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IJIE

The International Journal of Integrated Engineering

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

Review on Feasibility of Gravity Power Generation Mechanism in Malaysia's Sustainable Energy Program

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DOI: https://doi.org/10.30880/ijie.2021.13.02.013
Received 27 May 2020; Accepted 2 December 2020; Available online 28 February 2021

Abstract: Malaysia being an oil-producing country has a vast amount of other natural resources that has not been used efficiently. In regard to focusing more in producing oil and gas, natural resources such as sunlight, water, wind, geothermal and gravity have not received a huge recognition by the government. Although hydroelectric power has been up and coming in the energy policies to promote power production in a sustainable way, other means of gravity power generation mechanism were not reviewed for this country, due to the lack of knowledge in this particular field. Gravity power generation mechanism can be of small scale which can actually fit in properly in areas that are off-the-grid. Hence, literature must be reviewed to discover the different type of gravity power generation mechanisms and run viability studies to implement the right system that offers sustainable energy production in rural parts of Malaysia. This review paper will analyze the feasibility of two systems in Malaysia, by assessing the viability of these system through the Malaysian economic, social, environmental, and sustainable standards.

Keywords: Gravity, Malaysia, hydroelectric, feasibility, renewable energy

1. Introduction

Ever since the eighteenth century, after the invention of the steam engine, our modern society is more and more dependent on its energy supplies. Nowadays every basic need relies on an energy income and the easiest way to fulfil those is to use natural fossil fuels. But after an intensive industrial development and a heavy consumption of fossil fuels such as coal, petrol and gas, a clear degradation of our ecosystem and a serious global warming has been observed. In order to reverse the tendency while keeping our modern lifestyle, the energy income must be known for stopping the use fossil fuels, or any energy production that lead to accelerated global warming conditions [1,2]. The ideal solution is to use renewable energies, which are defined by being naturally replenished on a human timescale and are not harmful for the environment. In classical physics, gravitational energy is the potential energy associated with Earth's gravitational field [3,4]. Its most natural interpretation is related to the work that must be done to move an object immersed into that force field. Therefore, this ideology will be synthesized in this report, where different existing

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systems for converting gravitational energy into electrical energy will be reviewed, in order to know whether they are feasible, or efficient, especially in Malaysia.

2. System Review

2.1 Hydroelectric-Gravity Power Generator

2.1.1 System Operation

The application of this system has a possibility to change energy production and transmission on a larger scale if the particular requirements are fulfilled. However, it would not matter even if it had no application on a larger scale, it would still fit into a miniscule energy production in rural areas with a water source. This particular system has currently been used in the UK. The stand-alone systems have been installed in West Midlands county of Wolver Hampton, Dudley and Birmingham. Furthermore, there are feasibility studies that has been undertaken to submerse the shafts underwater in the lakes of East Midlands, England [2,5]. The viability of this system applied and implementing in Malaysia will be discussed further down this paper. The main components in this system would be the hollow cylindrical shaft, connecting pipeline, suspended weight air tank, pump and a turbine.

The shaft is an integrated structure that can either be mounted on solid ground or can be submerged underwater in lakes, seas and rivers. The shaft can be made of heavy cement block or could be of tough glass structure that can offer visibility underwater. The diameter of the cylindrical shaft plays an important role in power generation. A review paper suggests that the optimum energy production should have a shaft depth of 30 meters and a diameter 6 meters. The system sizing is based on the total volume of the shaft and other factors will be adjusted to meet the requirements in maintaining the flow rate of water and a model of the hollow tubing is shown in Fig. 1. The energy storage capacity depends on the diameter and the depth. The efficiency of the shaft in a full operable condition is approximately 80 per cent [2,6]. The suspended weight is basically a deadweight that will be inserted into the cylindrical hollow shaft. In this embodiment, there is an allowance of two suspended weights which will be fitted into the hollow cylindrical shafts. The suspended weights are tied with high tension cable cords that would withstand the weights when they move inside the shaft. These weights are as important as the shaft because they will be used to push the water downwards through the connecting pipeline and will move upwards when the water pressure difference causes it to move upwards [3,7].

The turbine is classified as a Francis turbine that will be connected to a generator which will produce electric power to be transmitted. This water turbine will receive pressurized water into it which will rotate it and this rotational motion will be relayed to a motor or a generator. This turbine will be set up in the powerhouse where it is made sure that pure gravitational potential energy is converted into kinetic energy. The water turbine efficiency is about 90 per cent and it is assumed that most of the potential energy is converted into kinetic energy, again assuming that there are frictional losses due to turbulence [4,8]. The pressure of water is related in water flow rate that would be later related with the change in elevation.

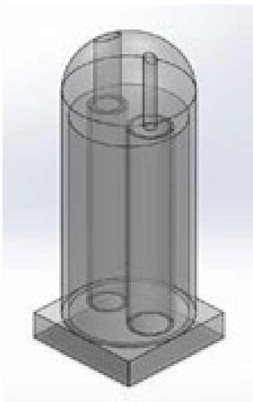

Fig. 1 - Model design of Hydroelectric-Gravity Power Generator produced from SolidWorks™

In order to regulate the fluid flow rate inside the cylindrical shaft, a pre-selected pressure valve is introduced at the end and at the top of the shaft so that pressure is regulated. Water flow will be rectified using this pressure seal valve as well as controlling the flow of both the chambers. The pressure valve is calibrated using the Orifice flow relations so the governing equations that affects pressure differences are addressed [9]. The pressure seal valves are attached to the air tanks which makes it attached to the walls of the cylindrical shafts that makes it immovable when water begins to flow up while the weight is dropped. The seals would open at a point making the air tank to move up, hence pushing the water above it to the turbine.

2.1.2 Design Considerations through Economic, Social, Environmental and Sustainable Standards

In this particular design, there is only minor investment costs for governments and the energy production is off grid so the transmission costs will be lowered [10-13]. Also, this paves job opportunities for the local community. In addition, it aids in preserving animal and plant life and people will not be subjected to migration as the system is stand-alone [3]. Cleaner approach of energy production which causes the least negative impact to the environment [14]. Offers 34 % sustained energy production for one stand-alone system. Offers a positive impact on the environment, economic and social aspects. This system can be implemented in communities surrounding water bodies like rivers, lakes and seas. Hence, making it very sustainable [6,15].

2.2 Small Hydropower Plant

A Small Hydropower Plant (SHP) is defined as an energy production facility with a capacity of less than 10,000 kW, transforming the hydraulic power of a watercourse into electrical energy. According to the UNIPEDE (International Union of Producers and Distributors of Electric Energy) SHP is classified according to the installed capacity. Thus, a small power station has a power of between 2,000 kW and 10,000 kW, a mini-power station has a power between 500 kW and 2,000 kW, and micro-power station has a power between 20 kW and 500 kW. Finally, a pico-power station has a power below 20kW [16-19].

2.2.1 System Operation

From a technical point of view, the role of the turbine is to convert the kinetic energy of water into mechanical energy that will operate an electric generator. The principle is quite simple: the water rotates a wheel connected to a mechanical axis which transmits itself directly or indirectly (gears or belt-pulley system) the mechanical energy to the generator which will convert it into electricity. The choice of the turbine is of course essential in this type of domestic installation and depends above all on the topology of the site and the specificities of the exploitable watercourse. A turbine will be chosen based on the drop height and design flow, as well as the operating speed of the generator. While several types of turbines exist, Pelton or Turgo type turbines are still the most used in micro- hydro systems because of their low cost, efficiency and reliability. In general, the action turbines are more suitable for low elevation / flow ratios while jet turbines will be recommended for high throughput / elevation ratios [20, 21].

2.2.2 Pre-installation, Preliminary Studies and Investment Costs

First and foremost, to choose the best possible equipment, it is necessary to determine the theoretical hydroelectric potential of the site (by integrating seasonal variations and annual variations in flow) and to compare it to the needs in terms of electricity to see if such an energy solution is sufficient and relevant. As an order of magnitude, for installations with power over 100 kW, the budget is between 400 and 2100 € / Kw and can reach 6000 € / kW for installations of less than 30 kW. This cost includes studies and license applications, the civil engineering part, turbine-generator equipment, electrical equipment and grid connection to resell the excess production.

Available in three models of various powers (Lynx 0.6 to 0.8 kW, Leopard 3 to 9 kW and Lion 6 to 60 kW), this technology has a miniaturized generator for a reduced cost of installation exploitation. Depending on their power, the cost of the turbines ranges from € 1,200 to € 2,950 per nominal kW. The Lion turbine of 36 kVA for example, will produce more than 300,000 kWh per year, the equivalent of 3,000 m2 of solar panels for an investment (excluding civil engineering) 20 times lower. So far, the company is operating in France, Germany, Switzerland, and UK. These facilities do not require neither retention nor spot draining that can disrupt hydrology, biology or water quality, and generally allow for stable and local electricity production. They can be installed on the banks of rivers or on drinking water networks and represent in total an estimated potential of more than 1000 MW on the French territory [3, 8, 22].

2.2.3 Design Considerations through Economic, Social, Environmental and Sustainable Standards

The construction project will be considered miniscule so, initial capital will be lesser. The job opportunities for the local community will eventually increase and also would satisfy the household energy consumption [9, 23]. There can be allowances for a stream around the plant for rearing fishes that can be consumed. However, construction process can cause the soil to erode as the riverbed will be tampered for plant specifications [24]. Lastly, the amount of clean energy that is produced from this system is high, but, the adverse impacts that this mechanism causes makes it not close to a very sustainable solution [25].

2.3 The Wave Dragon

Detrimental sources are being pushed aside and which is giving room to alternative energy sources like waves which are natural and always available for endless harvesting. The current technologies used of energy harvesting includes, nuclear power and biofuels which has brought many negative impacts towards the environment. The strength of the waves is the deciding factor for wave energy [26,27]. The use of wave energy brings a variety of mechanism that can be exploited to harness the energy source. Some systems are installed at the coast to harness wind energy which is due the forces of waves that produces large masses of air. The change in pressure and the force of waves is another method to harness energy by using system of lever and piston which are usually installed in shallow water. In deep water, floating systems are placed where the maximum potential energy is achieved [28-30].

There are many harvesting devices to harvest ocean energy which includes floating wind turbines and tidal, wave and thermal energy converted. Despite having other sources of renewable energy sources, wave energy provides many advantages [9, 31]. One of the advantages is that there is a huge span of locations where it can be used for harvesting and its always available at all times. The wave harvesting industry has been progressing well and many startup companies are emerging with innovative ideas to harness this energy. One of it is, The Wave Dragon, which is an overtopping wave energy converter with a rated power of 4-10 MW, which will be exported, to the national grid. This systemis currently being used in Nissum Bredning, located at Northern Denmark for the past two years and this system is currently being constructed in Wales. Portugal, Spain and South Africa are in talks to build this system. The development of The Wave Dragon was supported by the European Commission together with the Danish and Welsh government [10, 32].

2.3.1 System Operation

The Wave Dragon device consists of three main parts: The waves are directed using the two patented wave reflectors which is linked with the main structure. The wave reflectors have proved that it can double the wave height increases the energy captures remarkably by 70% in strong waves condition. A patented double curved ramp and a water storage is part of the main structure.

- To convert the energy into electricity, a set of low head propeller turbines was installed [10,14, 33].
- The construction of the system has been built in way that it maximizes electricity production, lowest costing setup and environmentally friendly [34-36].

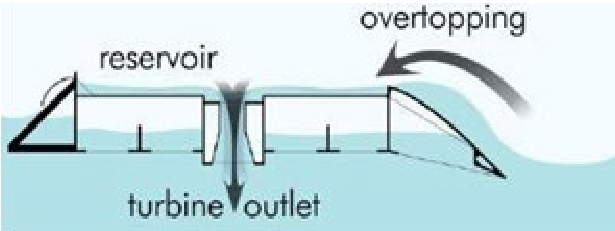

Fig. 2 - Pictorial representation of the wave dragon [34]

A white container which is mounted at the back of the Wave Dragon platform is used as the room for the control devices. The control device is run by a Programmable Logic Control (PLC). The purpose of the PLC is to maintain the buoyancy of the system which is to provide a stable and rigid platform. To achieve more stability, the buoyancy system is being optimized [37, 38]. Furthermore, is it also used to control the speed of the turbine which is to harvest maximum power from the water. The PLC also controls the valves and the water hydraulic system which is to control the water flow of the system. The floating height is changed every 20cm every hour which is to improve the capturing of waves. This is part of their regulatory implementation in the PLC. To provide accurate readings from the sensors, the sensors has to be cleaned to avoid marine growth [7, 39, 40]. Fig.2 shows the pictorial representation of the Wave Dragon.

2.3.2 Design Considerations through Economic, Social, Environmental and Sustainable Standards

The humungous structure could be a tourist site which can be a good income. However, it can be difficult to set it up as the initial cost will skyrocket [37]. There will be a total 70 people working constantly on the zone and more people would be needed for construction, which opens up options for jobs [39, 41]. In addition, the existence of waves will always reveal various energy production that is sustainable, and this Wave Dragon design makes it one of the most sustainable systems in terms of power generation. However, the negative effects which includes the increased carbon footprint and the degradation of the ocean floor, this system would not fall under the sustainable energy producers [38, 42,43].

2.4 In-Stream Devices

In order to produce energy from the flow of water generated by the tides, in-stream devices have been designed. In a similar way as wind power generation systems, these devices consist on horizontal turbines generators placed on the ocean floor. When the stream current flow across the blades, a generator is powered. The advantage of in-stream devices is that they can easily be installed and removed which can be clearly seen from Fig. 3. They can also be scaled up gradually from only one turbine to a full farm. Some of the leaders of such a technology are the Singapore based society, Atlantis Resources and the Spanish one Magallanes Renovables [10, 25].

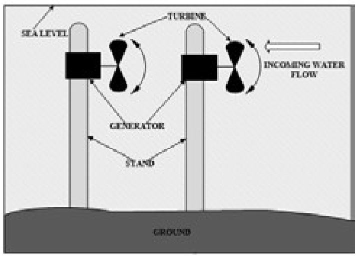

Fig. 3 - Pictorial representation of an in-stream device [38]

2.4.1 MeyGen Tidal Energy Project

Located in the Pentland Firth in Scotland, owned and operated by Atlantis Resources, MeyGen is a pathfinding project leading to one of the world's first tidal stream power stations. The construction commences in January 2015 and the first power was delivered in November 2016 with 4 turbines producing 1.5 MW each (phase 1a). The objective of this project is to implement at least 57 turbines, bringing a total capacity of 86 MW until 2021 [10, 25, 36].

As the implementation of the first turbines was declared financially viable and technically feasible, the installation of 4 next turbines (phase 1b) has already begun while the installation of the next 49 turbines (phase 1c) is already well on his way. Indeed, in august 2017, enough power was generated to power 2,000 Scottish homes despite the fact only two turbines were operational at that time. Eventually, Atlantis is planning to reach the maximum capacity of 398 MW with the MeyGen project. Two different design of turbines are currently used, the AR1500 from Atlantis Resources and the Hammerfest AH1000 MK1 from Andritz Hydro [16].

2.4.2 AR1500 Project

A comprehensive condition monitoring system allows the prediction of failure and planned maintenance, as necessary. The turbine is designed for a 25-year life, with three services in that period, at 6¼ year intervals. The AR1500 blades are formed in two halves made from carbon fiber 'skins' which both give the foil shape and carry the loads. The blades are fitted to shafts on the hub, located with a cross-pin in an arrangement that can be mounted and dismounted very quickly. The outside casings of the integrated gearbox and generator are in direct contact with the seawater so that both are passively cooled by water flowing past them. The generator is a permanent magnet type which operates at high efficiency over a wide speed range. The turbine is connected to its support structure via a gravity stab mechanism [32].

2.4.3 Design Considerations through Economic, Social, Environmental and Sustainable Standards

The initial cost would depend on the size of the tidal farm, so the investments made in this project will depend on it as well. This system would not be considered very economical as this is much more expensive than solar and wind power systems [9, 10]. On the other hand, to maintain a tidal power system such as this requires a lot of expertise which would be very vital. This paves way for people in the local community to pursue education that can achieve the expertise for handling the systems when this is used on a larger scale in the future [13]. The ambient ecosystem of the ocean can be affected by the introduction of a foreign entity such as this device. Studies have shown that fishes and seabirds can be badly impacted when in-stream devices are installed. In addition, the natural tidal flow will be affected due to this device, causing a change in the seabed morphology [14- 16]. In-stream devices will not be considered sustainable as the most important aspect, that is to preserve the environment is clearly addressed as a negative effect [10, 12, 13].

2.5 Gravity Assisted LED Lamp

2.5.1 Functionality

Although the concept of power production on a larger scale could be a great idea for the collective good of a larger community of people, gravity power generation mechanisms can also be commercialized in a way that they can be utilized inside a house, for instance, basic lighting of a living in places where there is no light after sun down. A research conducted in the United States on alternative energy solution through gravity as a power source, a meticulous invention was made. A lamp that uses brass weights that moves up and down to produce electricity by converting gravitational potential energy into kinetic and rotary energy [18].

The components of this device are easy to obtain as materials like aluminum, brass weights, acrylic lens, LEDs, generator and rubber washers are used. The arrangement of all these components makes it a fully useable lamp which lights up a huge living space in a house. The lamp is about 58 inches tall and 16 inches wide taking a cylindrical shape, making it an appropriate size that is both vivid to see its presence and provide luminescence in the dark [19]. This development project was later named “Gravia” from the researcher from Virginia Polytechnic Institute and State University, Virginia. The main functionality of any lamp is to provide light, however, the method or process through which light energy is produced may differ from each type of lamp. In this particular lamp, the production of energy is altered from the conventional lamps as this will use gravity as assistance to rotate a high torque yielding overdrive [19].

At the start of using this lamp the brass weights would usually be down the ball screw and when the light has to be turned on, the user must bring the weights up by disengaging the gear head from the base and move the weights upwards. When 50 lbs. (five times 10 lbs.) of brass weight is drawn downwards through gravitational pull, the overdrive transmits the torque to the end of the gear box providing a maximum torque output through the high efficiency ball-screw [21]. The torque that is produced is supposedly at ratio of 1:160. This substantial change in torque ratios are brought by a harmonic gear head that is situated in the powerhouse at the base itself. There are 12 high-strength neodymium magnets which will get inducted when the rotor spins between them and therefore electricity is produced [20]. The electrical energy is readily transmitted to the LED lights, that lights up. The light energy that is emitted from the LEDs will be amplified by the acrylic lens along the cross-section, thus increase the luminescence of the area around it. This self-sustaining lamp can operate for 4 hours emitting light with an intensity of 600-800 lumens. In contrast to its aspect of self- sustenance, the time constraint of restarting this device would be a possible problem. At present, the technology and the research development have received its patent rights and is intended to commence manufacturing in the USA [22].

2.5.2 Design Considerations through Economic, Social, Environmental and Sustainable Standards

The design of the lamp is elementary, and the components can be readily available in Malaysia and can be manufactured there. [6, 25]. The application of this system can be very beneficial for the people who are affected in the night to perform their mundane activities, since the product is very easy to use for the general populous [26, 7]. The impact on the environment from this device is very minimal as the components can be made from a low carbon footprint material [28]. The social, ethical, economic and environmental aspects of this product have been very well received making it a sustainably successful device. This device will clearly fit in the areas in Borneo island and some of the remote places in West Malaysia [26, 29].

2.6 Gravity Light (Utility System)

According to Our World in Data, 940 million of people leave without electricity. The majority of those people, thus, use kerosene lamps to light up. The problem is most acute in rural, sub-Saharan Africa, where over 600 million people live in homes without electricity [26]. It is a problem for the mere reason that those type of lamps are dangerous for the health and the environment. First, concerning the health, these lamps gives off a toxic smoke, irritating to the respiratory system and spray applications of kerosene may provoke signs of pulmonary irritation [28]. Beside these dangers, kerosene is expensive. Using it for lighting consumes sometimes up to 30% of a household's income. It creates a vicious circle by maintaining the poverty that drives the poorest to use it. It is to fight against this scourge that Gravity Light was born.

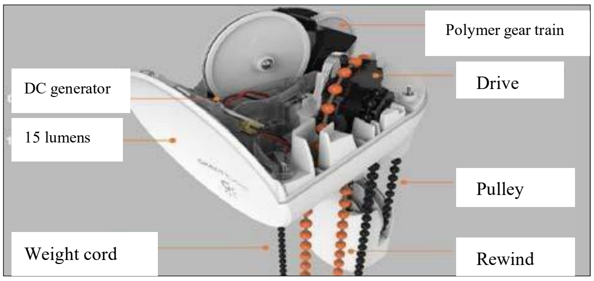

Fig. - 4 GravityLight design specification [22]

GravityLight started in 2014 after a successful crowdfunding campaign, receiving enough funding to produce prototypes for 1,300 families that were cut off from the grid. Today, after improving the original model (shown in Fig. 4), the London-based company has just launched the GravityLight 2.0, a higher-performance model produced directly in Kenya, where the devices are most in demand, creating new jobs in the process [19].

2.6.1 Efficiency of Gravity Light

In the process, the gravitational potential energy is converted into electrical energy. Therefore, the efficiency of the system can be calculated by considering the potential energy acquired by the bag and the energy converted by the motor. To perform the calculation, the ideal case is considered: the bag weights exactly 12kg and the height is exactly 1.80m. The specification of Gravity Light is clearly shown in Figure 4. Thus, the maximum efficiency of the system is really high. In comparison, the maximum efficiency of a solar panel is about 45%. But in a more realistic view; it is usually around 20% [26].

2.6.2 Design Considerations through Economic, Social, Environmental and Sustainable Standards

This particular lamp can be manufactured from the cheapest available materials. However, the cost of neodymium magnets is considered very expensive in Malaysia [18]. The lamp can be used in the remotest places in the world where there is no electricity, and the communities relying on light energy in the dark can make use of it [20]. The materials used in the manufacturing of the lamp has very less impact on the environment. Although the use of acrylic lens in the lamp can leave a minor carbon footprint. In this regard, there has been research on going to replace with a transparent composite that reduces the environmental impact [23]. The gravity assisted LED Lamp would definitely fall under the sustainable energy sources, but to implementing the system is still under research as to sustain light energy production for a longer period of time [20, 22].

3. Viability Study of Reviewed Gravity Power Generation Mechanisms

This section of the review paper would help the reader to get a clear understanding of the comparisons that has been made to all the seven different systems which uses gravity to generate power. Design comparison is an important aspect in this review, as it would be the steppingstone to offer insights on the viability of implementing this system in Malaysia. In this process, there is a set of criteria that these different working mechanisms have to fulfil, that would clearly address the issues such as cost, resource availability, feasibility and industrial involvement corresponding to Malaysian standards. Each and every one of the systems' designs will be reviewed in this section in accordance to the above-mentioned features.

Table 1 - Viability study on gravity power generation mechanism

	Cost	**Resource Availability**	**Industrial Involvement**	**Feasibility**	**Efficiency**
Hydroelectric Gravity Power Generator	Comparatively Low to Small Hydropower Plant	Locally Available	Manufacturing sector	Yes	Moderate

Small Hydropower Plant	Relatively lower than The Wave Dragon	Locally Available	Construction sector	Yes	High
The Wave Dragon	High	Not locally available	Logist-ics sector	No	Low
In-Stream Devices	High	Not Locally Available	Manufacturing sector	In future	Lower compared to The Wave Dragon
Gravity Assisted LED Lamp	Cheap	Not Locally Available	None	In future	~ absent (still under resear ch)
Gravity Light	Cheap	Locally Available	Manufacturing sector	Yes	High

4. Discussion

The study shown above addresses the issues that are related to each system's viability, specifically in Malaysia. The most sustainable product design would have an equivalent proportion of all the design considerations from the earlier section. Based on this comparison, it can be seen that the Gravity Light would be a better choice for the rural areas of Malaysia comparing to the Gravity Assisted Lamp. Not only in Malaysia, the Gravity Light can be a huge benefit for small or rural communities who do not have access to electricity [20]. According to the viability study from the Table I, the Hydroelectric- Gravity Power Generator is the best system for rural areas in Malaysia. However, this is a brand-new system that will have to be tested before being used on a larger scale. Regarding the systems (2)(3)(4) and (5), they are not fully viable in Malaysia because of their environmental impact [33]. Indeed, biodiversity in this country, especially in Borneo (Sarawak and Sabah), has to be protected. Thus, all systems that have a negative impact on the environment and more specifically on biodiversity must be avoided. Therefore, the most viable system for electricity generation in rural Malaysia is the Hydroelectric-Gravity Power Generator.

5. Conclusion

In this review paper, there were four large scale and two small scale gravity power generation systems were reviewed. The primary aim of this review was clearly satisfied through the design consideration in socio-economic, environmental, ethical and sustainable aspects of the design. This research review will serve as paper to bring awareness for a community of researchers who can follow up on this research to continue more on these selected systems. At the end of this review, two sustainable designs which can produce power through gravitational force were identified, namely the Gravity Light and the Hydroelectric-Gravity Power Generator which is considered.

Acknowledgement

The authors would like to thanks Faculty of Engineering, Computing and Science Swinburne University of Technology Sarawak, Kuching, Sarawak, Department of Electrical and Electronic Engineering, Faculty of Science and Engineering, University of Nottingham Malaysia, Semenyih and Centre of Excellence for Renewable Energy (CERE), School of Electrical System Engineering, University Malaysia Perlis.

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