Wind-Solar Streetlight with Hydro-Powered Charging Station

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ABSTRACT

This research points out an innovation on solar streetlights owing to the issues caused by prolonged period rainy seasons through the provision of engineering solutions to street lighting design assembly and in a bid to utilize renewable energy to the fullest. The developed technology consisted of three combined assemblies with the integration of various renewable sources, which included the solar panel assembly, wind turbine assembly, and hydro-electric mini-turbine assembly. The solar panel and wind turbine sets work in tandem to drive the LED street lamp efficiently, while the hydro-electric mini-turbine set is ready to regulate and supply additional power to the charging panel found at the bottom part of the streetlight. Voltage and current readings generated by said sets were tested, assessed, and measured using a digital multimeter to ensure accuracy and consistency. From the observations, the assembly of the solar panel stored a mean value of 5.39V and 1.0A caused current, while the assembly of the wind turbine produced 4.80V and 1.0A, respectively. Additionally, the hydro-electric mini-turbine had the capability of registering an average of 3.08V and 0.01A, which, while lower, also provides complementary power during rainy days. In short, the prototype device was successfully able to execute its intended function in testing and operation and demonstrate its capability to provide continuous and sustainable street lighting through a hybrid renewable energy system even under adverse weather conditions.

Keywords: streetlight, solar, wind, hydro, hybrid

INTRODUCTION

Electricity holds a vital role in contemporary society. The operation and functionality of newly emerging technologies and new innovations—such as machines, devices, transport systems, and communication and manufacturing industries—are all facilitated through the application of electrical energy. Due to this, electricity is commonly known as an essential element of technology. Despite its enormous environmental footprint owing to the consumption of fossil fuels and the release of greenhouse gases from different power plants used in the production of electricity, it keeps up with increasing needs and requirements of societies, offering comfort, convenience, and simplicity in daily life (Kumar, 2020). In turn, recent research has centered on the discovery and examination of other means of tapping and transforming readily available energy into electricity, leading to a significant focus on clean, renewable energy resources (NAS, NAE & NRC, 2010 and Owusu et al., 2016).

According to Gielen et al. (2019), the integration of renewable energy with electrification may cut industrial emissions by as much as 94% and cover almost two-thirds of the world's energy needs. Besides, it can help in the mitigation of greenhouse gas emissions—a global issue that continues to persist (EPA, 2021). With advancements in renewable energy technologies, there is increased interest in hybrid renewable energy systems for power generation, particularly in remote areas (Adaramola et al., 2014). A hybrid renewable energy system entails the combination of two or more electricity generation alternatives, mainly from renewable sources, owing to their advantages such as cleanliness, extensive availability, cost-effectiveness, and abundance (Sinha et al., 2014 and Lian et al., 2019). Thus, such systems are now believed to be a better option for the development of advanced electrical grids that are economically, environmentally, and socially beneficial (Krishna et al., 2015).

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In recent years, hybrid renewable energy systems have become widely used for public street lighting. The President Cory Aquino Boulevard, which serves access to various tourist spots in the province of Camarines Norte, traverses three municipalities of Daet, Mercedes, and Talisay. This highway was mainly built to support the ecotourism sector of the Bicol Region, after it was declared a tourist area by the Department of Tourism (DPWH, 2015). Along the whole length of this boulevard, a good number of solar-powered streetlights were seen. Their dependability in operation, however, has been undermined by uncontrollable conditions such as harsh weather and long rainy seasons. Moreover, cases of deterioration and theft of parts of the solar streetlight system have been reported.

Confronted with such setbacks, researchers were encouraged to develop and create a hybrid renewable energy streetlight system that combines solar, wind, and hydroelectric power—a wind-solar streetlight with a hydroelectric charging station to provide power to a streetlight unit.

MATERIALS AND METHODS

The research employed descriptive type of research design in the data collection that defined its functionality through the established and specified parameters in designing the desired output in terms of its technical and systematic diagram that is confined to electrical aspects only. Descriptive research is fact finding with sufficient interpretation (Krishnaswamy et al., 2009). It is deemed an appropriate process in information gathering and acquiring results that will remedy the mentioned problems in this project. In addition, the researchers collected ideas, principles, theories, and concepts from a number of sources. It was contrasted with other comparative studies to ascertain the limitations, similarities, and differences and also the initial draft setup of the draft and working design needs and requirements and the construction process for a unit design.

A systematic set of research procedures were conducted to achieve the objectives set forth for this study. Figure 1 shows the flow in conducting the research experiment through the design process. The framework is basically composed of four stages namely: a) planning; b) designing; c) fabrication and d) testing and evaluation.

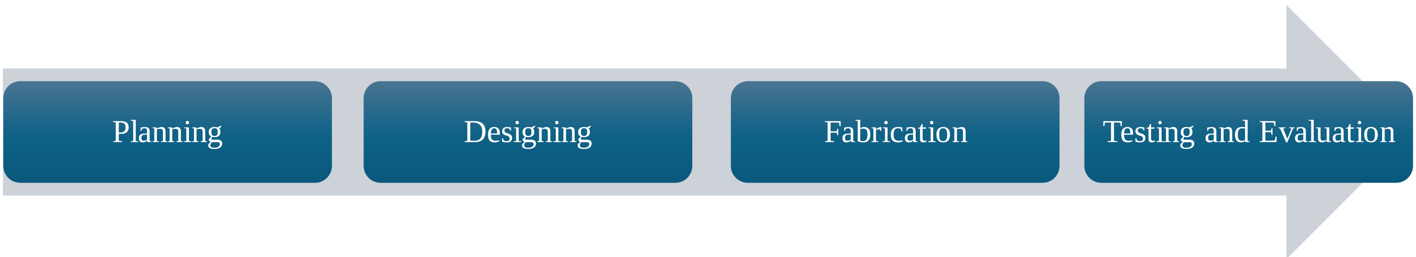

Fig. 1 Research Procedures

Planning. This stage includes the process of providing solution to the identified problems that this study seeks to address. The researchers gathered information that strengthened the concept of this study. This also included the review of different literatures and studies as its bases and references.

Designing. This stage includes conceptualizing the perceived design. Other technical concerns such as wiring diagrams and circuitry were also included. Moreover, conventional drafting software such as SketchUp and AutoCAD were used during this stage. The 3D design of each assembly as well as the overall design for its intended purpose was shown with the use of the mentioned drafting software.

Fabrication. This stage considered the provision and preparation of the needed materials, tools, and equipment for the development of the prototype. Researchers made used of locally available materials and equipment for expediency and ease of provision. The fabrication of the prototype was mainly based on its perceived design. During the fabrication stage, it was divided into four phases namely: a) assembly of pole and solar panel; b) assembly of wind turbine; c) assembly of hydroelectric mini-generator and d) overall integration and final furnishing. In addition to this, standardized methods and rules in electrical wiring and connection were considered to provide safety.

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Testing and Evaluation. This stage includes the validation of the prototype design for its intended function. For the conducted testing, the amount of generated voltage and induced current shall be measured for each assembly by using a multi-tester. Three trials were considered for the computation of its average output.

RESULTS AND DISCUSSION

Fig. 2 presents the actual design of the developed prototype. Said prototype consists of three assemblies namely: solar panel assembly, wind turbine assembly and hydro-electric mini-turbine assembly.

Fig. 2 Actual Prototype

Fig. 3 shows the actual picture of the solar panel assembly. The functional concept of the assembly is predicated on the solar energy that is absorbed by the photovoltaic cells on the panel in which the mentioned energy creates electrical charges and thus leads to the flow of electricity. The electric energy is stored in the used battery to drive the streetlight. An electronic sensor for nighttime light detection was also integrated.

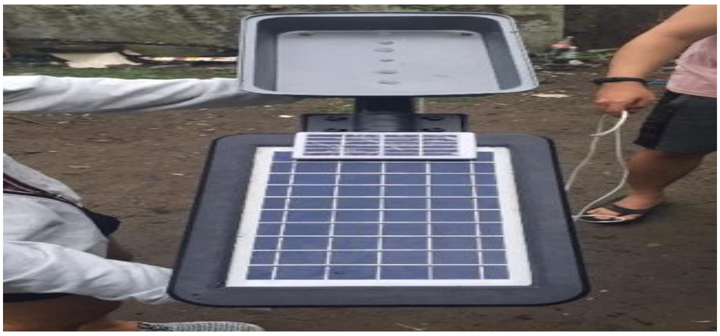

Fig. 3 Actual Image of the Solar Panel Assembly

Fig. 4 is the actual photograph of the assembly of the wind turbine. The concept of this assembly comes up when the wind passes over the blades, it subsequently generates a lift which leads to the rotation of the said blades. This motion affected the turbine and generator that subsequently generated electricity. This assembly acts as an addition to the functioning of the streetlight in the event of no sunlight or solar energy being absorbed.

Figure 4. Actual Image of the Wind Turbine Assembly

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Fig. 5 presents the actual image of the hydro-electric mini-turbine assembly. Its operation starts from collating the rain water falling through a container with a tube connected to a mini-generator. The gravity causes the rain water to move downwards in the tube and hits the blade causing it to rotate. This rotation is linked to the turbine and produces electricity. The harvested electrical energy is used to power the charging panel.

Figure 5. Actual Image of the Hydro-Electric Mini-Turbine Assembly

Table 1 shows the summary of the results for the generated voltage and induced current per assembly considering three trials.

Assembly	Generated voltage and induced current			Average
	Trial 1	Trial 2	Trial 3	
Solar Panel Assembly	5.57 V	5.33 V	5.28 V	5.39 V
	1.00 A	1.00 A	1.00 A	1.00 A
Wind Turbine Assembly	4.00 V	4.50 V	5.90 V	4.80 V
	1.00 A	1.00 A	1.00 A	1.00 A
Hydro-Electric Mini-Turbine Assembly	2.40 V	3.29 V	3.56 V	3.08 V
	0.01A	0.01A	0.02 A	0.01 A

Table 1. Summary Results of the Generated Voltage and Induced Current

The solar panel assembly had an average voltage of 5.39V and an average induced current of 1.0A in three trials. The outputs measured were consistent with the required requirements and specification ratings of the solar street light. The results obtained were comparable to Montelpare, S.'s study. et al (2014) where the primary parameters that outlined the success of the system are its energy savings independence in comparison to traditional power generation, and lighting reliability. The prototype was reportedly supposed to produce voltage and cause current, so the information collected is adequate to determine that the prototype is functionally operational.

The wind turbine assembly possess the ability to convert power based on the speed of the wind at a location. The configuration of this assembly is made up of 3 blades with 14 inches long, the tail, bearing, a rectifier and a regulator. Besides, the tail and the bearing act as an indication of direction for the wind and to rotate smoothly. Results indicated a mean generated voltage of 4.80V and mean induced current of 1.0A on the aforementioned assembly. Moreover, the charger indicator shows that the measured parameters is enough for the assembly to work successfully.

The hydro-electric mini-turbine assembly consisted of a container, water pipe, and hydro-electric mini-turbine where setup is the same as in the study done by Del Rosario, J.A. et al (2019). The findings of the research indicated that the average voltage generated was 3.08V and mean induced current 0.01A. These readings were barely of any useful value as it is only concerning loads and specs ratings to be taken into consideration is merely mobile phone charging, as well as other devices similar to it.

CONCLUSION

The innovative design and layout of the assemblies of the wind-solar street light with hydro-powered charging station were able to serve its purpose. The voltage generated and induced current of the assemblies were also adequate to the specifications and technical requirements in terms of driving the connected loads and components of the prototype. In addition, with the design and structure of the technology being new in nature, the developed technology was successfully registered with intellectual property protection. It is suggested that the prototype be upgraded on a large-scale basis for potential actual installation on its perceived project site location.

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