



Design and Installation of a Rooftop Solar System for the Directorate of Research and Development, Unicross

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ABSTRACT

The Directorate of Research and Development, University of Cross River State is located in the basement of the Administrative Block, with limited natural cross ventilation and illumination. Electricity from the national grid is epileptic, and power from the school's central generator is sometimes insufficient. Owing to these, the offices of the Directorate are usually too dark, stuffy and not conducive for proper office work. To make the Directorate of Research and Development more conducive for the coordination of research-related activities in the University of Cross River State, this research sought to design and install a rooftop solar energy system to power the lighting and main office equipment of the Directorate of Research and Development, University of Cross River State. Using 4 numbers of 300W PVs and 3 units of 220AH tubular batteries, this study was able to provide uninterrupted power supply for the directorate, making work more conducive. The researchers installed solar fans with separate PVs in the offices, which relieved the battery bank and made it more sustainable.

KEYWORDS: Directorate of Research, illumination, electricity, roof-top solar installation.

Introduction

The Directorate of Research and Development is one of the very active directorates in University of Cross River State, Calabar. The Directorate coordinates researches from all departments, funded by agencies such as the Tertiary Education Trust Fund. The Directorate is headed by a Director, with a number of Administrative staff. Owing to the vital role the Directorate plays in the academic life in the university, the offices are very busy, with a high traffic of academics consulting with the Office for various research reasons.

However, located in the basement of the Administrative Block, Calabar Campus, the Directorate has a challenge of lighting. The offices in the Admin Block's basement do not receive enough natural lighting, because there are no windows on one side. Cross-ventilation is also a problem, because of the lack of windows on one side of the offices. Power supply from the Port Har-

court Electricity Distribution Company (PHEDC) is epileptic, and the university's central diesel generator is sometimes inadequate. Whenever there is no electricity from both the PHEDC and the school generator, the Directorate is put in pitch darkness and work is impossible. Also, when there is no electricity, the air in the Directorate becomes stuffy, making it difficult to breathe, because the fan is not on, to ventilate the offices. To make the Directorate of Research and Development more conducive for the coordination of research-related activities in University of Cross River State, it is important to provide alternative and dependable lighting. However, it is important to note that, as a Directorate of Research and Development, the alternative source of energy needed must be compliant with global best practices in renewable energy. For, it will make no academic, environmental and contemporary sense for the Directorate to take any option

based on fossil fuel, such as electricity generator. The more sustainable option is to explore renewable energy, such as solar installation for the Directorate of Research and Development.

Statement of the Problem

The Directorate of Research and Development, University of Cross River State is located in the basement of the Administrative Block, with limited natural cross ventilation and illumination. Electricity from the national grid is epileptic, and power from the school's central generator is sometimes insufficient. Owing to these, the offices of the Directorate are usually too dark, stuffy and not conducive for proper office work.

The location of the Administrative Block is compatible with solar energy sources because the university lies at the coordinates 4.9308° N and 8.3303° E (Google search). In this general area, there is much sunshine throughout the year (Weather.com). Thus, the sunshine available within the vicinity can provide sustainable, feasible and renewable sources of power for the Directorate. Since the renewable solar power system will be maintenance-free and will avoid the expenses of diesel generators and the unavailability of the national grid's power, there is a serious justification for designing and installing a rooftop solar-wind energy system to provide energy for the Directorate of Research and Development to light its offices and power its main equipment.

Objective of the Study

The general objective of this research was to design and install a rooftop solar energy system to power the lighting and main office equipment of the Directorate of Research and Development, University of Cross River State. The specific objectives are to:

1. Design a rooftop renewable solar energy system that will generate electricity adequate to power lighting and office equipment in the Directorate of Research and Development.
2. Install the rooftop renewable solar energy system in the Directorate of Research and Development.

Renewable Energy Sources: a Related Review

The most well-known renewable sources are solar and wind. The technology of wind energy conversion is has been in use for mechanical applications like grain crushing since 644 A.D. In areas like Persia, Afghanistan (Hau, 2000). Vertical axis turbines were the first wind mills used, which sailed around a pivot to generate mechanical power. The classical or horizontal axis wind turbine is independently attributed to European designers since 1180 (Kirsch 2009). The windmill technology reached its peak in Europe in the Early 19th century, and spread to the British and Dutch inhabited East Coast of the United States of America. The mid-west of

America had need for extracted artesian water for settlers' farms and the first suitable extractive solution was in 1850 (Kirsch 2009).

It was Dane Poul La Cour that built the first purely electricity generating wind mill in Denmark, which drove a dynamo in 1891. The Lykkegard Company and others developed the design further. World War 1 brought fuel shortages that accelerated the production of wind turbines. By 1918 there were about 120 electricity generating wind turbines operating around Europe (Kirsch 2009). From that time, wind has continued to be harnessed for generating electricity. In fact, Boyle (2007) states that wind power generation will end up being a sustainable and economically viable energy alternative in the world of the future.

According to McGowan (2003) the procedure for the design and installation of a wind energy system includes determining the application, the load and estimate costs (Alkhalidi and Husein 2018), to enable the system optimize the most suitable design for the situation. There are two basic styles of wind turbines, the horizontal axis and vertical axis types (see Fig. 1). The horizontal axis wind turbines (HAWT) are the most popular style in the market (Heier 1998, Gipe 2004). They take wind energy from one direction, as wind flows over the blades and creates lift, which is translated to rotational energy. Most HAWT are capable of rotating at much faster speeds than the wind is traveling. On the other hand, the vertical axis wind turbine (VAWT) is less popular but more effective at lower wind speeds. VAWTs use wind from all directions without the need to change the angle of incidence (Pond 2012).

While wind energy systems use wind turbine generators, solar energy systems depend on photovoltaic panels (solar panels) to generate electricity from the sun's rays. According to *National Geographic* (2019), solar energy is the technology used to harness and make the sun's energy useable. Made of semiconductor materials, the cells are like those found in computer chips. As sunlight hits the cells, electrons are knocked loose from their atoms. Electrons then generate electricity as they flow through the cell. In a solar system,



Fig. 1: Horizontal Axis Wind Turbine (left) and a Vertical Axis Wind Turbine (right).

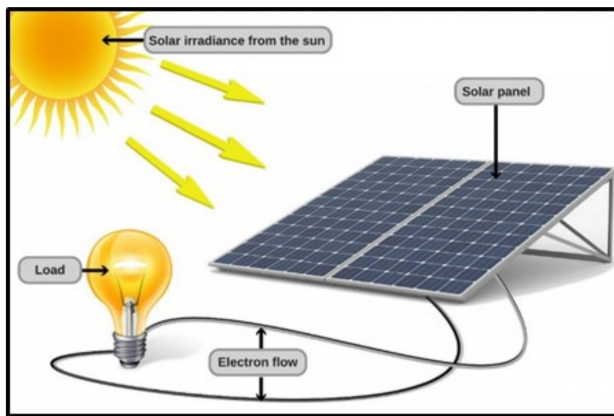


Fig. 2: Solar energy and configuration system.

the photovoltaic panels generate power that supplies gadgets directly and also feeds into battery until it is full, for night time energy demands (Hockenos 2019). As of 2011, the technology produced less than one tenth of one percent of global energy demand. However, solar energy use has surged at about 20 percent a year over the past 15 years because of rapidly falling prices and gains in panels efficiency. Solar energy is lauded as an inexhaustible fuel source that is pollution-free and often noise-free (*National Geographic* 2019). The growing popularity of solar panel and battery systems is driven by a drop in lithium-ion battery prices (Hockenos 2019). As Gearinoe (2019) notes, prevailing market forces are helping the world move away from fossil fuels, and coal-fired power plants will not be able to compete on price with new wind and solar power by 2025.

According to *The NEED Project* (2018) solar energy can be used to produce electricity by using photovoltaics (PV) and solar thermal systems. Photovoltaic comes from the words “photo”, meaning light, and “volt”, which is a measurement of electricity. Solar cells are made up of silicon and can supply energy to anything that is powered by electricity. Electricity is produced when radiant energy from the sun strikes the solar cell, causing the electrons to move around, which starts an electric current (see Fig. 2). This process takes place silently and instantly, without mechanical parts that will wear out. Opened in 2015, and generating 550 megawatts of electricity to power 150,000 homes, the Desert Sunlight solar project in California is one of the largest photovoltaic plants in the world (*The NEED Project* 2018).

However, photovoltaic systems are sometimes combined in hybrid installations. In *Designing a Hybrid Wind and Solar Energy Supply System for a Rural Residential Building*, Hessami (2006) sought to provide a hybrid renewable energy system for the building’s energy requirements, including a hot water service, space heating, other electricity supply and storage systems.

Performing a cost-benefit analysis for the building, the author found that it will be too expensive to heat up the large house on solar alone, because the house was designed with very large windows, which quickly decimate the indoor heat. Besides the heating requirements, power was also needed “not only for lighting but also for the operation of the air conditioner as well as various appliances that are normally used in the house” (p121). This power need is definitely high, and the high expenses of a completely solar power system dwarfed the benefits and made it unfeasible to execute. This made a hybrid system inevitable for the project. Since the building’s average power need for Summer and Winter was 11KWh a day, the author used five 80W photovoltaic (PV) modules and a 2.5 kW output wind turbine generator. At the end of the design and installation, it was discovered that the final cost was much higher than connecting to the grid, that is, minus the intangible environmental benefits like reduced greenhouse gas emissions.

While recognising that demand for more energy generates the search for newer sources, Fesli, Bayir and Ozer (2009) declare that wind and solar are the most popular because of their abundance, ease of availability and convertibility to the electric energy. In their work, *Design and Implementation of a Domestic Solar-Wind Hybrid Energy System*, they sought to realize a solar/wind hybrid renewable energy system for a domestic application. The project was implemented to allow the system’s batteries to be charged by either wind power via a small alternator or solar power via an MPPT Module. The system was also designed to allow real time monitoring and control. As the authors narrate, since photovoltaic solar panels and small wind turbines depend on climate and weather conditions, solar and wind power are often not sufficient alone. Thus, a number of renewable energy experts highlight the point that renewable energy projects are bound to be satisfactory if both wind and solar power are integrated within the system. In the summer time, for example, sun beams may be strong and wind velocity relatively small. At winter, sunny days are relatively shorter and wind velocity is often high. According to the authors, these disparities make solar and wind complimentary sources, meaning that there is more to be gained in a hybrid system than in a renewable energy solution in which only one of the sources is used. The point is that these two systems support each other to sustain the “continuity of the energy production in the system” (p30).

In their work, *Design & Integration of Wind-Solar Hybrid Energy System for Drip Irrigation Pumping Application* Shivrath, Narayana, Thirumalasetty and Narasaiah (2012) have noted that there is increasing demand for the use of alternative and renewable energy sources to generate clean and low-cost electricity for agricultural uses such as water pumping. They also

note the enormous potential for non-thermal onsite power generation in India, where people are increasingly investing in small-scale hybrid solar and wind power. To generate clean energy, while increasing energy independence for a rural agrarian uses, the authors designed and installed a renewable energy solar/wind hybrid system for a standalone drip irrigation system. Their product consisted of a submersible pump that drip irrigated 1.5 acres of mango crop. Their work provides a cost optimization of a wind-solar hybrid system, which outlines useful guidelines for small scale wind-solar hybrid system production. While they highlight the fact that solar-wind hybrid energy systems involve significant initial investments, the authors are convinced that the costs are competitive with conventional energy sources when a lifetime of reduced or avoided utility costs is accounted for.

In their research, *Designing a Rooftop Solar-Wind-Mains Hybrid Energy System to Light the Studios*, Ajibade, Takon and Ofem (2021) sought to provide power for lighting the studios of the Department of Visual Arts and Technology, University of Cross River State, Calabar. As with the problem of the present study, mains was very unreliable and epileptic, while the school diesel generator usual did not get to the facilities. Yet, students of that Department needed to be working in the studios at nights. To solve the problem, the authors designed a hybrid solar/wind system to fit the situation, and to ensure that power is also generated at nights. In their design, the authors installed 2 units of 24v panel lights in each of the 13 studios. They then used 6 numbers of 100AH gel batteries in a battery bank, 4 numbers of 300W PVs and 1 unit of 200W vertical axis wind turbine (VAWT) in the system. The authors used a vertical axis wind turbine because it maximises the prevailing wind at the location, at a start up speed of 1.2m/s. They also installed a 24v battery charger, to enable the system charge from mains, whenever it was available. Results indicated that the installed system provided enough lighting to eliminate the usual darkness and students were able to see, work and read in the studios.

From the review of related literature, Hessami's (2006) main challenge was the volume of power needed for heating, refrigeration, hair dryer and other high-energy appliances like air conditioning, which significantly increased the resources and components required to configure the renewable system for the building. The energy needed for just lighting was minimal, feasible and easily achievable with a much smaller budget. Thus, the present study completely avoids the challenges Hessami (2006) contended with, because the renewable system envisaged here is merely for lighting and having power for printing emergency documents in the Directorate of Research and Development. Also, this study differs from Fesli, Bayir and Ozer's (2009) project in that, while theirs were to pow-

er other appliances, the system in this study is a rooftop unit that will power the spaces within the Directorate of Research and Development. Finally, this study also differs from Ajibade, Takon and Ofem (2021), because, while the studios will be used at night times also, the Directorate needs power only in the day time. Thus, unlike Ajibade, Takon and Ofem's design that needed to generate power at nights, the design in this study is for a stand-alone PV installation, since no power is required at nights in the Directorate.

Method

The methodology for this research was experimental, using industrial standard components and materials, to design and install a solar energy system to power the Directorate of Research and Development, University of Cross River State, Calabar.

Various components were acquired for the project, to fit the design (Table 1). Aluminium profiles were used to install the 4 pieces of 300W PVs on the roof of



Fig. 3: The installed PVs on the roof of the Admin Block.

Table 1: Materials Used for the Installation.

S/N	DESCRIPTION OF MATERIAL/SERVICE	UNIT	QUANTITY
1.	12V 200A batteries	Nos.	3
2.	12v 3000w mini inverter	Nos.	1
3.	300w panels	Nos.	4
4.	20w solar fans	Nos.	3
5.	12V 40A Batteries charger	Nos.	1
6.	40A MPPT charge controller	Nos.	1
7.	PV Cable 6mm Flex Dual Core	Met.	30
8.	Batteries Cable 25mm	Nos.	4
9.	Dc SPD	Nos.	1
10.	63A Dc Circuit Breaker	Nos.	2
11.	Ac Breaker 125A	No.	1
12.	Voltage Protector	Nos.	1
13.	Circuit Breaker Box	Set.	1
14.	Change Over 100A	Met.	1
15.	Trucking Pipe	Nos.	1

the Administrative Block, where the Directorate of Research and Development is situated (Fig. 3). The PV 6mm dual core flex cable was then used to wire the PV array to the Directorate. 4 lengths of angle iron were bought and used to construct the battery rack, and painted. The 3 units of 220AH batteries were stacked inside the battery rack. The 40A MPPT charge controller, 63A DC circuit breaker, 125A AC breaker and voltage protector were mounted. Using the trunking pipes, all cables were connected inside the office. The battery cable was used to connect the batteries. The battery charger was connected to the mains and then to the battery bank, to ensure that the system also charges whenever there is supply from the mains. The 100A changeover was installed, to enable the Directorate change power source from mains only to solar only. The solar fans were installed in the office, and their individual PVs were also installed on the roof-top, and connected. The system was then tested, found to work adequately and was shut-down to charge the whole day.

Results

After the whole day shut-down, the system went online the following morning, and was left to run continuously. The rooftop solar installation was found to work effectively to provide power to light the directorate when mains is out. The switching was automatic, via the connection with the inverter system. The battery bank was also found to be optimally full, since the PVs charged it in the day time, and the battery charger provided alternate charging whenever mains was available. This way, there was always optimum charge in the batteries, enabling the Directorate to have lighting and to be able to print documents when the mains is out.

Conclusion

Apart from the illumination problem solved, as the solar fans worked, humidity was eliminated in the offices, making them more conducive for staff to work when there is no mains. Since the solar fans had their own PV and batteries, they did not constitute a load on the system's batteries, leading to much higher efficiency.

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