An Improved Photovoltaic System for The Operation of a Poultry Farm

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Abstract- The study considered the electronic power supply to the operations of poultry farm for improved power quality. The activities of poor and unreliable electricity power supply in the study case makes the marketing and business engagement in low breaking-even point (thetas profit), thereby driven the entire system with higher operational fuel cost (diesel). The research work adopted optimal economic sizing technique that required electrical load data profile determination for successful sizing and optimization of a micogrid PV/solar system as an alternative power supply system to the poultry farm (chicken farm) for reliable and consistent energy requirement. The solar irradiation and the ambient temperature data of the Rumu-ekene Community in Obia-Akpor Local Government Area, Rivers State was accessed from NASA database in order to determine adequate power generation from that location following to the load profile needed in the poultry facilities and electrical equipment consumption patter trend. The system configuration includes PV and battery in order to sustained the amount of energy from the solar PV system to the storage (battery). The optimal sizing technique was applied to the diesel-generator and PV-Diesel hybrid configuration for purpose of efficient power delivery to the chicken farm under investigation. The results shows that PV battery system has about 90% renewable energy penetration with little or no carbon dioxide (CO_2), carbon-monoxide (CO), unburned hydro-carbon etc emissions in the zone. That as this configuration is environmentally friendly essentially, the system cost is relatively higher compared to PV-Diesel hybrid system. The PV-Diesel hybrid system which had about 80% penetration even in cost.

Indexed Terms- Photovoltaic System, Power system, renewable energy, Battery capacity

I. STATEMENT

The challenges of developing an effective monitoring poultry farm operations needs sustainable electric power supply in order to service the activities of the economic operations under study. This mean that the tendency to enhance an effective poultry farm activities seriously in the study area required reliable and steady source of power supply (photovoltaic energy). Hence lack of poor electricity power supplied has led to: (i) Black-out (outages) in most time results into poor production activities of the poultry farm under study. (ii) More engagement of operational fuel cost for the poultry farm activities due to poor supply of electric utility. (iii) Low revenue (profit) in return of expenditure (poultry farm) due to inadequacy of reliable power supply in the research zone. (iv) To quest for an alternative electric power supply (photovoltaic) in order to minimize the operational fuel cost of diesel power plant under investigation (power supply). (v) Irregular monitoring records of the smart sensor device in the study area (in the view to capture thieves or unallowed present) as a results of unreliable electric power supply for purpose of the need to improve poultry farm production.

II. INTRODUCTION

In recent times, there has been renewed interests in developing low voltage control/monitoring electronics and green energy sources for livestock maintenance (protection and operational functions emphasized). Livestock maintenance forms a very important part of Precision Livestock Farming (PLF) which forms the basis of the Smart Agriculture industry.

For instance, a human agent monitor may tamper with livestock produce and deliberately or otherwise leak sensitive information that may lead to lose of livestock(s); watch dogs may also be tempted to feed on livestock and as a result the primary purpose of using such method is defeated. But in most cases, losses may be as a result of human or animal error.

Augmented Reality may also serve as a promising technique to improve maintenance efficiency and reduce the losses that result from human or animal error (Benbelkacem*et. al.*, 2013). Augmented Reality Systems (ARS) can allow the detailed capture and manipulation of data from real-time livestock monitoring devices (physical model) using a software (non-physical) model.

As the ever-increasing cost of maintenance remains a primary issue, the need for green energy alternatives and consequent effective utilization as back-up power source cannot be overemphasized (Bazen & Brown, 2007). Such systems should provide a veritable set of solutions that can reduce both long- and short-term cost of maintenance.

III. PAST REVIEW

In a review by Sutter (2013), the need for environmental monitoring systems that improve on human (manual) monitoring and the benefits that accrue from such systems have been emphasized. Corkery *et. al*., (2013) presented an overview of the challenges faced by the poultry industries including the need for proper environmental condition monitoring for poultry animals so that these animals can perform optimally; They particularly stressed the need for smart wireless gathering of poultry data over the internet through Precision Livestock Farming (PLF).

Bazen & Brown (2007) investigated the feasibility potentials of photovoltaic technology for poultry farms in two regions in Tennessee USA. They reported that Solar PV is a feasible option only as a backup source bearing the constraints in cost of PV panels and competing power sources as obtained from diesel and petrol engines and should be used only for small alternative power needs.

Mansor *et al*, (2014) developed a smart poultry concept with improved image processing capabilities with a mobile phone with built-in camera for image capture and improved algorithm/API for image classification in the cloud.

In Sohn*et al*., (2008), semi-continuous measurements of odour concentrations in a poultry farm was performed using an electronic nose.

Marcus (2010) proposed a web-based wireless sensor network for real-time monitoring of poultry birds via four distributed motes; temperature and relative humidity were monitored with a 5% packet loss achieved at a distance of 40m for a mote.

Goud & Sudharson (2015) proposed a model for monitoring and alert of poultry over the internet; data storage was done online using Google spreadsheet; their results show that it is possible to remotely obtain and store poultry environmental data remotely which is indeed very beneficial for the management of an existing poultry farm.

In Guo *et al.*, (2017), the practicalities of real time poultry monitoring using three variants of vision cameras (infrared, video and thermographic) were investigated using real time embedded hardware with open-source vision software tools/algorithms and under varying lighting conditions in poultry farm; their key findings indicate the need for a trade-off considering cost of hardware, performance at low light intensities and coverage area.

IV. METHOD

Data required for analyses and investigations include solar irradiation, ambient temperature, and energy demand. The solar irradiation and ambient temperature data were accessed from the NASA database. The electrical load profile data was gathered from the site under investigation. To determine the load/energy requirement by every household and the design for the needed solar radiation that will be imping on the solar panel which will be converted into electrical form of energy for daily consumption.

I. Photovoltaic Panel (PV) Configuration

Solar radiation is attenuated before reaching the Earth’s surface by an atmosphere that removes or alters part of the incident energy via reflection scattering and absorption, thus removing nearly all UV radiation and certain wavelengths in the infrared region. Diffuse radiation is the radiation scattered by striking gas molecules, watervapour or dust particles.

Clouds are able to reduce direct radiation in so far as 80 to 90% (McGraw-Hill 2005, p. 656). In quantum theory, light consists of packets of energy, called photons, whose energy depends only upon the frequency of the light.

II. Battery Bank (BE)

Electrochemical batteries in a stand-alone photovoltaic system, understanding the properties of batteries is critical in understanding the operation of photovoltaic systems. For systems in which the photovoltaic is the sole generation source, storage is typically needed since an exact match between available sunlight and the load is limited to a few types of systems

III. Converter

A converter is needed for any system that is composed of both the AC and DC configuration. It can be an inverter in case of DC to AC conversion or a rectifier for AC to DC or can serve both purposes.

A. Load Estimate for Poultry Farm Rumuekene Community

Ina remote rural village, the demand for electricity is not high compared to urban area. Electricity is demanded for poultry farm, agricultural activities poultry farm (such as water pump).

Table 1: Photvoltaic Characteristics

Appliances	Wattage (W)	No Appliances	Total Power consumed	Estimated Hours of Usage	Project how Load for 24 hour cycle
Bulb (Poultry)	100	10	100w (1kw)	12 hrs	12kwhr
Bulb (staff Rooms)	18	5	90w (0.09kw)	10 hrs	0.9kwhr
Fridges	400	1	400w (0.kw)	12 12 hrs	4.8 kwhr
TV's	150	2	300w (0.4kw)	10 hrs	3kwhr
DVD	50	2	100w (0.1kw)	10 hrs	2 kwhr
Radio	9	2	18w (0.018kw)	10 hrs	0.18 whr
Computer	100	1	100w (0.1kw)	8 hrs	0.8 kwhr
Water Pump	100	1	100w (0.01kw)	6 hrs	0.6 kwhr
Fan	60	2	120w (0.12kw)	15	1.8kwhr
Total			2228		

Source: Research desk, Study Area Rumuekene community, Rivers State.

This total energy generated and its power obtained as

$$E = A \times r \times H \times PR \quad (1)$$

Where;

E : Energy (kWh)

A : Total

$$P(PV) = F_{PV} \times C \times \frac{E}{x} \quad (2)$$

Where;

F_{PV} : PV dc-rating factor

C_{PV} : rated power of the PV (kW)

G : solar radiation incident on the surface of the PV

K : peak solar intensity at the earth surface (1kw/rn2)

$$C_{wh} : (E_1 \times AD)/(\eta_v \times \eta_{wh} \times DOD) \quad (3)$$

Where

AD : Daily autonomy

El : Loads requirement at certain the time interval

$\eta_v and\ \eta_{wh}$: Efficiency of inverter and battery bank respectively

Battery depth of discharge is specified and not to be exceeded. So that;

$$E_{min} : EBN \times (1 - DOD) \quad 3.4$$

Where;

E_{min} : Minimum allowable capacity of the battery bank

EBN : Nominal capacity of battery bank

DOD : Depth of discharge

Total load estimate for 24 hour lad cycle = 25.08kwhr

P4 for 24 hours operation = $\frac{25.08kw}{24}$ = 1.045kw/hr

The load estimate for the community in KWI-IR for a 24 hour circle is 25.8KWI-IR so the Load per hour is given as;

PH in 24 hours of operation in (kWh) given as;

The P11 = 93.5/24 = 3/9Kw/h

Considering the load demand in the poultry farm, load estimate for poultry farm, (Rumuekene Community).

$$= 3{,}900 \times 2 = 7{,}800w \quad or \quad 7.8Kw \tag{7}$$

$$Or\ P_{LA} = 7.8Kw \tag{8}$$

Converting to KVA given as;

$$P_{LA} = \frac{7.8}{0.8} = 9.75\ KVA \tag{9}$$

The load demand is 9.75KVA allowing for 20% tolerance given as;

$$P_{RLA} = \left(P_{LA} \times \frac{20}{100}\right) + P_{LA}KVA \tag{10}$$

$$P_{RLA} = \left(7.8 \times \frac{20}{100}\right) + 7.8 = 11.7\ KVA \tag{11}$$

The rated power Demand for Rumuekene Community (P_{RLA})11.7KVA 12

C. Cost of Installing and Running Suitable Diesel Generator

The total cost of running a Diesel Generator (CUMMINS) with Perkins Engine) ratedat I6KVA.

The current capital cost of purchase is N1,200,000.00.

The total cost of transportation and installation to site is N50,000.00

The cost of the Diesel Generator (DG) and installation to provide 24 hours electricity as off-grid in Rumuekene Community;

$$C_{NP} = Cost\ of\ purchase + \frac{Logistic}{Installation} \tag{13}$$

$$Cost\ of\ purchase = 1{,}200{,}000 + 70{,}000 = N1{,}270{,}000.00 \tag{14}$$

V. RESULTS

This result analysis shows three system models. That covers the technical and economic system performance and environmental effect for 25 years lifetime. The simulation performed with HOMER is aimed towards finding the optimized system based on the cost and size for the existing components.

A. PV-Battery System

This system configuration included PV and battery. This model was simulated to examine the advantages and disadvantages of considering 100% renewable energy system. The simulation result is shown in figure 4.5.

RESULTS										
CS6U-340M (kW)	H3000	Converter (kW)	COE (US$)	NPC (US$)	Operating cost (US$)	Initial capital (US$)	O&M (US$)	Ren Frac (%)	Elec Prod (kWh/yr)	CO_2 (kg/yr)
365	4,104	306	US$1.25	US$5.82M	US$53,430	US$5.13M	US$0.00	100	474,083	0

Figure 1: Optimized result for PV-Battery System (Homer Simulation Tool).

PV capacity was 365 kW, 171 strings of battery which consist of 4,104 batteries and provided 29,341 kWh of electricity. The total net present cost (NPC) for the system, which is 5,820,000 USD and the cost of energy (COE) is 1.25 USD/kWh.

B. PV-Diesel Hybrid System

This system configuration was to examine an optimum system with best technical and economic benefit. The result of the simulation was shown in figure 4.6.

RESULTS											
CS6U-340M (kW)	H3000	Converter (kW)	COE (US$)	NPC (US$)	Operating cost (US$)	Initial capital (US$)	O&M (US$)	Ren Frac (%)	Total Fuel (L)	Elec Prod (kWh/yr)	CO_2 (kg/yr)
365	240	105	US$0.274	US$1.27M	US$34,118	US$832,676	US$3,036	86.6	15,563	435,919	40,738

Figure 2 Optimized result for PV-Diesel Hybrid system (Homer Simulation Tool)

The optimum selection of PV, Diesel generator and batteries provided COE and NPC of 0.374 and 1.27 respectively. The total system cost for the period of 25years which included capital, replacement, M&O, Fuel and salvage was $1,273,733.59. It recorded a renewable percentage of 86.6%and an excess energy of 3.42%.

C. Environmental Analysis

Table 2: System emission data (Homer Simulation Tool)

Emission (Kg/year)						
System Description	Carbon Dioxide	Carbon Monoxide	Unburned Hydrocarbons	Particulate Matter	Sulfur Dioxide	Nitrogen Oxides
PV-Battery	0	0	0	0	0	0
Diesel Generator Only	290,125	1,829	80	11	710	1,718
PV-Diesel Hybrid	40,738	257	11	2	100	241

The result shown in Table 4.1 indicated that Diesel system offered the highest rate of harmful emission into the sounding environment against the PV/Battery system which had no harmful emission. The PV-Diesel system showed a high reduction of emission.

D. Techno-Economic Analysis

As shown in Figure 3, the results obtained showed that the Diesel generator system has no renewable penetration and recorded the highest fuel and maintenance cost making the system economically viable. The PV-Battery system shoed the highest PV penetration of 100%, no emission but had the highest NPC and COE of 5,820,000 USD and 1.25 USD/kWh respectively. The high NPC is as a result very large battery bank required. The battery bank size is 4,101 batteries. It also has the highest excess energy. This system is not the best in terms of economic consideration.

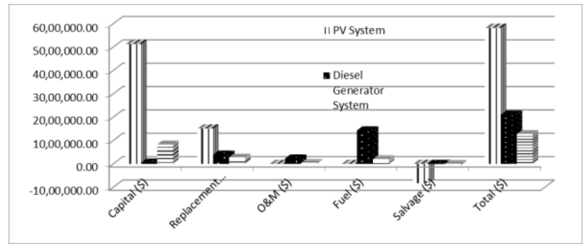

Figure 3: Comparison of system cost (Homer Simulation Tool)

CONCLUSION

The performances of system configurations were examined for a livestock farming. The results showed that PV Battery system has 100% renewable penetration, no emission which made it most environmentally friendly than other systems but it required a very large battery bank which made it most expensive system with highest NPC and COE. Diesel generator recorded the highest emission into the environment and increase greenhouse effect and global warming. It is also identified with highest fuel consumption.

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