Proposed Synergy of Electrical Energy Sources in The Administrative Building of The Educational Institution in Bacolor Pampanga, Philippines

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Abstract—The use of electricity has become significant in modern society as it serves various purposes. However, power interruptions are unavoidable and have a negative impact on people's daily activities, particularly in schools and industries, because electricity is used in almost every aspect of life. Specifically, a lack of electric energy can result in lower productivity because it incapable workers of properly performing their duties. This feasibility study proposes continuous energy supply to offices and other important building facilities for the institution's administrative building in Bacolor, Pampanga. The analysis involves explicitly identifying the equipment and other materials used in the electrical energy synergy plan, objective evaluation of the initial investment, calculating the payback period, and determining the return on investment. The design used in this research is a grid-tied system with solar energy as the primary source, utility as secondary, and Gen-set for a backup power system in case the utility fails. This study involves assessing site suitability, solar access, shadowing considerations, and other factors. The results obtained 120 pieces of solar panels of 500 Wp each, a 60kW inverter, and a 100 kVA generator were calculated to run the system for the total demand of 57.2125 kW of the administrative building. The payback period is 3.97 years and a return of investment is P 13,744,020 for 25 years. If implemented, the project will solve the institution's electric power problem at the Administrative Building by providing stable, sufficient, and dependable 24-hour electricity.

Indexed Terms—Explicit, Productivity, Synergy, Utility

I. INTRODUCTION

Electricity is one of the most significant technological advances that science has bestowed upon humanity. It's become an essential part of modern society, and it is hard to imagine life without electricity. Electricity serves many functions in our daily lives. It is used to light rooms, run fans, and power household appliances like computers and air conditioners. All of these offers people comfort[1]. Electricity is critical to the quality of modern life. It is a highly valuable, versatile, and controllable form of energy that can efficiently perform a wide range of tasks. Electricity has transformed the way the majority of the world lives in just over a century[2]. Lighting, refrigeration, electric motors, medical technologies, computers, and mass communications are just a few of the advantages it offers the world's growing population. We can run our businesses 24 hours a day, seven days a week because of electricity. Because working at night would be more difficult and dangerous without electricity, the majority of the work would have to be done during daytime. Working fewer hours leads to less productivity. Without electricity, all types of work would have to be done by hand[3]. Countries that once provided cheap labor will now command high prices because machines are no longer as efficient as they once were. Without electricity, industries will be unable to function effectively. They require a high capacity of electric supply and will have to close down or reduce their operations if there is insufficient electricity. Students have been unable to perform laboratory practices in recent times due to frequent power interruption; buildings have become inconvenient and uncomfortable to attend due to lack of electric energy to power fans, bulbs, and as well as electronic systems, printings of official documents, photocopying, and internet surfing have become more expensive as academic departments and businesses have had to rely on costly electricity in the campus. Workers have also been unable to properly carry out their duties during major events such as enrollment, meetings, registration, and graduation[4].

The administration building is the most vital component of the educational institution in Bacolor, Pampanga. The cashier, registration area, and other critical school areas that require constant power supply are being placed in the facility. Significant damage can occur to office buildings, when building operations are disrupted due to a power interruption, economic losses occur[5]. The impact of a power interruption on modern society, which relies on electricity in practically every aspect of life, is significant[6]. Consumers' everyday routine activities that rely heavily on electricity, will be immobilized if power is interrupted.

Don Honorio Ventura State University (DHVSU), located in one of Pampanga's provinces is a government-run institution, according to PELCO II the institution has suffered from frequent power interruptions, particularly the administration. Based on the idea that most administrations are interconnected with computers and the internet, and that the majority of students' and employees' files are stored in the system, any power interruption would result in the operation being non - functional. Another concern is the rapidly increasing cost of electricity with a total amount paid of P 3,663,327.9 and 403,004.00 kWh power consumption from the calendar year 2016 to 2021, it was recorded that 2019 has the highest power consumption . As a result of this factual information, the researcher is developing an alternative approach to address these issues. This study intends to offer a multi-power source utilizing a photovoltaic panel, utility, and gen-set that will provide a continuous power supply to power the administrative office's essential electric equipment. The primary functions of solar power systems and generators are to provide power users with dependable and high-quality electricity. Multi-powered source systems allow electric consumers to have alternative sources of electricity by using solar panels and generators. Furthermore, it considers the utility's assistance in having a consistent and more reliable power source for the generation of power. This design adjusts for the power consumed by the consumer from the grid, resulting in a lower electricity bill with the use of green energy. Electricity is becoming extremely valuable, and global warming caused by greenhouse gas emissions is adding to the problem. The "Renewable Energy Act of 2008," also known as Republic Act No. 9513, makes it possible to use renewable energy (solar). This act promotes the development and use of renewable energy sources as a means of preventing or reducing harmful emissions, thus balancing the aims of economic growth and development with health and environmental protection. By storing extra energy injected by PV during off-peak hours, batteries can give power autonomously[7]. As a result, the battery should be managed in a way that allows it to appropriately store excess PV energy but the difficulty that could face is, that it would consume a lot of space and batteries are prone to corrosion that may mutilate people surrounding the building, so this study proposing a battery-less system that will resolve the problem of spacing and safety of the employee.

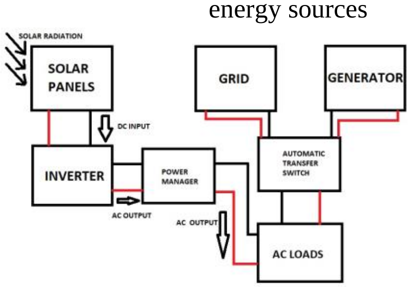
The study proposed an alternative source of electrical energy to provide a continuous supply of electricity for the administrative building of an educational institution in Bacolor, Pampanga. Specifically, to identify the size of the inverter, size of wires, size of the Gen-set and number of PV panels, strategic location for the generator and inverter, and compute the total cost of investment and savings.

The researchers adapted the study of Becquerel 1839 as cited by Knier 2002[8], while experimenting with a cell made of metal electrodes in a conducting solution, the photovoltaic effect. He demonstrated that when the cell was exposed to light, it produced more electricity. Adell & Fonsecam, 2017[9] stated that solar panel manufacturers typically provide warranties of 25 years or more. Panels can last for 25 to 30 years in the case of newer or well-built systems. The relatively high current cost of energy, combined with power interruptions caused by underinvestment in power facilities, remains the primary driver of the solar demand in the Philippines[10]. Furthermore, the Philippines has a natural advantage for solar growth due to its large number of peak sun hours (4.5-5 hours on an average day). In countries with unreliable utility grids, solar photovoltaic (PV) diesel hybrid systems are viable options for achieving a sustainable energy transition[11]. Generators have recently played an important role in providing energy during a power interruption, and they can be combined with various energy systems to improve the power quality and reliability of the system[12] [13]. The researchers adopt the studies because of the following factors: when the cell was exposed to light, it produced more electricity during peak sun hours, power interruption can disrupt the operation of activities and institutional productivity; environmental, financial, and economic performance; and the combination of various energy systems to improve the system's power quality and reliability.

II. PV PLAN DESIGN

The technical plan of the study consists of the synergy of solar panels supplying the building with the support of the utility and generator. If the solar panels are no longer sufficient, as well as the grid experiencing a sudden loss of power flow the generator will act as a backup power source.

Fig.1 Diagram of the proposed synergy of electrical energy sources



The process of mounting major materials such as solar panels is typically mounted using stainless steel, corrosion-resistant steel, or aluminum alloys. The lower end of the solar cell panel is inserted into the lower supporting part of the bottom structure, and the upper end of the solar cell panel is secured to the base frame with stainless set screws. In addition, during system installation, various power materials such as an aluminum junction box, and copper wires oxidize over time to form a green patina, which protects the metal from further corrosion, and galvanized steel panel boards complete the circuit. While the inverter is located in the administrative building and should be covered to protect it from weather conditions to increase the inverter's lifespan, it is necessary to consider the shady area. Lastly, the Generator should be placed away from the building, with a clearance on each side from any structures

III. METHODOLOGY

The energy demand is one of the tools in data collection, and was adapted from Don Honorio Ventura State University. It was modified in part to meet the study's requirements. The data gathering guides the collection of information about energy demand, which is then used as input for the design process of the proposed solar power system. The researchers gathered the necessary information to propose a synergy electrical energy system in the administration building. The year 2019 was chosen after analyzing the data provided by the admin building the given time frame and cost. According to the findings of the study, the year 2019 has the highest demand between the time frame of 2016 to 2021. The energy demand was conducted in two stages: The first stage involves gathering the data on the provided load schedule, and layouts to determine the electrical demand in the building. It contains information such as the lighting used and total wattage. The total installed power capacity was calculated by adding the kilowatt loads of lighting, ventilation, and air-conditioning units, as well as other electrical units. The second involved a review of the monthly electric bills in the area for the previous twelve months. The goal is to inspect and analyze educational institutions' power consumption.

- Site assessment

Site requirements and factors that assist in the output optimization of a solar power system. A solar power system study involves assessing the suitability of the site, solar access, shadowing considerations, and other factors. Identifying the location and arrangement of the panels is an important stage in building a Power Supply system because it will streamline the later components. The researchers will inspect the site to determine the actual load utilization during working hours, generators, solar panels, and inverter locations. The amount of power needed to construct solar power systems is determined by the amount of power required, grid connectivity, and the square footage area of the roof where solar modules will be installed. The researchers adopt the number of lighting outlets, convenience outlets, and air-conditioning units used based on the administrative building's load schedule and the electrical demand per month.

- Panel Sizing

After determining the entire load to be powered by the PV system, determine the area and size of solar panels required to provide that quantity of power. Electricity demand usually provides information, and it is feasible to estimate the needed size of a PV system that balances monthly energy use based only on the electricity demand.

The formula for Sizing the PV panel is[14]:

Power Output = Daily energy use / Peak sun hours

Number of PV panels needed = Power output / PV Wattage

- Inverter sizing

The inverter must be capable of handling the maximum power of AC loads when it is chosen. Inverters for the systems must be large enough to handle the total number of Watts used at any given time. The inverter should be 25-30% larger than the overall Wattage of the system with additional capacity added to accommodate surge current during startup[15].

- Generator

For emergency purposes, the backup generator allows the administrative building to continue supplying and supporting the needs of students on getting their important documents and employees in the admin on doing their office work, specifically computers, printing machines, internet, and other devices keeping all critical administrative functions operational. The major factors of the diesel-generator size and optimal functioning are that the diesel is not lightly loaded, that it runs for a sufficient period to reach operating temperature with manual and automatic starting, and that self-regulation using a governor provides the engine with an accurate fuel quantity at different load requirements [16].

The formula for the calculation of the generator is[17]:

Total kVA = (I x E x 1.732)/1000

Ampere = (kVA x 1000)/1.732 x E

- Mounting of Panels

The researchers used Aluminum for solar panel rails and mounts. The system is secured to the roof by penetrating the roofing material and securing the system feet. The roof mount system consists of L-foot brackets that are attached to the roof surface. The L-foot bracket is attached to a set of rails by bolts. Solar modules are mounted directly to the rails using mid and end clamp connectors. End clamps secure the modules to the rails. Keeping the module's edges away from the roof's corners can help to mitigate the effects of any wind forces. The space between the last row of solar panels and the edge of the roof should be at least 12 inches or 1 foot. It is best to leave four to seven inches between two solar panels. The space for maintenance workers to climb onto the roof and make repairs as needed[18].

- Sizing of Wire, Breakers, and Switches

Wiring is a critical component of power systems, particularly PV systems, for the safety of the systems and users. Improper wiring and cable size can cause overheating, fire outbreaks, electric shock, high losses, and poor PV system performance. A #8 AWG wire or 10 mm^2 solar cable is preferable since it is thicker and allows for greater voltage-transfer[19]. The correct ampacity of wires and breakers will be specified using the Philippine Electrical Code (PEC) 2017 to ensure that electrical wiring installations are designed with safety considerations. The maximum voltage and current of the PV string being isolated must be considered in the isolator rating, and these parameters must then be modified in line with the safety considerations required in current standards[20].

When calculating Surge Protective Devices, the Institute of Electrical and Electronics Engineers (IEEE) makes suggestions on surge ratings but does not publish them[21]. Any information provided by a manufacturer, whether through calculations or other means, is merely a recommendation. It is common that the larger the panel, the higher the kA device rating required for protection. The size of the transfer switch corresponds to the load schedule of the building to ensure the system operates efficiently and safely. Automatic transfer switch connected to two power sources must be able to handle the voltage[22].

- Cost of materials of the system

In every engineering job, the cost is important. The overall fixed and operating expenses for the life of a PV system and Gen-set are expressed in today's money in the cost analysis. The sum of the present worth of

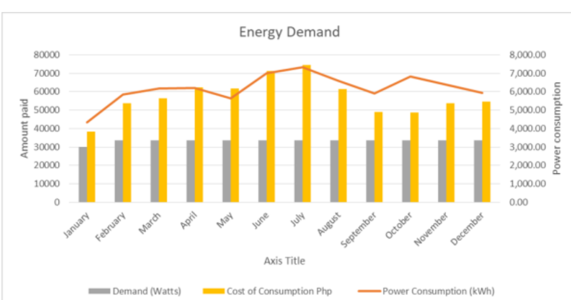
PV modules, inverter, installation, and operation and maintenance costs makes up the entire cost of a PV system because there are no moving parts and the input fuel (sunlight) is available, annual maintenance costs are almost non-existent. The system requires module cleaning and basic preventive and corrective maintenance to function properly. Maintenance costs for larger systems are typically about 1% of the initial cost[23]. While the installation cost is about 10% of the total system cost[24]. Lastly, the Total Investment is equal to the Total panel Cost added by the Total inverter cost, Total mounting cost, Total Installation/Service cost, and Total wiring/switches/fuse cost.

The formula for the Payback Period[25] is Total System Cost subtracted from Value of Incentives and divide by Cost of Electricity and divide by Annual Electricity Usage and the Return of Investment is the lifetime cost of electricity from the utility subtracted by lifetime cost of solar. Lastly, to calculate the life-cycle cost of electricity the cost of electricity per kWh will be multiplied by Monthly kWh usage, 12 months, and 25 years.

IV. RESULTS AND DISCUSSION

The administrative building at Don Honorio Ventura State University employs over 100 people and serves over 20,000 students. DHVSU's current statistics on energy use and cost of electrical use have gradually increased with the increase in student population due to its free tuition fee system and its continuous work. In calendar 2019, the administrative building used 74,152.00 kilowatt-hours of electricity, which cost P 685,989.6.

Graph 1. Energy demand for the building in 2019



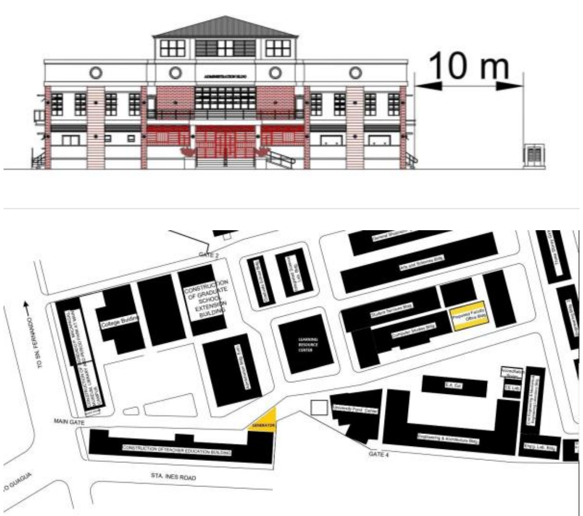
The Total kWh per month is 6,179.33. While the Total kWh per day is 205.98. The total peak sun hours is 45.77 kWh and for the Future loads is 57.2125 kWh. The number of solar panels is 120 pieces with 500 W each panel with an area of 2m2 each panel to sustain the 205.98 kWh average demand per day . The solar panel has a specification of Open-circuit Voltage (VOC) of 51.7 V, Voltage Maximum Power (VMP) of 42.8V, and Current Maximum Power (IMP) of 11.69A. The solar panel to inverter has 12 PV arrays with 10 pieces series connection in a single array . The total PV voltage output (VOC) is 517V and the total PV voltage output (VMP) is 428V, which means the inverter can handle the output per array. The total PV output current (IMP) is 11.69A. The electrical materials used, size of wire is 2-10 mm² PV CABLE, circuit breaker 1-20AT DC MCB, 2P, 10KAIC, insulator 20 A DC ISOLATOR (EACH), surge protective devices 1-800V DC SPD, 2P, 40KAIC and conduit size 15mm Ø PVC PIPE.

Figure. 2 Location of Inverter

The inverter is located on the east wing of the administrative building, parallel to the generator. The inverter should be covered to protect it from weather conditions. The system's average daily demand is 45.77 kW, with an extra 25% future load of 57.2127 kW according to market availability the inverter size is 60 kW. The On-Grid Three Phase Inverter consists of a maximum input DC voltage of 1100V, maximum input DC of 26 A per Maximum Power Point Tracking

(MPPT), the maximum PV input power of 66 kW, a rated grid voltage of 220 V, and rated output AC of 157.5A. The inverter can handle the output per array and the total PV output current of the solar panels. The total current (IT) of the inverter to utility total is 196.875A. The electrical materials used for size of wire is [3-80mm² + 1-22.0mm²(G)] THHN CABLE, circuit breaker 1-200AT/300AF, 3P, AC MCCB, 40KAIC, surge protective devices 1-385V AC SPD,3P, 20KAIC and conduit size 50mm Ø RSC PIPE.

Figure. 3 Location of Generator

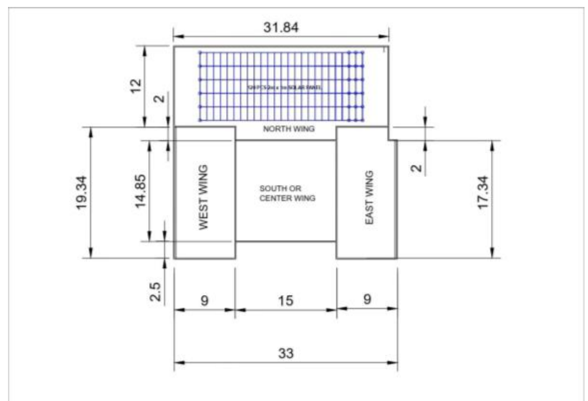


The Generator should be placed 10 meters away from the east wing of the building, with a 1-meter clearance on each side and a top clearance of at least 1.5 meters from any structures. Taking into consideration the need to avoid breathing the hazardous gasses that generators emit, the source of obstruction to students and workers, as well as the availability of the area in the institution. The constant three-phase generator calculated the size of the diesel generator with a value of 92.30 kVA with a current of 231.7 A. Using the total computed VA, use 1-100KVA, 3PH, 230V GENERATOR. The electrical materials used, size of wire is 2[3-150mm² + 1--50mm²(G)] THHN CABLE, circuit breaker 1-250AT/300AF,3P, AC MCCB, 40KAIC and conduit size 65mm RSC PIPE.

The Surge protective devices securing the system from lightning strikes occur near the PV system, USE 1-385V 3P AC SPD 20 KAIC and 1-800V DC SPD. The ATS switches between the diesel generator and the utility connected to the administrative building. The function of the Transfer switch is to shift the secondary source which is the diesel generator in a catastrophic event such as a power interruption. Using 250AT/300AF, 3P, AUTOMATIC TRANSFER SWITCH is enough to handle the load for the diesel generator and the utility. The current transformer clamp limiter allows the export power manager to monitor and control the backflow power from the inverter to the grid. This limiter detects the current going from the grid to the load and guarantees that the grid-tie inverter only provides the amount of power required by the load, preventing excess power from being delivered to the grid and generator.

- Roof Plan

Figure 4. ADMINISTRATION BUILDING SOLAR PANEL LAYOUT



The solar modules are placed on the roof of the building, upon inspection of the sun allocation, it is preferred to place all the PV modules on the north wing of the building to lessen the shading of the solar panels in the sunlight during daytime. The roofing plan of the administrative building is divided into four sections: the first area of the north wing located at the back is 382.08 m2, the second area of west wing at the left portion is 174.06 m2, the third area of east wing is located in the right part is 171.74 m2, and the fourth area of the south wing is located at the center is 222.75 m2. It is then calculated for the number of panels that will be installed on the roof, with an area of 2m2 per panel with a total of 120 solar modules with a weight of 23 kg per module the solar panels are distributed equally to disseminate the weight of each module. The distance between the row of solar panels and the edge of the roof is 1 foot, and the distance between two solar panels is 0.33 feet. According to experts, the structure analysis of the admin building has passed and can manage the design loads of 120 PV modules in the north wing.

- Cost of materials of the system

The researchers calculated the total cost of the materials, system installation cost, total cost of the system, and the annual maintenance cost which are P 2,475,360, P 247,536, P 2,722,896, and P27,228.96 respectively. The value of the equipment shown is based on the current market price, and the materials of the proposed design are based on market availability. The overall system installation cost is approximately 10% of the total material cost. Larger systems typically have maintenance costs that are about 1% of the initial cost. The calculated payback period is 3.97 years, and the Life-cycle cost of electricity has P 17,147,640.75, with Return of investment of P 13,744,020.

CONCLUSION AND RECOMMENDATION

Conclusion

The proposed synergy project of the Solar Power System, Utility, and Diesel generator design is sustainable, reliable, and has high quality. Although the initial cost is very high, the design implementation is a worthwhile project for the institution since it is far less expensive than what the building is currently using and costs less than the utility bill. As confirmed by the results, the proposed synergy of electrical energy sources is capable of providing stable and reliable electric energy to power the institution's Administrative Building. It can assist the institution in generating electric energy for its use while also serving as a good motivator for other institutions. To run the administrative building the study promotes the installation of 120 pieces of Photovoltaic panels with 500 watts each in the roofing on the admin building to have a 60 kW total power supply, when a power interruption occurs, there will be a 100 kVA to support the system and guarantee an uninterrupted electricity system. With all of the information gathered, the payback period is 3.97 or 4 years given that solar panels have a lifespan of 25-30 years. The calculated return of investment is P 13,744,020.

Recommendations

The administration may apply net metering in the administrative building, allowing them to use electricity whenever they need it while contributing to the grid and lowering their electricity bill even during a power interruption . If the institution has a suitable location for the energy storage battery, this may be included in the system. The design may be used by future researchers in various buildings at the Institution in Bacolor, Pampanga. Future researchers may also include the title “electrical sustainability” since its purpose is to maintain electrical power supply and can assume 30% for the installation cost based on the Philippines price.

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