015 to 2020 tends to experience a decrease in rainy days, starting from March, April, May, June, July, August, and September for each year, while in October, November, and December the number of rainy days has increased quite significantly.
Figure 3. Total days of rainfall each month from 2015 to 2020

The rainfall intensity (I) can be calculated by total precipitation of rainfall divide by total days of rainfall, then divide again by 24 hours. Table 2 summarizes the water discharge for each month from 2015 up to 2020 by using equation 3.

Table 2. Water discharge each month from 2015 to 2020

| Month | Rainfall Flow in Year (ltr/s.m²) |
|-------|----------------------------------|
|       | 2015    | 2016    | 2017    | 2018    | 2019    | 2020    |
| 1     | 1.003   | 0.811   | 0.706   | 0.544   | 0.970   | 1.756   |
| 2     | 1.257   | 1.548   | 1.179   | 1.002   | 0.990   | 2.868   |
| 3     | 1.073   | 1.216   | 1.008   | 0.490   | 0.939   | 0.662   |
| 4     | 0.751   | 0.783   | 1.190   | 1.079   | 0.611   | 0.861   |
| 5     | 0.589   | 0.776   | 0.622   | 0.472   | 0.394   | 0.369   |
| 6     | 1.042   | 1.353   | 0.684   | 0.371   | 1.194   | 0.199   |
| 7     | 0.000   | 0.629   | 0.051   | 0.048   | 0.000   | 0.200   |
| 8     | 0.089   | 0.665   | 0.288   | 0.000   | 0.000   | 1.333   |
| 9     | 0.000   | 1.180   | 0.075   | 0.000   | 0.000   | 0.086   |
| 10    | 0.079   | 0.891   | 0.998   | 1.459   | 0.066   |
| 11    | 0.597   | 1.184   | 0.683   | 1.109   | 0.331   |
| 12    | 1.164   | 0.471   | 1.091   | 0.601   | 0.916   |

One of the uses of rainwater that occurs in Jakarta every month is to convert it into electrical energy using a water turbine. As shown in Figure 4, the estimated power generated from rainfall shows that the potential for utilizing rainwater to produce electrical energy, such as in January, February, March, April, November, and December, has the potential to generate electricity above 1000 Watts per month. With 1000 Watts of power, it can be used to turn on lamps and electronic devices that do not need a lot of power.
Figure 4. Estimated Power generated from rainfall each month from 2015 to 2020

4. Conclusions
In this work, the estimation of power generated from rainfall each month from 2015 up to 2020 is presented. The data of rainfall shows that in 2020 the month of February has the highest average value of rainfall and has decreased in rainfall starting from March, April, May, June, July, and August for each year. Based on BMKG data, the trend of decreasing rainfall occurs from March, April, May, June, July, August, and September for each year, while in October, November, and December the number of rainy days has increased quite significantly. Calculation of water discharge in the DKI Jakarta area aims to determine the potential of electric power that can be generated and utilized from water turbine system by producing at least 1000 watts per month of January, February, March, April, November, and December. However, further work should be conducted in order to reveal the power generated from rainfall with more precisely.

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