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DESIGN AND DEVELOPMENT OF A STREET LIGHTING SYSTEM UTILIZING SOLAR AND WIND ENERGY SOURCES ON A PUBLIC ROAD BYPASS

Barandino, Clarence M.*[1], Calma, Jerico S.*[2], Dela Peña, Reynan N.*[3], Hilario, Vincent Brylle M.*[4], Marquez, Allan Mark B.*[5], Melgar, Mike Daniel B.*[6], Tolentino, Armie C.*[7], Favorito, Rhoderick M.*[8]

*[1,2,3,4,5,6,7,8]Department Of Electrical Engineering, Don Honorio Ventura State University, Bacolor, Pampanga, Philippines.

ABSTRACT

Road safety is a major concern, particularly in areas where accident rates are high, such as the bypass roads in Sta. Cruz Lubao, Pampanga. Lack of lighting systems on these roads contribute significantly to the risks faced by drivers and pedestrians, leading to an increasing need for innovative and sustainable lighting solutions. This study addresses this need by proposing the design and development of a hybrid prototype street lighting system that harnesses wind and solar energy. By integrating solar energy and wind as energy sources, this system offers an even more reliable lighting solution, regardless of weather conditions. The convergence of wind and solar technologies helps uninterrupted illumination and also enhances the efficiency and sustainability of the lighting infrastructure. Key components of the proposed solution include a wind turbine and solar panel, intended to maximize energy capture and optimize performance. The main purpose of this study is to implement this innovative street lighting system along the bypass roads in Sta. Cruz Lubao, with the aim of reducing accidents, enhancing road safety, and improving overall community well-being. Through rigorous testing and data collection, including analysis of wind speeds, solar intensity, and system charging dynamics, this study focused on validating the feasibility and effectiveness of the hybrid prototype. Furthermore, this study outlines the methodology for designing the prototype, calculating appropriate illumination levels, and sizing of the solar panel and wind turbine to meet the specific requirements of the target location. This study confirms that the hybrid use of solar and wind energy is an effective solution for maximizing the potentials of current street lighting systems.

Keywords: Solar And Wind Energy Sources.

I. INTRODUCTION

As for today the current global emphasis on Sustainable Development and promotes efficient utilization of renewable power like Solar and Wind energy sources. With regards to this study, it seeks to develop a street lighting system that shall be highly efficient and sustainable for the public road bypass. While inhabiting cities and consequently, the usage of utilities increases in relative magnitude, many cities still utilize several traditional street lighting systems that deploys mainly non-renewable power sources. Instead, there is so much belief and focus placed on accessing fresh energy like solar and wind energy, hence, effective usage of energy, reducing emission levels and creating sustainable cities.

Renewable energy or also known as clean energy, is produced by natural processes or resources that are continuously replenished. Solar and Wind Energy are currently dominating the renewable energy market. For instance, even if their availability is dependent on the time and weather, sunlight and wind continue to shine and blow. In terms of alternative energy sources, solar and wind energy are rising to the top and are increasingly being used in a wide range of applications.

One source of renewable energy is solar energy. This involves converting sunlight into electrical energy and storing this energy in batteries to power your home and appliances. According to Kabir, E., et.al (2018), one of several important strategies for meeting the rising demand for energy on a global scale is the development of unique solar power technology. Since the solar energy is constant, it is convenient to use as our sources of power.

Moreover solar energy is considered as an inexhaustible source of energy and also a nature friendly renewable energy source. It has several advantages in achieving solutions for sustainable development in the energy sector. Because the availability of solar energy makes it attractive for generating power sources. Also, because of the implementation of this renewable energy source it plays a pivotal role globally in supporting the energy sector as stated by A. Maka et.al (2022).

However, according to Ugli (2019), solar energy is dependable in the light produced by the sun, because of different weather conditions there is a possibility of lack of sunlight that can lessen the amount of energy collected. To address this, Widyaningrum et.al (2022) stated that the solar and wind energy system is one of the solutions. However, based on the findings, solar panels can also generate power even in the absence of direct sunlight.

Another source of energy is wind energy. Wind energy produced by harnessing the wind using wind turbines. Based on the study of Menezes (2018), today's environmental concerns, particularly those related to global warming, have sparked a push for the usage of renewable energy sources. In this context, wind energy is a significant player. It Is currently the most popular renewable fuel, but there are still many technological advancements that need to be made. The great efficiency and cost-effectiveness of wind energy applications are ensured by the control of wind turbines (WTs). This topic has undergone much investigation,and its advancements are essential for creating wind turbines that are even better and more effective. We can also use wind energy as the source of energy because it is also infinite and never-ending.

Wind power stands as a well-established renewable energy technology with the capability to address numerous contemporary technological and societal challenges. Its applications extend to providing a sustainable energy source and mitigating air pollution. Various applications of wind power cater to meeting the growing energy demand. These include onshore wind, offshore wind, and wind paired with battery storage for grid optimization as stated by G. Nikitas et.al (2020).

However, wind energy varies with the wind speed in a particular place. The selection of parameter estimation methods and goodness-of-fit test statistics is not standardized, requiring consideration of all potential models for a specific site based on their advantages and disadvantages. Wind characteristics, influenced by geographical elements, show constant variations, urging comprehensive wind energy assessments that account for long-term changes in local wind patterns rather than solely focusing on current energy output as stated by Shi H et.al (2021).

Also, Bhagat et.al (2023) explained that this innovative system combines solar panels and wind turbines to ensure a reliable and uninterrupted power supply. Solar panels capture sunlight during the day, while wind turbines operate continuously, even at night, reducing dependence on fossil fuels, mitigating emissions, and promoting sustainability. Its adaptability makes it suitable for diverse locations, contributing to both rural energy needs and environmental conservation.

The background of the street lights problem on the Sta Cruz, Lubao, Pampanga public road bypass is that the road is often congested, particularly in the populated areas, and so there was a need to construct a bypass road, however, has been identified as having inadequate pavement markings, insufficient shoulders, and high potential for road crashes due to various safety concerns.

The Lubao Public Road Bypass serves as a critical thoroughfare for each neighborhood citizen and commuters, but the loss of streetlights along this course poses enormous safety concerns for pedestrians, specifically the ones living in the nearby regions. The absence of right lighting fixtures creates a dangerous environment wherein pedestrians are susceptible to vehicular accidents, especially during midnight while visibility is limited. This has prompted residents dwelling within the region to express apprehensions about their safety even as they stroll to and from their houses after dark. The aggregate of inadequate lights, high vehicle speeds, and the absence of streetlights has led to a deadly surroundings, increasing the hazard of injuries and near-misses. The fear of not being visible to drivers is a regular worry for those citizens who find themselves navigating the skip in the dark, frequently with restricted visibility. This survey seeks to evaluate the need for streetlights alongside the Lubao Public Road Bypass, specializing in enhancing pedestrian safety and decreasing the chance of injuries. By comprehending the issues and stories of citizens who traverse the bypass at night time, this research aims to provide treasured insights into the significance of streetlights in ensuring pedestrian protection in this region.

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The municipality of Lubao Technical Office said that the bypass road is too long and requires too many cables to install lighting. The solar wind street light will provide adequate and sufficient light to the user, specifically to the people living in remote areas that don't have access to enough electricity. The implementation of traditional road lights structures on public roads has been a massive contributor to electricity intake. In addition to supplying safety for drivers, those structures provide increased visibility and enhance driver awareness, specially along bypasses frequented by heavy trucks and other motors transporting goods. With less renovation required, wind and sun-powered road lighting fixtures structures can function constantly for 10 years or extra. Opting for a renewable strength road lighting fixtures gadget may be the best desire over traditional electricity, because it no longer handiest benefits the environment however additionally gives lighting fixtures for close by residents. This shift aligns with the developing awareness on sustainable and efficient infrastructure answers. The primary objective of this study is to design and develop a street lighting system that utilizes solar and wind energy sources. The specific objectives are as follows: To determine the appropriate illumination design on the road as regards visibility. To install a prototype of Solar and Wind energy Street Light on public road bypass by using solar panels and wind turbines combined. To design an electrical system that could access the energy provided by the wind turbine and solar panel to give total energy production.

II. METHODOLOGY

The researchers used an agile type of conceptual framework. Agile is a flexible and iterative approach to project management that emphasizes collaboration, customer satisfaction, and rapid response to change. In the context of hybrid street lighting systems, Agile would seek to ensure that the system is designed and implemented well and in a timely way.

The figure 1 below shows the design and development of a street lighting system maximizing solar and wind energy sources on public road by-pass involving several components and steps.

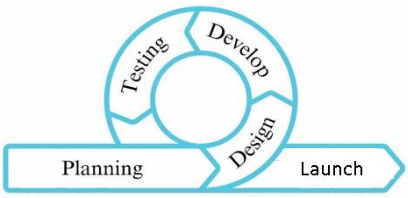

Figure 1. Conceptual framework of the prototype

Planning. The researchers gathered data by interviews, site visits, and surveys to understand the current situation at the research site. The scope of this study only focuses on the implementation of wind solar power one lamp street light to ensure the safety of public road bypasses by designing wind and solar power street lights. Design. Presentation of Equation of Sizing of the Solar Panel and Sizing of turbine.Solar System Size equal to Daily kWh divided by the Average Sun Hours then Multiply by the Efficiency Factor lastly Convert to Watts. Sizing of Generator Load Factor, (LF).To calculate the load factor, average load is divided by peak load. Demand Factor ,(DF)Demand factor is equal to the peak load divided by the connected load. Development. Figure 1 below shows the final design and figure 2 shows the wiring diagram.

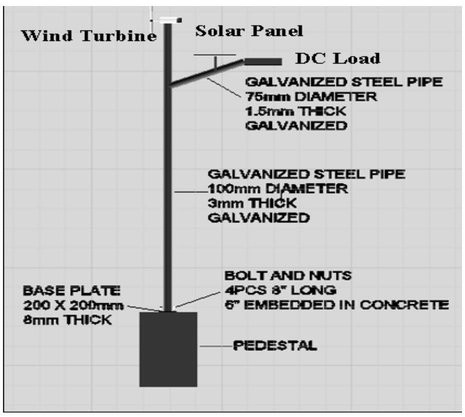

Figure 2. Final Design

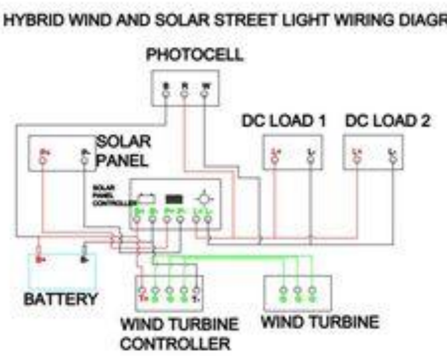

Figure 2. Wiring Diagram

Testing. The project will be tested, gathering data and monitoring the prototype, making sure if it is functioning or a malfunction, if there is anything to improve or to maintain. Launch. The solar and wind energy street lighting system on the public road bypass in Lubao, Pampanga is a pioneering showcase project of the town, standing for its commitment to sustainability and innovation. Harnessing renewable sources of energy shall enable us to design a street lighting system that is safe, efficient, and environmentally friendly to the community. This will set a precedent for other municipalities.

2.1 Presentation of Equation

A. Sizing of the Solar Panel

B. Sizing of turbine

DC SOLAR SYSTEM SIZE

DC Solar System Size equal to Daily kWh divided by the Average Sun Hours then Multiply by the Efficiency

$$\text{Factor lastly Convert to Watts} = \left(\frac{\text{daily kW−Hour}}{\text{Average Sun hour}}\right)(1.15 \text{ efficiency})$$

DAILY KILOWATT HOUR

To calculate the daily kilowatt-hour, you add up the energy consumption of all the devices used throughout the day.

Daily kilowatt-hour= total consumption in a whole 24 hours

AVERAGE SUN HOURS

The Philippines is at natural advantage for solar development because of its high number of peak sun- hours (4.5-5) hours on an average day

Average sun hours= the average peak sun hours in the Philippines

Solar Panel Capacity

Solar Panel Capacity equal to daily energy production requirement divided by the average sun hours.

$$\text{Solar panel capacity} = \frac{\text{Daily Energy Production requirement}}{\text{average Sun hours}}$$

Number of Solar Panels is equal to the actual solar panel Capacity divided by the Capacity of single solar panel

$$\text{Number of solar panels} = \frac{\text{Actual solar panel capacity}}{\text{Capacity of single solar panel}}$$

C. Sizing of Generator

Load Factor, (LF)

To calculate the load factor, average load is divided by peak load.

$$LF = \frac{\text{average load}}{\text{peak load}}$$

Demand Factor ,(DF)

Demand factor is equal to the peak load divided by the connected load.

$$DF = \frac{\text{peak load}}{\text{connected load}}$$

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Average Load,(AL)

The daily average load is equal to usage in kilowatt-hours divided by the number of operating hours

$$AL_{daily} = \frac{\text{usage in kilowatt– hours}}{\text{number of operating hours}}$$

Capacity Factor,(CF)

Capacity factor is equal to the average load divided by the installed capacity multiplied by the demand factor.

$$\textbf{Capacity Factor}=\frac{\text{Average Load}}{\text{Installed Capacity}}(\text{Demand Factor})$$

Installed Capacity,(IC)

Installed capacity is equal to the product of total period of time and rated power of the turbine

Installed Capacity = (total period of time in hrs)(rated power of turbine)

Size of Turbine :

Size of the turbine is equal to the daily average load divided by the capacity factor.

$$\textbf{Size of turbine} = \frac{\text{AVERAGE LOAD}_{\text{DAILY}}}{\text{CAPACITY FACTOR}}$$

D. Sizing of Blades

Sizing of blades is determined by the formula, power output is equal to (k) the constant to yield power in kilowatts, multiplied by the maximum power coefficient, multiplied by constant one and a half, multiplied by the air density, multiplied by the rotor swept area, multiplied by wind speed in cubic meter per second.

Power Output,(P)

Power Output = k(Maximum Power Coefficient)$(\frac{1}{2})$(Air Density)(Rotor Swept Area)(Wind Speed)^3m/s

Rotor swept area is equal to air density multiplied by 2 divided by 1 divided by air density multiplied by cubic of maximum power coefficient

$$\text{Rotor Swept Area} = \frac{\text{air density}(\frac{2}{1})}{(\text{air density})(\text{Maximum Power Coefficient})^3}$$

Width is equal to rotor swept divided by the number of blades of the turbine .

$$\text{Width} = \frac{\text{Rotor Swept Area}}{\text{No.of blades}}$$

Length is equal to number of blades multiplied by the width of the turbine

Length = No. of Blades(Width)

E. Sizing of Tail Fin Area

Length of the tail is equal to 120 percent multiplied by the number of blades, is also equal to 120 percent multiplied by the length of blades.

Length of the tail = 120% x length of blades = 1.2 x length of blades

F. Sizing of Battery

Size of the battery is equal to the total load of the system multiplied by the number of operations in hours.

Size of battery= (Total Load of the System)(number of operation in hours)

G. For the Illumination

In this equation it states that the average lumens is equal to illumination in lux multiplied by width and also to distance divided by the types of fixture multiplied by the maintenance factor.

$$\text{Average Lumens} = \frac{\text{illumination in lux x width x distance}}{\text{Types of fixtures x maintenance factor}}$$

III. RESULTS AND DISCUSSION

The RPM of the turbine will increase with an increase in wind speed. The turbine was working at 442 RPM with a speed of 4 m/s and increased to 549 RPM at 5 m/s. This implies that the turbine has a higher efficiency at higher wind speeds.

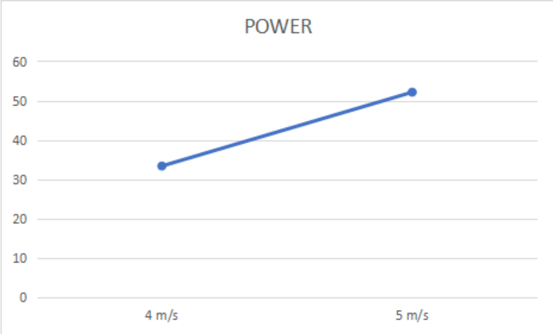

Figure 1. Turbine Voltage and Wind Speed

The voltage generated by the turbine increases with wind speed. The voltage increased from 9.52 volts at 4 m/s to 13.78 volts at 5 m/s. This implies that the turbine may generate more power at higher wind speeds.

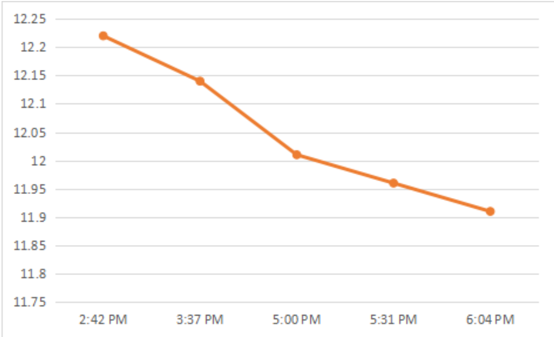

Figure 2. Discharging Voltage of Battery

It can be seen that the discharge voltage of the battery decreases with time. At the beginning, the voltage was 12.22 V, which dropped to 1.22 V after 16 hours and 17 minutes. The battery is recharging as time passes; however, it is making small increases in voltage.

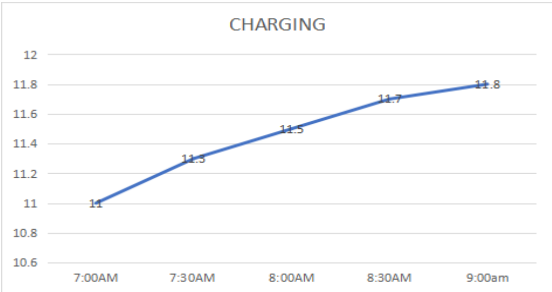

Figure 3. Charging Voltage of Battery

Charge of Battery from a Single Load of Lighting. The battery was charged from 1.0 V to 1.2 V after 2 hours and 30 minutes. The total potential attained was 0.9 V, which shows a quite high potential attained at the time taken for its charging.

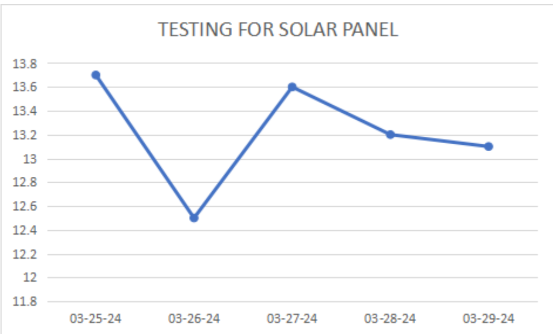

Figure 4. Solar Panel Testing

The voltage readings have shown a slow decrease over a period of six days. The readings varied from 13.7V to 12.5V, indicating variations in solar panel performance. The decrease in voltage may be attributed to the variability in the weather, degradation of the panel, or some other environmental aspect.

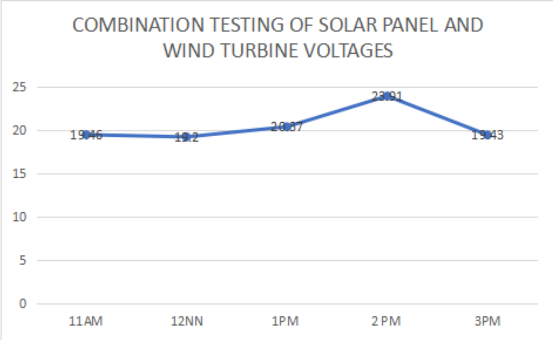

Figure 5. Solar and Wind Turbine Voltage Combination

The voltage readings indicate that there is a general pattern in which the levels increase over time. Through the combination of solar and wind turbine power, the system derives more power during peak hours. This data indicates that the solar panel and wind turbine are effectively working together to accumulate more power during the day.

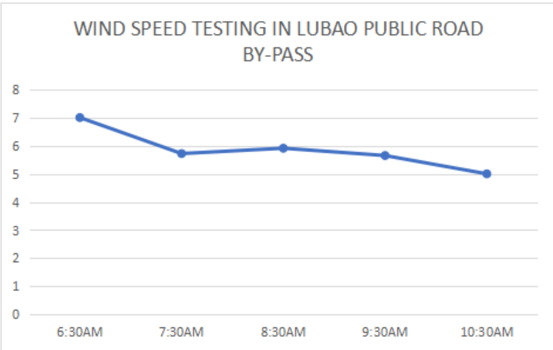

Figure 6. Wind Speed Data

There is a dramatic difference in the wind speed data in the course of the day, peaking between the late afternoon and early evening. Wind speed was relatively low in the morning, with an average of 5.3 m/s. Wind speed was relatively higher in the afternoon, at an average of 8.5 m/s. The highest wind speed recorded was 13.0 m/s at 5:30 PM, which may demand infrastructure development and maintenance measures to remain stable and safe.

IV. CONCLUSION

The researchers therefore concluded that the idea was to use solar and wind as the alternative power source by harnessing the sunlight and also the wind and converting it into clean energy. The material used can prolong the lifespan of the prototype. Also because of the energy source it helps the environment and also it is useful for the community. The wind and solar street lighting system is a success though it can also be improved in the future study.

V. RECOMMENDATION

For future researchers, the proponents of this study recommend that further studies for the development of this project can help prolong its life span and to be more efficient to the community. Since this study is experimental it is open for the future researchers to develop more streetlights on the said locale.

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