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# Generating a Lighting System by Using Pico Hydro System

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***Abstract***

*The main aim of this research is to design and develop LED based lighting system by using Pico hydro power. The proposed system is to use renewable energy to generate power in remote areas. The system is designed in a small scale which capable of lighting up a LED and sustain power when turbine stop to rotate. Reaction turbine is selected to be the suitable model for this Pico Hydro System (PHS). The performance of the system is tested by changing the materials for the blades and determines the suitable number of blades for the system to perform at maximum efficiency. Additional features, such as displaying generated voltage and flow rate has been implemented. It is observed that, the system could generate maximum voltage of 5.46V at the head height of 65 cm with flow rate of 5.51 L/Min. A total of 4.62 watt of net electrical power generated from this PHS, the value is obtained by using theoretical calculation. Finally, the system proves to be efficient in terms of generated voltage and cost, as compared to the journals which is reviewed in the literature. The scale of the design has to be remodified to be implemented in river areas.*

***Keywords***: *pico hydro system, renewable energy, reaction turbine, number of blades*



## 1. Introduction

There are several types of natural resources such as wind, water, and biomass. Water is the most reliable source of energy for living things. One of its important usage is in the form of hydroelectric used in hydroelectric systems. There are many ways of utilizing the natural water resources which one of it will be by using the Pico Hydro System (PHS) where it converts water into electricity. According to Sujith et al. in [1], hydro power is a useful technology where it fully utilizes the gravitational fall of water. This system can be implied in rural areas to generate electricity efficiently. This PHS works similarly as the hydroelectric concept but in a smaller scale which can provide less power to light up a LED (Light Emitting Diode) system by implementing the latest technology in the modern era.

According to Sachdev & Akella [2], the most commonly used generator in rural areas to provide electrification will be the diesel generator where the maintenance cost is low but a hike in the price of fuel has been a major challenge in recent years. Another drawback of the diesel generator, it creates a noisy environment which is not advisable to be used as it could cause noise pollution.

The existing problem faced by the people related to the PHS is the lack of power supply in rural areas which affects both the environment and people where no facilities can be built in these areas. Electric machinery which consumes low power can't develop in agriculture due to the above factor. Not only that, a student's life in rural areas is also being affected due to the teachers and school operating hours which clashes during the class sessions.

In technology wise, the system has additional features which will make the PHS system more valuable in the current market and it provides an advantage for people living in rural areas. The turbine designed for this system is developed by using recycle materials which can help reduce both the cost and power consumption in a small scale. The system can also be enhanced to generate greater power in the future if it's necessary. Furthermore, this system will be analyzed on its uses in lower head height environment and the effect of the water flow towards generating power.

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One of the main reasons for PHS system to be developed is due to the high demand of electricity in rural areas. The lack of electricity in these areas affects the daily routines of the inhabitant who seek to earn a living. Eventhough this system is designed in a small scale; it will be reliable for the people who live in rural and remote areas. The further development could be done in this system by implementing the same ideology provided in this research.

Authors in this work focus on the design and develop LED based lighting system by using Pico-hydro power. This work is organized as follows: section II reviews the works have been done in the PHS system. Concept design used to build the system is presented in section III, while the working principles are presented in section IV. In section.

## 2. Research Method

In recent years, a high demand for electricity access has been growing rapidly in urbanized areas whereas rural areas have been isolated where communities living in rural areas faces lack of access towards electrifications. Many types of research were being carried on by experts to supply enough electricity in rural areas.

Akhilesh & Gopal in [3] proposed an idea to set up a PHS in a run of the stream. This system uses gravitational force, in which the water will move from a higher gradient to a lower gradient through a penstock. The rotation of the blade depends on the vertical drop of the water to the turbine, which makes the turbine to rotate and thus generate electricity. To overcome the fluctuation of the voltage output, the system has come up with an electronic controller. The output result shows a measurement of 230V with a tolerance range within +- 5%. Limitation part this system can be improved by using sustainability way where the material costing for this project will be high.

Masjuri et al., in [4] developed a test rig model system of PHS, the researchers has investigated on the generated power output from a low head and less flow rate. The developed system has a head height of 1.5m and the Q (flowrate) is in a range of 24l/s, the flow rate can be varied by using a ball valve. The system has implemented 2 types of turbine which consist of axial flow turbine and cross flow turbine. Before the fabrication of the model complete analysis of the structure has been critically analyse by the using COSMOS. Simulation software CFD (Computational Fluid Dynamics) and simulation based result has been recorded, the design of the turbine blades has used the angle of 410 and the diameter of the turbine blade is 162mm. The test-rig model has generated a total power of 627.84 watts with a maximum velocity of the flow reaches 14.09 m/s.

Komgrich & Kanit in [5] proposed a system which uses a pump in order to rotate the turbine and generates electricity. The system includes a submersible pump where it will inject the nozzle of the turbine to drive the turbine to rotate faster. vortex model in which the combination of both designed has developed a sufficient output of 21.7W.

Gopal & Saajan in [6] developed PHS system with a medium head and power jet pelton turbine design, the system by including factors such a cost, power demand in specific region of application and materials. Total of 2.3 kW useful electrical energy has been generated by the system and it could supply up to 100 household. The system has included a battery and an inverter to change the power to DC to AC, there are certain limitations on the system has spending for the battery will be increase. In addition, the system is only applicable at the medium head areas.

Seema et al., in [7] proposed a development of PHS by using a Pelton turbine, this relative turbine consists of a semi-ellipsoidal shape in where the rear bucket is designed so that the water exiting from the turbine never backflow to the incoming of the turbine. The inlet angle used in this turbine is 1º to 3º. The material used to build the turbine is by using the UPVC (Unplasticized Poly Vinyl Chloride) into total of 36 pieces with a dimension of 65mm width each, the distance provided from each of the blades is 5mm. The edge of the blades designed in a v-shape, where this will benefit on the weight of turbine, less weight turbine can make a faster rotation. The rotation of the turbine when the water hits the jet were recorded where this turbine rotates at a flow range of 11/s with the head provided is 9m, overall the system had achieved the output power of 13.9W.

Gunjan & Chauhan in [8] developed a Pico Micro Hydro System (PMHS) to generate DC voltage. The system has used Pelton turbine design by including a pulley system. There is a total of 12 blades with a length of 0.14m. The materials for the blades is a stainless-steel spoons.

The blades were attached on the cycle rim which has a total dimeter of 0.21m. The ratio between the pulleys is 10:1, hence this shows that small pulley rotates 10 times than a big pulley. The designed system has generated a total power of 8.408W with 5.646 V. Furthermore, rpm of the system rotates at 1500 rpm at maximum load.

The major concern of the existing system is that no measurement or reading shows the output power of the system by using technology, according to Seema et al., in [7], the output power generated will be measured by using an ammeter and voltmeter, by implementing this technology or enhancement to the system it will ensure that the reading will always be shown to make sure the user knows the amount of power drawn by the system in a certain amount of time. This can prevent short circuit as the system uses dc components. The power developed through this PHS will be more sustainable compared to the current system which uses a generator to generate electricity.

## 3. Methodology

To design an efficient type of PHS several types of sensor and software's has been used, this is to ensure the implemented system achieves a high level of efficiency. The flow rate of water [L/min] has been determined by using YF-S201 sensor and it is connected to Arduino UNO. Wiring diagram of the system has been developed by using software PROTEUS. DC motor is used in this PHS, in addition, 16x2 LCD display has been used to display the reading of the flow rate and voltmeter. During the investigation period, the design of the turbine consist of 12 blades with each of the blades has 7.5 cm length from the outer radius of the turbine and the material used is bamboo shoots. However, the changes were made to the material and the length of the blades, plastic bottles will be used instead of bamboo shoots.

The reason for selecting plastic bottles is that, plastic bottles are commonly known as recycle materials and it is easily available. Moreover, the use of plastic bottles has its own advantage in terms of cost and performance. In terms of cost, bamboos were widely used in many products such as bamboo flooring [9] the cost of the bamboo sticks has seen a hike in recent years. Secondly, performance of the system will be affected, this is because bamboos has tendency to absorb water when soaked into water for a longer period of time, since the turbine blades are exposed to the water, the increase in the weight of the blades will be affecting the rotation of the turbine [10].

Besides that, the selection of the DC Motor has been given importance as it affect the generated voltage. Initial, proposed design is using 9V DC motor with maximum Revolution Per Minute (RPM) of 1600, but during the system implementation similar maximum voltage of 9V DC motor will be used but with lower rpm. No load rpm will be 30rpm, this selection is made as in this PHS DC motor will be used as a generator. A lower rpm generator can generate more consistent power output. Moreover, the selection of the DC motor is made as higher rpm motors have a thick shaft which is more than 4mm hence it cannot be fitted in the runner of the turbine [11]. The specification of the selected motor has been tabulated in Table 1.

Table 1. Specification of DC Motor

| Parameters | Data |
|---|---|
| RPM (No Load) | 30 rpm |
| Torque (Stall Torque) | 7.5 Kg.cm |
| Rated Voltage | 9V |

Theoretical calculations which is done by extracting values from the hardware and by applying the fundamental law of physics. Theoretical calculation of power obtained from Potential, Kinetic and Electrical were calculated by using equation such as:

$$P_{in} = H\ (m) \times Q\ (L/s) \times g\ (m/s^2) \quad (1)$$

Where:
H = Head (m)

Q = Flow Rate (L/s)
g = Gravitational Force [9.81 m/s2]

Net head= H (m)x0.25%
Net Power of Electrical=Mechanical Powerxgenerator efficiency (2)
Net Power of Electrical = 5.683 Wx 0.85

Torque (T)= ρxQ (RinVin-Rout Vout) (3)

Where:
Rin=Length of the blade (17.5 cm)
Rout=Interior radius of the runner (2.5 cm)
ρ=Density of Water [ 1 gm/m3]
Q=1.78 [L/s]
Vin=Tangential Fluid velocity (m/s)
Vout=Released fluid velocity (m/s)

## 4. Working Principle

There will be 3 main parts which will be briefed in this section first will be on the basic concept extracted from physics, second focusing on the flow sensor and thirdly will be on turbine mechanism. The basic working principle of this PHS is by converting Potential Energy to Kinetic Energy then to Electrical Energy. The changes in the energy occur when stored water from tank falling thru a pipeline which then rotates the blades of the turbine in which the runner is connected to the shaft of the DC Motor. This turbine mechanism is known as reaction turbine. The gravitational fall of water can be related to this phenomenon.

The pressure of the liquid needs to remain high as an increase in pressure will increase the density of water. Flow sensor has been used to determine the flow rate of the falling water. The flow sensor has its own built pinwheel sensor in which it is connected to a magnetic hall effect which will measure the amount of water which has fallen over it, the flow rate of the water will be displayed in 16×2 LCD display. The turbine will rotate in a CW (Clock Wise) direction to generate electricity. If the turbine rotates in opposite way around the voltmeter will display 0V. The rotation speed of the turbine depends on the flow of water, as high flow of water and greater height the rotation will increase. The shaft of the motor will rotate upon T (Torque) rotation of the turbine, the movement will generate power.

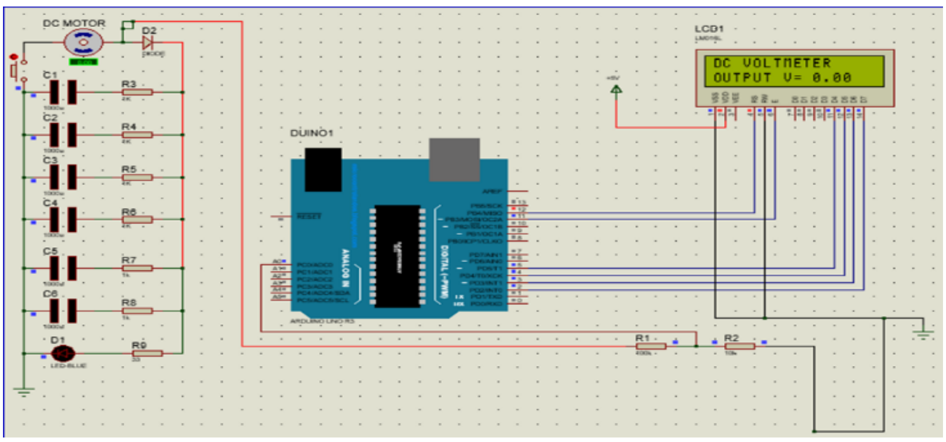


Figure 1. Wiring diagram of DC Voltmeter

The output of the system will be indicated from two ways. Firstly, will be in terms of the generated voltage of the DC motor which will be displayed in the 16×2 LCD display, the second indication will be shown in 5mm LED which will turn “ON” when there is a presence of voltage.

Once the turbine has stopped rotating the fully charged capacitor will discharge the charge (Q) to the LED, the LED will turn "ON" for a certain amount of time but the brightness will be dimming as the charged in the capacitor reduces. These were the basic principle of the designed PHS. Figure 1 shows the design of wiring circuit which is used in this PHS, while Figure 2 shows the hardware implemetd of the charging circuit, which is connected thru capacitor and 5 mm LED.

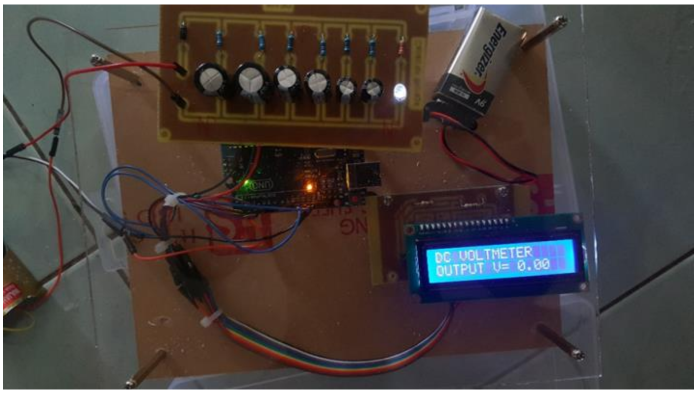


Figure 2. Charging Circuit

## 5. Testing

To identify the optimum efficiency of the system, 3 test were conducted. The explanation for the each of testing and figures will be shown. Each of the test results will be analyzed by providing data in the form of table and graph. All tests are carried out for the hardware system of the design. Figure 3 displays the experimental setup.

Figure 3. Experimental Setup

### 5.1. Test to determine Optimum Height for the PHS

This test is conducted to identify the optimum height for the modeled PHS to generate the highest voltage. Head height in the PHS is necessary as it can determine the suitable head range which can affect the rotation of the turbine. Furthermore, this test is conducted to apply theoretical knowledge on the PHS which relates to the effects on the power generation from various heights. Due to the limited equipment's, maximum range of the head height could not be performed.

Tank A were placed at the top by using support from tripod stand, the height of the tank is varied by 10 cm. The minimum height is 15 cm, this is decided as below this range the pipe system will be in touch with the blades of the turbine. Height Measurement were taken from the center of the runner to the early point of the pipeline system. Upon completion of each height, the water level of the tank is refilled to ensure that there will be no changes on the water pressure inside the tank. The designed voltmeter circuit were connected to the turbine which will display the generated voltage for different range of the height. The result of the testing has been tabulated in Table 2.

Table 2. Optimum Height

| *Height (cm)* | *Voltage output (V)* |
|---|---|
| 15 | 1.89 |
| 25 | 2.47 |
| 35 | 3.33 |
| 45 | 4.01 |
| 55 | 4.96 |
| 65 | 5.46 |

The vertical distance of the tank from the turbine affects the generated output voltage, at 15 cm the generated voltage of the PHS was 1.89V, when the height was increased by 10cm, changes on the voltage output increased by 0.58V. The highest margin was identified in between of 45 cm to 55cm with a difference of 0.95V. Besides, when the height was further increases to 65cm only 0.5V margin were seen from 55cm to 65cm, and highest voltage generated at 65 cm which was 5.46V. The reason for the reduction of the voltage margin was due to the falling water from the pipe which started to spread and hit on the blades of the turbine. Hence, all the upcoming test has been set to 65 cm as it has the highest output voltage.

### 5.2. Testing on Number of Blades in Turbine

This test is performed to identify the suitable number of blades which needs to be implemented to generate the highest voltage. The number of blades affects the voltage as the blades must occupy the full circular area of the runner. The spacing of each blade is very essential as when the water pushes the turbine blades the velocity reduces pressure at the runner shaft which will be an issue.

The number of blades could be proved significant to the cost of the product as an increase in number of blades without a marginal change of voltage output will not be sustainable. The blades made up from plastics bottles were placed by a margin of 2 until 10 blades and it should be connected to the runner of the turbine. The margin is set from 2 blades to provide a balance for the runner. A maximum of 10 blades can fit in the runner, thus maximum of 10 blades were used to test.

The generated voltages for each different number of blades were recorded by turning on the ball valve for 100%. The height of the tank is placed at 65 cm and water level in the tank is maintained for all the testing. The designed hardware for the turbine is shown in Figure 4, while the result of the voltage output and number of blades from 2 to 10 blades were recorded in Table 3.

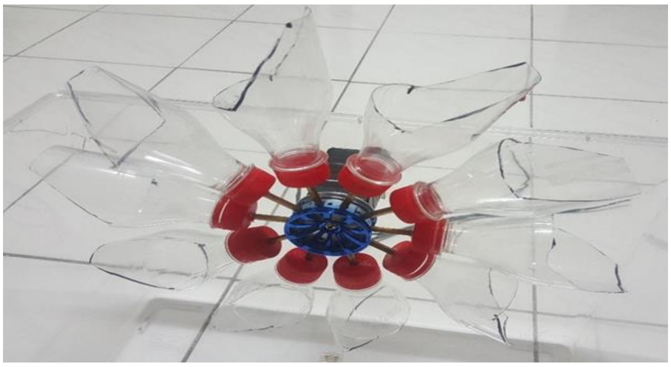

Figure 4. Hardware design of turbine

Table 3. Number of Blades

| Testing on the Number of blades | |
|---|---|
| *No of blades* | *Voltage output (V)* |
| 2 | 0 |
| 4 | 1.89 |
| 6 | 3.54 |
| 8 | 4.52 |
| 10 | 5.46 |

Table 3 proves that an increase in the number blades affects the generated voltage. By using two blades the turbine could not rotate due to the lack of surface for the flowing water to hit the blades, additionally the turbine could rotate up to half a cycle of the rotation hence 2 blades were not sufficient. The major swing in the voltage output occurred when 4 blades to 6 blades were used, hence from that we can conclude that minimum number of turbine required to rotate was 4 blades. The highest changes of the voltage output of 1.65V were occurred in between of 4 blades and 6 blades.

The highest voltage recorded when there was a total of 10 blades in which it generated 5.46V. Eventhough, there was a slight drop of voltage margin in between 8 blades and 10 blades but the generated voltage difference was 0.94V hence maximum of 10 blades were chosen in this PHS.

### 5.3. Testing on Different Material of Blade

Material selection is important as it could affect the rotation of the turbine. In this PHS, the focus is given to recycle materials such as Plastics bottles and Aluminium Tin. 390 mL coke bottles were used as plastic material and 240mL Nescafe Tin were used as Aluminium.

The setup of the experiment remained the same. Two materials for the blades had been tested within the range of 2 to 10 blades. The Aluminium were cut into half and placed in the runner spacer. Voltage output for each of the different types of materials and number of blades were recorded. The data collected for the testing of materials against voltage output has been tabulated in Table 4.

Table 4. Result of Testing for Different Materials of Blades with Voltage Output

| **Testing on the Materials Comparison** | | |
|---|---|---|
| ***Materials*** | ***No of Blades*** | ***Voltage output (V)*** |
| Aluminium | 2 | 0 |
| Plastics | 2 | 0 |
| Aluminium | 4 | 1.56 |
| Plastics | 4 | 1.89 |
| Aluminium | 6 | 2.86 |
| Plastics | 6 | 3.54 |
| Aluminium | 8 | 3.32 |
| Plastics | 8 | 4.52 |
| Aluminium | 10 | 4.46 |
| Plastics | 10 | 5.46 |

It can be concluded that the use of 2 blades will not generate voltage even though the materials were changed. The margin of the voltage output changed drastically when 8 number of blades had been used as the difference is at 1.2 V. In this PHS, there will be a total of 10 blades which were made up of plastic bottle used.

### 5.4. Testing on Flow rate and Output Voltage

This test is conducted to identify the effect of the flow rate towards the voltage output. From this test, the suitable flow rate for the PHS can be identified. Moreover, this test was conducted to recognize the voltage output generated in different condition of water flow such as in high flow, medium flow and slow flowing. It is necessary to conduct this test as it required types of flow which can be identified.

In this experiment, the 3/4-inch ball connected in the pipeline system was used to control the flowing rate of the water and flowing rate of the water was determined by connecting

YF-S201 sensor to the LCD display, which was attached to the exterior part of Tank A. The ball valve has a 900 turn to close or open a valve, the valve was controlled manually. The DC motor was connected to LCD to display the output voltage. The result obtained were tabulated as shown in Table 5 the data were listed in terms of percentage as it shows the control rate of the flow from 25% to 100%.

Table 5. Results of Testing Flow Rate and Output Voltage

| Valve Opening | Flow Rate (L/Min) | Voltage Output (V) |
|---|---|---|
| 25% | 2.11 | 1.73 |
| 50% | 3.37 | 3.65 |
| 75% | 4.58 | 4.26 |
| 100% | 5.52 | 5.46 |

It can be concluded that the output voltage is directly proportional to the increase in the flow rate, lowest value of the flow rate was 2.11 L/Min with the output voltage of 1.73V. The highest marginal of flow rate was in between of 25% and 50% as the rate was 1.26 L/Min with voltage difference of 1.92V.

The difference of the flow rate was decreasing at 75% to 100% as the difference was 0.94 L/Min with a voltage of 1.2V. The voltage difference at 25%-50% went higher to 75%-100%. This is due to the loss of water in the pipeline system. The highest recorded voltage was 5.46 V with a flow rate of 5.52 L/Min. Hence, the it's proven that increase in the flow rate of the water has made effect to the generated voltage.

### 5.5. Testing on Discharging rate of LED with Flowrate

This testing were conducted to identify the affect of different types of water flow acting towards the discharging rate of 5mm LED when the ball valve was turn ON for 20 seconds. This test was performed to determine the competence of the system to sustain the charge in the charging circuit when the turbine stop to rotate. The flow rate will be affecting the generated voltage where the influence of the flow rate is visible to the discharging rate of the LED.

In this experimental setup, voltmeter had been connected to the dc motor. 2 stopwatch were used in this testing, which measures the time taken in seconds for the water to flow and measure the time taken in seconds for the LED to discharge. The flow rate of the water was controlled from 25% to 100%. At the end of the testing the flow rate, output voltage and time taken were recorded. In table 6 result of the discharging time of the flow rate has been tabulated.

Table 6. Result of Testing for Different Materials of Blades with Voltage Output

| **Testing of the flow rate versus time taken for the LED to discharge** | | | |
|---|---|---|---|
| *Flow Rate (L/Min)* | *Time Taken for the flow of water (s)* | *Voltage output (V)* | *Time taken for LED to discharged (s)* |
| 2.11 L/Min | 20 | 1.73 | 47 |
| 3.37 L/Min | 20 | 3.65 | 58 |
| 4.58 L/Min | 20 | 4.26 | 75 |
| 5.52 L/Min | 20 | 5.46 | 98 |

Analyzation of the data from Table 6 proves that flow rate of water influences the generated voltage output which effects the discharging rate of the LED. The maximum time taken for LED to be fully discharged was at 98 seconds with a flow rate of 5.52 L/Min. Lowest rate of the discharging were seen at 47seconds as the generated voltage was at 1.73V with a flow rate of 2.11 L/Min.

The discharging rate gradually increases against the generated voltage. The difference of 0.94 L/Min affects the rate of discharging up to 23 second, this was analyzed by referring to the flow rate at 5.2 L/min and 4.58L/min. Hence, it can be concluded that the changes of the rate of flow influenced on the discharging rate.

## 6. Conclusion

Sustainable development research has been given importance in reason years, as it could benefit providing electricity in remote areas. Common system of this Pico Hydro System has been reviewed. An efficient generated output voltage has been generated by this system with an overall voltage of 5.46 V at a optimum height of 65 cm. Moreover, the system has acquired in technology performance such flow sensor and voltmeter for easy maintenance work can be done. His small scale of hydro plant can be used in a household, where it can be completed by doing dual task at a time.

This project will be beneficial in terms of its sustainability where the world is currently focused on, materials which were used will be more towards the sustainability inclusive of the technology part as the technology used will be an affordable one. This system is also expected to sustain the power which is supplied with less fluctuation.

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