Perceived Challenges in The Design and Construction of a Gravity-Based Generator and Assessment of Its Performance

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Abstract— The gravity-based generator is a renewable energy technology that employs the gravitational force to generate electrical energy. However, the efficiency and output of the generator can be affected by various factors. Despite the growing interest in this concept, there is a lack of comprehensive research on perceived challenges involving design and construction, as well as its performance based on design factors - heights and weights used. In addition, actual data on variations in perceived difficulties and performance are required. This study aimed to fill this gap by investigating gravity-based generators' perceived challenges and performance. It enables researchers, engineers, and innovators to develop effective strategies for improved efficiency and reliability of GPG. This research yielded valuable information on how to enhance and optimize the practical utilization of GPG. It quantified the perceived difficulties associated with the design and construction of GPG. It also established a direct correlation between the incorporation of weights into GPG and the resultant impact on both voltage and running time. The researchers suggest that future studies undertake a more in-depth analysis of specific challenges encountered in the construction of GPG's and also innovate existing GPG designs to generate higher output for longer period of time.

Indexed Terms— Gravity-based Generator, Assessment of Performance of Gravity-Based Generator, Electrical Engineering, Renewable Energy Technology

I. INTRODUCTION

Natural resources that are sustainable and replete, such sunlight, wind, rain, tides, and geothermal heat, are the source of renewable energy. However, in some parts of the world, energy requiring processes are used in cities and households. For example, lighting is still reliant on expensive and polluting kerosene, leading to health and environmental hazards. Additionally, it was projected that every year in India alone, nearly 2.5 million people experience severe burns as a result of kerosene lamps that have overturned in addition to the enormous amounts of carbon dioxide produced (Hossen, et al., 2015). In this regard, the use of renewable resources is crucial in mitigating the effects of pollution and global warming, making it imperative to explore alternative energy sources (Srikanth, et al, 2020). Because gravity is constant, abundant, and accessible everywhere on Earth, it is a viable energy source. In this project, a heavy particle's gravitational energy is transformed into electrical energy. Researchers are now looking into gravity, one of our renewable resources, to identify signs of competitive advantage in the emerging eco-industries marketplaces and the related business opportunities for pioneering countries. Gravity-based power generation offers a promising solution as it is widely available, abundant, and consistent (Kuik, 2019).

The challenges in designing and constructing gravity-based generator include the need for robust mechanical design to efficiently convert potential energy into electrical energy, ensuring system stability by managing weight distribution and vibrations, optimizing power output through design considerations, incorporating safety mechanisms for user protection, and designing for ease of maintenance and long-term durability by addressing accessibility by minimizing wear and tear. Overcoming these challenges is crucial to developing efficient and reliable gravity-based generators. Furthermore, there is a need for empirical evidence regarding the differences in perceived challenges and performance between various designs of gravity-based generators (GPG).

In the realm of renewable energy generation, gravity-based generators stand out as a unique technology that harnesses immense power of gravity. One concept used utilize gravity power generation mechanism with a DC generator transform the potential energy into electricity. (Ambade, et.al., 2014). However, the design and construction of these generators pose several challenges that need to be addressed to ensure their successful implementation and efficient performance. This research aimed to recognize and assess the key perceived challenges encountered in the design and construction of gravity-based generators. By understanding these challenges, researchers, engineers, and innovators can develop effective strategies and solutions to overcome them. This exploration of obstacles faced during the design and construction procedure will provide valuable insights into improving the gravity-based generators' reliability, efficiency and durability. Additionally, this study would investigate how variations in the heights and weights used in the generator's design impact its overall performance. These components play a crucial role in determining the generator's output and efficiency. By comprehending the relationship between design parameters and performance metrics such as power output, rotational speed, and energy conversion efficiency, researchers can optimize the generator's design to maximize its effectiveness. Material selection affects durability, energy loss, and energy conversion. Proper mechanical configurations minimize energy losses and enhance efficiency. By identifying effective combinations, researchers can advance the practical application of gravity-based generators in renewable energy systems Furthermore, the research would establish specific performance metrics that serve as benchmarks for evaluating the effectiveness and efficiency of GPG.

Analyzing variations in performance metrics across different conditions will gain a comprehensive understanding on how GPG can potentially be improved.

Challenges in designing and constructing GPG include robust mechanical design to efficiently convert potential energy into electrical energy. Consider conducting further research on materials that offer high strength, durability, and low friction to minimize energy losses and maximize the generator's efficiency. A robust design is something that can tolerate variation. It should be insensitive to external noises and tolerance, enabling the efficient conversion of potential energy into electrical energy (Dehnad, 2012). Aside from weight distribution, GPG also had vibration management. In many engineering fields, dynamics, vibrations, and impacts are crucial components for guaranteeing structural integrity and operational functionality. However, practical challenges related to these areas have often remained unresolved despite significant investments. (Jia, 2018). Achieving system stability necessitates adept management of weight distribution and vibrations. It is also a challenge to optimize power output for GPG since we have several factors to consider. We also need to prioritize safety by incorporating safety mechanisms in the generator's design. Incorporating safety mechanism to safeguard users is essential. This includes features such as emergency stop buttons, overcurrent protection, and insulation to mitigate potential hazards and ensure safe operation. Lastly, another challenge in designing and constructing GPG is maintenance and long-term durability. We could consider incorporating features such as removable panels, accessible components, and modular designs that simplify maintenance tasks and extend the generator's lifespan, and minimize wear and tear. A study of Hossein of India explored varying effects of a 1 kg mass released from varying heights produces varying outputs and varying masses released from a constant height. The safety of the project should also be considered during design and construction. (Hossen, 2015).

The findings of this research will contribute to the existing knowledge on gravity-based generator technology. Additionally, the study will shed light on the impact of key design parameters on generator performance and establish performance metrics for evaluating their efficiency and effectiveness.

Ultimately, this research will facilitate the development of improved gravity-based generators, paving the way for their wider adoption and contributing to the advancement of sustainable energy solutions.

Several studies have been done regarding gravity-based generators. The first gravity-powered generator was developed by Chun-Chao Wang and Yuh-Suiang Wang in 2007. According to their patent US20090115195A (Kızılors et al, 2017). They thought the concept, which involves a straightforward machine that is environmentally friendly and produces power, would be groundbreaking for the engineering field. However, because it was based on perpetual motion, machine produced was a failed design. It is well known that Martin Philip Riddiford's hypothetical machines cannot function as generators and can only operate in isolated systems. First operational gravity-powered generator was made in 2009, and it was later published in 2011 under Patent Number: WO2011045606A1 with "Therefore Limited" as its assignee. The GPG was still in its conceptual stages at this point. With Martin and James William Reeves, this model was further enhanced in 2014. The final "Portable Apparatus for Generating Electricity" was made in 2015 by Martin, James and T. A. Polak. It was crowd funded by "Indiegogo Inc." Modified versions were later developed, and their production was done in Kenya. The revised design was dubbed "Gravity Light 2: Made in Africa.".

Another specific study conducted in India focused on the design and construction of a gravity- powered light. (Madhuri, et al., 2022). The study involved a gravity energy conversion unit that consisted of a transmitting member with external single directional swing arms. The transmitting member circulated with the direction of gravity, generating a larger positive torque when the single directional arms were cast outwards and a smaller negative torque when they cooperated with the inward-folding action of the swing arm. This process allowed for continuous casting of the single directional arms using gravity. Once cast, the swing arm descended under the force of gravity from a higher position to a lower one, enabling the connected transmitting member to operate continuously. As a result, gravitational potential energy (GPE) was converted into kinetic energy and transmitted outward to generate power through energy conversion.

Another study explored the potential for transforming energy production and transmission on a larger scale through the use of a Hydroelectric-Gravity Power Generator. Currently, gravitational potential energy is effectively harnessed in hydroelectric power stations, which store water behind dams built across rivers or reservoirs. The stored water creates a pressure head that propels water through an opening, generating power for a generator (Hunt, 2020). In the context of Malaysia's Sustainable Energy Program, a specific study focused on reviewing the feasibility of implementing a Gravity Power Generation Mechanism. (Nabipour, Hadi, et al., 2015). Despite being an oil-producing nation, Malaysia possesses abundant untapped natural resources such as sunlight, water, wind, geothermal energy, and gravity, which have not been fully utilized due to the predominant focus on oil and gas production. While hydroelectric power has gained traction in energy policies to promote sustainable power generation, other gravity-based power generation mechanisms have not been adequately explored in Malaysia, primarily due to limited knowledge in this field. However, the study revealed that gravity-based power systems are more suited for small-scale applications in off-the-grid areas. Therefore, conducting a comprehensive literature review to identify various gravity power generation mechanisms and undertake viability studies to implement the most suitable system for sustainable energy production in rural regions of Malaysia is crucial.

Another study examined the design of a gravity light for home use An LED bulb was coupled to an adjustable LED lamp that could be hung on a wall or hanging from the ceiling to make up the gravity light. The pendulum-based operating system of this gravity lamp was used. It included a puller mechanism and a ballast bag for weight. When the ballast bag was suspended, the potential energy stored in it was converted into kinetic energy through gravity. This kinetic energy was then transformed into electricity by a dynamo that moved along a larger wheel. The design of the gravity light was straightforward and user-friendly. Several calculations were performed to determine the rotational speed of the two wheels involved, namely the larger bicycle wheel and the smaller pulley. The study concluded that for a 1 kg weight released from a height of 1.45 meters, the input energy was measured at 14.23 J, while the output from the generator was 1.62 J. Consequently, the efficiency of the gravity-powered light was determined to be 11.23%. The study also explored the varying effects of a 1 kg weight released from heights of 3.5 until 5.5 feet, and varying masses from a fixed height of 3.5 feet as shown in the accompanying tables (Hossen, 2015).

Please see the observations made for the recorded time the LED light is turned on, and the different voltages made when weight differed.

Table 1 – Lighting Time

Observation	Weight	Height (feet)	Lighting Time (seconds)
1	1 kg	3.5	42
2	1 kg	4.0	49
3	1 kg	4.5	56
4	1 kg	5.0	64
5	1 kg	5.5	75

This table was the observations of lighting time for different height of a 1 kg mass

Table 2 - Current and Voltage Measurement

Observation	Weight	Voltage (V)	Current (mA)	Lighting Time (seconds)
1	1.0 kg	3.2	12	42
2	1.5 kg	3.6	15	49
3	2.0 kg	3.9	17	56
4	2.5 kg	4.3	19	64
5	3.0 kg	4.7	22	75

This table show the actual voltage and current measurements made from a fixed height of 3.5 feet for various masses.

Research work conducted in India focused also on designing and developing a Gravity-Powered Generator (Hossen, et al., 2015). In contrast to other studies, the researchers leveraged advanced technology and incorporated customized planetary gears, Cable and Bag Shaft, Sprag Clutch Bearings Shaft with Key Gear Mesh, Gear mesh, Belt system, Wires, and Gear Housing. The GPG utilized a high gear ratio of 1:654, enabling a single rotation of the gear to generate a maximum of 20 minutes of electricity that can be utilized by everyone. The estimated overall dimensions of the GPG were approximately 415mm x 340mm x 300mm, with a weight of around 10.5kg. The generator consisted of a total of 122 parts, including fasteners, as per the CAD models generated for the study. In addition to the electrical aspect, the study also evaluated the mechanical performance of the generator

However, the aforementioned studies did not address the perceived challenges involved in creating a gravity-based generator. This research aimed to assess both the perceived challenges in GPG and evaluate its performance. Additionally, the research serves as an awareness initiative regarding the potential energy resource that can be harnessed from gravity, particularly with the inclusion of a turbine in the system. The findings of this study will be significant for engineers, researchers and innovators on their endeavors aimed at designing and developing more efficient gravity-based generators. Here is the conceptual framework of the research study:

- Design and Construction

Design a GPG as per the given standard construction.

Perceived challenges in GPG Design and Construction (Scale of 1 – 5, 1 – Highest, 5 – Lowest)

a) Robust mechanical design
b) Stability by managing weight distribution and vibrations
c) Optimizing power output
d) Incorporating safety mechanisms
e) Output with easy maintenance and long-term durability

- Performance Test

Performance Assessment Test of GPG

1) Observation of running time and voltage from different heights (constant: 1.25 kg weight)
2) Observation of running time and voltage with varying weights (constant: 5.5 m)

- Output

Conclusion and Recommendation on Gravity-Based Generators

For the design of GPG, principle of converting potential energy into kinetic energy, and then into electrical energy was used. The design would include a wheel, dynamo, weight, led light, belt, and stand. The GPG utilizes the force of gravity acting on the weight or mass that is lifted to a certain light. Variable weights or loads can be mounted on the belt through pulleys. The belt is connecting a DC dynamo and a wheel with the weight.

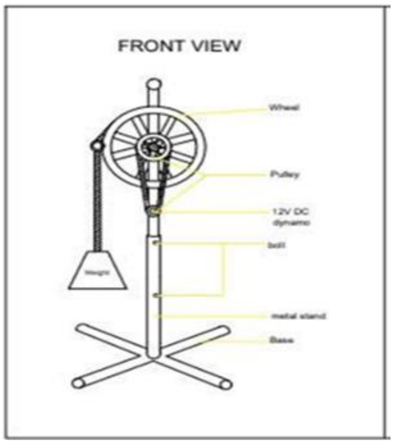

Figure 1 – Front View of GPG

Figure 1-a shows the front view of the GPG where an attached cable and weights on the wheel can be seen. The wheel and the dynamo are connected and aligned.

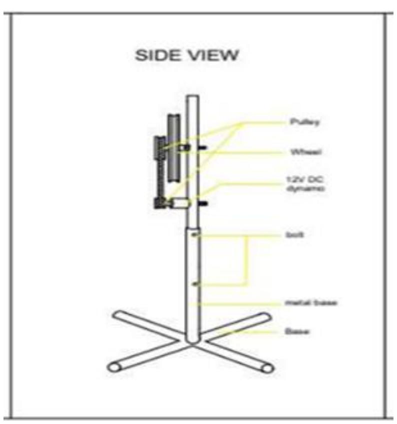

Figure 2 – Side View of GPG

Figure 2 shows the side view of GPG where the connection of the belt from the two (2) pulleys is shown.

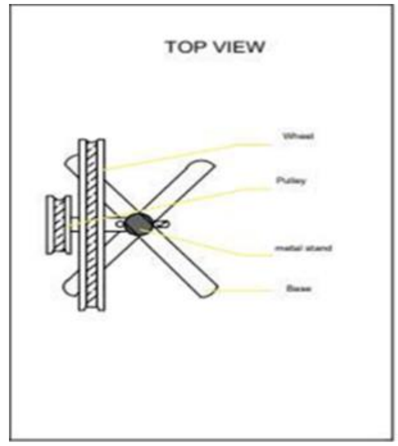

Figure 3 - Top view of GPG

Figure 3 shows the top view of the GPG where the stand can be shown and where the wheels and dynamo are installed to the top view angle.

II. METHODOLOGY

- *Research Design*

The research study utilized the quantitative methodology. It employed the use of experimental design. The researchers did not manipulate any of the variables, but rather only assessed the sample and/or the variables. Two (2) variables are varied – weight and height. Three (3) trials are done to get the mean of voltages and running time. The researchers examined how the performance of GPG is affected by varying heights with constant weight, and varying weights with constant height. The researchers analyzed the mean of the data samples. Also, the researchers computed the correlation of voltages and running time in varying heights and varying weights.

The research was designed to quantitatively measure the perceived challenges encountered by participants during the design and construction of a gravity-based generator. The study focused on assessing various challenges associated with mechanical design, system stability, power output optimization, safety considerations, and maintenance and durability aspects of the generator. To evaluate the performance of the gravity-based generators, specific metrics were employed as part of the Performance Evaluation Metrics. These metrics included measuring the electrical output of the generator in voltage units and determining the running time for the load in seconds. This approach allows for a more comprehensive and reliable assessment of the design factors affecting the generators, ultimately contributing to informed improvements in future construction and design processes.

- *Research Instrument*

By harnessing the force of gravity, a gravity- based generator provides a renewable and sustainable source of energy. It offers an alternative to traditional power generation methods and can be particularly useful in areas with limited access to electricity or as a backup power source. The design would include a wheel, dynamo, load, led light, belt, and stand. Five (5) perceived challenges encountered are included in the first set of categories.

After design, installation and testing, data recorded were based on the outcomes observed as per voltage and running time on varying conditions. Quantitative analysis was performed on the data following the completion of the GPG activity. The analysis included mean and t-tests to be able to correlate voltages and running time at varying heights and varying weights.

- *Data Collection:*

Data collection was conducted after design, construction, and activities using a structured assessment form. The researchers carefully consolidated, tallied, and recorded the collected data for further analysis. This process allowed for a comprehensive examination of the challenges encountered during the design and construction of gravity-based generators and the assessment of their performance.

The researchers aimed to gather valuable data that would reach our objective. The records on voltages generated and the generator's running time under varying weights and heights would provide insights on the performance of the project output, which allowed evaluation of how different weight loads and heights influenced the electrical output and overall performance of the generator. Such observations provided valuable information on the efficiency and effectiveness of the gravity-based generator in converting gravitational potential energy into electrical energy

- *Data Analysis*

Using the data garnered, the data analysis plan encompassed a number of procedures leading to the findings or the result of the study about perceived challenges in designing and constructing gravity--based generator and assessment of its performance - mean and standard deviation and independent correlation test. The researchers first assessed the level of perceived challenges in design and design and constructing gravity-based generators and then the performance tests in terms of voltage and running time-based on varying loads.

III. RESULTS AND DISCUSSION

This paper was guided by its purpose to get the perceived challenges in the design and construction of a gravity-based generator and an assessment of its performance. The results were presented in the following table.

Table 3 – Perceived Level of challenges in the design and construction of a of GPG

Work Status	Mean	Interpretation
Robust mechanical design	2	High
Stability by managing weight distribution and vibrations	2	High
Optimizing power output	3	Neutral
Incorporating safety mechanisms	3	Neutral
Output with easy maintenance and for long-term durability	4	Low
Mean	**3**	**Neutral**

As shown in Table 3, producing an output that has an easy maintenance and long-term durability has the lowest value of 4 meaning is the lowest perceived challenge in design and construction. The highest has a mean of 2 for creating robust design and stability which means they are the perceived with the highest level of challenge.

The ratings produced where based as to how the challenges were experienced during the design and construction. Achieving stability in robust mechanical design posed a high level of challenge, primarily due to managing weight distribution and vibration. The design could be innovated through effective damping and control mechanisms.

On the other hand, the challenge in optimizing power output is neutral since we have resources and height for the GPG can be adjusted or selected gaining more power output. Advancements in computational tools and well-established engineering principles can make this aspect relatively manageable. Also, incorporation of safety mechanisms was seen to be of neutral level of challenge since there are standard safety protocols and guidelines that can be followed to implement appropriate mechanisms such as emergency stop systems, safety interlocks and protective covers. On the other hand, the least perceived challenge is easy maintenance and long-term durability since GPG can be accessible, serviceable and requires minimal downtown for maintenance activities.

- *Assessment of GPG Performance*

Table 4 – Voltage and Running Time Measurements Using Constant Weight

Observations	Weight (kg)	Height (meters)	Voltage, V (mean after 3 trials)	Running Time, seconds (mean after 3 trials)
1	1.25 kg	2.5	11.5	7.0
2	1.25 kg	3.5	12.0	9.0
3	1.25 kg	4.5	12.3	16.0
4	1.25 kg	5.5	12.9	18.0
5	1.25 kg	6.5	14.0	20.0
Average			**12.54 V**	**14 sec**

Table 4 shows average for voltage is 12.54 V and running time is only 14 seconds at 1.25 kg, using a constant weight 1.25 kg and varying heights from 2.5 meters to 6.5 meters. This is with respect to a wheel at 14 inches diameter as per the output made for this research.

Standard deviation for voltage is 0.8593, while standard deviation for running time is 5.099.

Table 5 – Voltage and Running Time Measurement with Constant Height

Observations	Weight (kg)	Height (meters)	Voltage, V (mean after 3 trials)	Running Time (seconds) (mean after 3 trials)
1	1.25	5.5	11.0	10.5
2	2.50	5.5	11.3	13.93
3	3.00	5.5	11.5	15.64
4	4.25	5.5	12.5	18.00
5	5.50	5.5	14.0	20.00
Average			**12.08 V**	**15.61 sec**

Table 5 shows average for voltage is 12.08 V and running time is only 15.61 seconds using different weights from 1.25 kgs to 5.5 kgs with a constant height of 5.5 meters. This is with respect to a wheel at 14 inches diameter as per the output made for this research.

Standard deviation for voltage is 1.093, while standard deviation for running time is 3.284.

Please refer to Tables 1 and 2 for a comparative analysis of this current research to the study of Hossen (2015) that used also a basic gravity powered led light. Our study used a higher capacity for dynamo which is 12VDC. Voltages from previous study were only from 3.2 V to 4.7 V while in this study, highest voltage generated was 14V. Also, the height had a higher range from 2.5 to 6.5 meters (8.2 feet to 21 feet) while the previous study was only from 3.5 to 5.5 feet. However, the researchers note that despite achieving higher voltage output, the running time is shorter in the current study.

Table 6 - Significant Differences of Voltages and Running Time

Variable	p-value	Interpretation
Voltage Outputs (varying heights, constant weight)	0.2547	No significant difference
Running time (constant height with varying weights)	.304511	No significant difference

Significant Difference between Voltages in two (2) varying conditions; Significant Difference between running time in 2 varying conditions

Voltage Outputs (varying heights, constant weight, and constant height with varying weights) have a p-value of 0.2547 On the other hand, running time (varying heights, constant weight and constant height with varying weights) has a p-value of 0.304511. The results are both less than 0.05 which are considered no significant, the researchers concluded that there is no significant difference between varying heights and varying weights to the performance of GPG in terms of running time and voltage output. The two varying conditions will not pose any relative effect to each other.

Figure 4 – Front view of actual GPG

The figure shows GPG constructed as per design in Figure 4.

Figure 5. – Different weights used in the experimental setup

The figure shows different weights of one (1) pc for 3kgs and two (2) pcs for 1.25 were used in the experiment

Figure 6 – Actual testing done on GPG

The figure shows the setting up of the GPG 5.5 meters from the ground. Three (3) trials to get both the means of voltages and running time.

CONCLUSION

This research provided valuable insights into how and where we can enhance and optimize the practical utilization of GPG. The study quantified the perceived difficulties associated with inches diameter as per the output made for this research. Upon examination of the data, it is observed in Table 4 that standard deviation for voltage is 0.8593, relatively low degree of variability while running time's standard deviation is 5.099, which indicates a high amount of variability. Table 5 also presented deviation was slightly low at 1.093, while the running time standard deviation was high at 3.284.

Thus, these findings suggest that there is consistency and relatively less variation in the voltage outputs, while the running time exhibit more variability.

Tables 4 and 5 also show increase in values of voltage and running time as masses' weight and height increases. Researchers conclude that as lifted weight increases, the stored potential energy increased correspondingly amplifying both rotational speed and torque produced by the weight. GPG is of great potential when innovations are done. With further design advancements, there is an opportunity to commercialize the GPG, allowing people to harness more renewable energy resources in the future.

RECOMMENDATIONS

The research contributed to filling the gaps made by previous researches by investigating GPG's perceived challenges and performance in terms of voltage and running time.

It is recommended the future researchers undertake a more in-depth analysis of specific challenges encountered in the design and creation of GPG's. Additionally, future researchers can innovate existing GPG designs to generate higher voltage and current for extended periods of use.

REFERENCES

[1] Hossen, M. S., Islam, M. T., & Hossain, S. (2015). Design And Fabrication Of A Gravity Powered Light. In International Conference on Mechanical Engineering and Renewable Energy (ICMERE), II.

[2] Dasgupta, P., & Srikanth, K. (2020). Reduced air pollution during COVID-19: Learnings for sustainability from Indian Cities. Global Transitions, 2, 271-282.

[3] Kuik, O., Branger, F., & Quirion, P. (2019). Competitive advantage in the renewable energy industry: Evidence from a gravity model. Renewable energy, 131, 472-481.

[4] Ambade, M. R. S., Prabhakar, M. R., & Tayade (2014),

[5] Dehnad, K. (2012). Quality control, robust design, and the Taguchi method. Springer Science & Business Media.

[6] Jia, J. (2018). Introduction to Dynamics, Vibrations and Impacts. In Engineering Dynamics and Vibrations (pp. 1-38). CRC Press

[7] Kızılörs, S. I. C., Ozada, A. D. P. N., & Asmael (2017), A. D. P. M. JURY MEMBERS.

[8] Madhuri, G., N. Varshitha, T. Sai Kumar, J. Akshith, and G. Srikanth (2022). "Gravity Power Generator."

[9] Hunt, J. D., Zakeri, B., Lopes, R., Barbosa, P. S. F., Nascimento, A., de Castro, N. J., ... & Wada, Y. (2020). Existing and new arrangements of pumped-hydro storage plants. Renewable and Sustainable Energy Reviews, 129, 109914.

[10] Nabipour, H., PVS, H. P., Sundram, H., Kieh, T. S., Mehranzamir, K., & Wooi, C. L. (2021). Review on Feasibility of Gravity Power Generation Mechanism in Malaysia's Sustainable Energy Program. International Journal of Integrated Engineering, 13(2), 109-118.