# Sizing And Performance Analysis Of Off-Grid Solar Photovoltaic Power System For Remote Smart City Application-Ready Bus Shelter

Okpura I. Nseobong<sup>1</sup> Department of Electrical/Electronic and Computer Engineering, University of Uyo, AkwaIbom, Nigeria

**Ogunrombi**, Tijesuni Samson<sup>2</sup>

Department / Office of National Space Research and Development Agency, (NASRDA), Abuja, Nigeria tijesunisamson@yahoo.com ORCHID- https://orcid.org/0000-002-1527-1837

> Itoro E. Udosen<sup>3</sup> Department of Electrical/Electronic and Computer Engineering,

University of Uyo, AkwaIbom, Nigeria

Abstract— In this paper, sizing and performance analysis of off-grid Solar Photovoltaic (SPV) power system for remote smart city application-ready bus shelter is presented. A smart city application-ready bus shelter is a shelter built at bus stops with lighting points, mobile phone charging points and above all, wireless sensors and internet connection to enable users of the facility to connect to a wider smart city applications. The PVSyst simulation software was used to implement the components sizing operations and also to determine the various essential performance parameters of the system. The daily load demand is 2298 watt hours per day. The meteorological data of the SPV installation site is downloaded from NASA portal via PVSyst meteorological data import dialogue box. The optimal tilt angle is 9° and transposition factor (FTranspos) of 1.01 for the PV array. The SPV system was modeled with 5% loss of load probability and 4 days of power autonomy and it has a total of eight (8) 105 Ah 12V batteries with 2 connected in series and 4 strings of batteries in parallel. Also, the PV array consists of three (3) 235 Wp Si-mono PV modules with 1 module in series and 3 modules in parallel. The results show that the yearly average performance ratio is 0.652 (0r 65.2%) and in about five months of the year, the system operates at performance ratio below the yearly average. The best performance ratio of 80 % occurred in the month of June. Also, the yearly average produced useful energy is 3.09 kWh/kWp/day while the yearly average array collection losses is 1.315 kWh/kWp/day.

Keywords— Solar Photovoltaic Power, Smart City Application, Off-Grid Solar Power, Bus Shelter power supply, Sizing of solar power system

### 1. Introduction

Nowadays, the emergence of smart city and related technologies has affected virtually every area of our lives [1,2,3,4]. Smart transport, smart energy system, smart agriculture, cashless polices, zoom meetings, smart learning facilities and the rest of our day-to-day activities are expected to become dependent on smart applications [5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19, 20]. However, for system to be smart, some basic elements must be considered, namely, wireless sensor network and hence Internet connectivity as well as electric power supply [21,22, 23, 24]. In many cases, where the power from national grid is inadequate or unavailable, solar or wind or a hybrid of solar-wind power is used for alternative power supply, especially in Nigeria where there abundance of wind and solar energy resources [25,26,26,27, 28,29,30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42].

Notably, in this paper, off-grid solar power system for a smart city application-ready bus shelter is presented. The shelter is built at bus stops with lighting points, mobile phone charging points and above all, wireless sensors and internet connection to enable users of the facility to connect to smart city applications. The sensor enables remote monitoring of the immediate environment of the bus shelter and also to remotely control the lighting points and internet signal reception in the immediate surrounding of the bus shelter [43,44,45, 46,47, 48,49, 505,1,52, 53,54, 55,56, 57]. While it may be easier to setup the sensor and Internet connectivity as well as the rest of the electrical facilities for the bus shelter, providing the requisite power supply that can enable those the facility to function effectively can be a running challenge especially in the remote rural area where there is no access to the national power grid. The essence of powering the bus shelter with solar PV power supply is to enable installation of such facility in remote locations is to overcome the problem of no access to the national grid and also to provide clean alternative power supply. However, it is essential that such solar power supply be properly designed and its performance parameters should be

determined. Accordingly, in this paper, the sizing of the solar power system for the bus shelter is presented along with the performance analysis. The study is conducted using PVSyst simulation program. The requisite mathematical expressions for the solar power sizing computation are presented. Also, the daily load profile of the bus shelter and the meteorological data of the bus shelter location are also provided for the study.

#### 2. Methodology

## 2.1 Sizing of the PV power system for the remote smart city application-ready bus shelter

The main focus of this paper is to determine the effective size of the PV array, battery bank for the solar power and other key components of the PV power system, and also determine some key performance parameters of the PV solar power system realized from those component sizing computations. In order to size the PV array and battery bank for the PV solar power, the optimal tilt angle for the PV array is needed. For any given location latitude ( $\emptyset$  in degrees), the optimal tilt angle ( $\beta_{\text{Yopt}}$ ) for PV module installation is given in degrees as;

$$\beta_{\text{Yopt}} = 3.7 + 0.69 \left| \Theta \right| \tag{1}$$

The transposition factor (Tf) realized with  $\beta_{\text{Yopt}}$  is given in terms of the global irradiation on horizontal plane (G( $\beta$ ))

where the angle  $\beta = 0^{\circ}$  and the global irradiation on optimally tilted plane  $G(\beta_{Yopt})$  with angle  $\beta_{Yopt}$  as

follows;

$$1/Tf = 1 + [4.46(10^{-4})(\beta - \beta_{\text{Yopt}})] - [1.19(10^{-4})(\beta - \beta_{\text{Yopt}})^2] (2)$$
$$1/Tf = \frac{G(\beta)}{G(\beta_{\text{Yopt}})} (3)$$

Hence;

$$G(\beta_{\text{Yopt}}) = Tf(G(\beta)) \quad (4)$$

When the daily load demand ( $E_l$ ) is known along with the average daily peak sunshine hours (PSH), the efficiency of the inverter ( $n_{inv}$ ), the efficiency of the charger controller ( $n_{cc}$ ) and the effective cumulative derating factor ( $f_{dl}$ ), then the output power ( $P_{pva}$ ) required from the PV array that will

supply the daily load demand is computed as;  $P_{pva} = \frac{E_1}{(n_i)(n_c)(f_{cll})(PSH)}$ 

and in parallel respectively, while  $V_{sys}$  and  $V_{pv}$  are the line

voltage of the system and nominal PV panel voltage respectively, then,

$$N_{pvs} = \frac{V_{sys}}{V_{pv}} \tag{6}$$

$$N_{pvp} = \frac{P_{pva}}{N_{pvs}(P_{pv})} \tag{7}$$

If the efficiency of the battery  $(n_{ba})$ , days of power autonomy  $(n_a)$  and allowable maximum depth of discharge( $DOD_{max}$ ) are given, then the required battery

capacity ( $C_{ba}$ ) is computed as;

$$C_{ba} = \frac{(E_1) n_a}{(n_{ba}) (DOD_{max})(V_{sys})}$$
(8)

Again, if  $N_b$   $N_{bs}$  and  $N_{bp}$  denote the total number of battery in the battery bank, the number of battery connected in series and the number of battery string in parallel respectively, and also C<sub>b</sub> denotes the capacity of each battery while V<sub>b</sub> denote the nominal voltage of each battery then,

$$N_{bs} = \frac{V_{sys}}{V_b} \tag{9}$$

$$N_b = \frac{C_{ba}}{C_b} \tag{10}$$

$$N_{bp} = \frac{N_b}{N_{bs}} \tag{11}$$

The actual sizing of the PV system component are conducted through simulation using PVSyst software. The key performance parameters considered in the simulation incudes; the array yield  $(Y_a)$ , the final yield  $(Y_f)$ , the reference yield  $(Y_r)$ , the performance ratio (PR), the array capture and the system losses. Again, the listed performance parameters are all obtained from the PVSyst simulation.

### 2.2 The daily load demand and meteorological data of the remote smart city application-ready bus shelter

The daily load demand profile of the remote smart city application-ready bus shelter is presented in Table 1 while the global daily mean irradiation on the horizontal plane (kWh/m<sup>2</sup>.day) for the bus shelter location in Akwa Ibom State is presented in Figure 1. The daily load demand is 2298 watt hours per day. The screenshot of PVSyst dialogue box of the geo-coordinates (Latitude: 5.05 and Longitude: 7.90) for the bus shelter from which the solar irradiation was extracted are given in Figure 2. The PVSyst optimal tilt angle dialogue box showing optimal tilt angle of 9° and transposition factor (FTranspos) of 1.01 for the PV array is shown in Figure 3.

Table 1 The daily load demand profile of the Remote Smart City Application-Ready Bus Shelter (source: [58])

(5)

S/N	Electrical Appliance	Quantity	Wattage Rating (Watts)	Hours of operation	Energy Consumed per day (Watts Hours/Day)
1	LED Lights	2	3	14	84
2	High Flux LED	6	18	14	1512
3	Cell Phone Charger	2	5	15	150
4	WI-FI Router	1	20	24	480
5	Solar Charger Controller	1	2	24	48
6	Sensor	1	1	24	24
				Total Watt Hours per day	2298

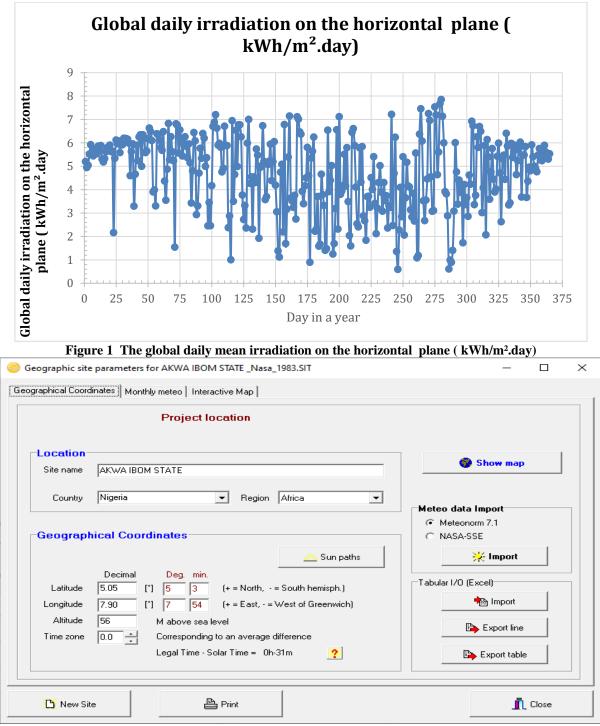
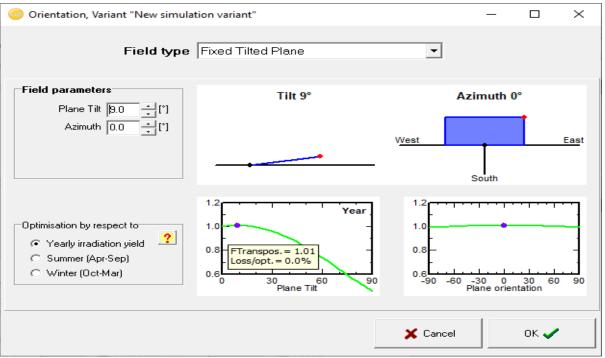
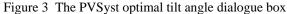


Figure 2 The geo-coordinates of the bus shelter from which the solar irradiation was extracted





### 3. Results and Discussions

The Standalone PV (SPV) power system model in PVSyst software was used to perform the component sizing and performance analysis. The PVSyst screenshot layout of the standalone solar power system is shown in Figure 4. The cut section of the PVSyst screenshot for the system components selection and battery bank sizing is shown in Figure 5. According to the information in Figure 5, the SPV system was modeled with 5% loss of load probability and 4 days of power autonomy and it has a total of eight (8) 105 Ah 12V batteries with 2 connected in series and 4 strings of batteries in parallel. The details of the selected battery used for the battery bank are given in Figure 6. The details of the

selected PV module used for the PV array of the SPV system are presented in Figure 7 while details of the selected details of the selected battery charger controller used for the SPV system are presented in Figure 8. The SPV system configuration is such that the PV array consists of 3 PV modules with 1 module in series and 3 modules in parallel. The PV module is Si-mono PV produced by Samsung SDI and rated 235 Wp at STC. The PV array has a total of 705 Wp power and a occupies a total area of 4.8  $m^2$ . The battery bank is made up of 8 units of Solar Block SB 12/130A battery produced by Sonnenschein.

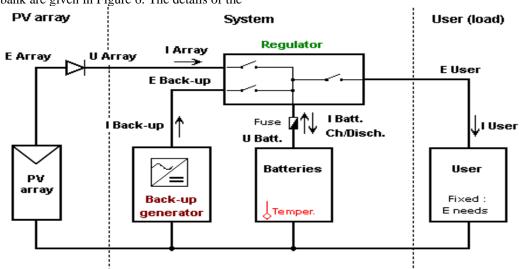


Figure 4 The PVSyst screenshot layout of the standalone solar power system

Specified User's needs       Free sings suggestions       System summary         Av. dely needs:       Enter sequented LOL       Single ?       Battery (uned) value       ?4       .4         2.3       KWh/day       Enter sequented autonomy       40       ?       Suggestide RV power       757       Wp fr         race       PV Array       Back up [       Suggestide RV power       757       Wp fr         race       PV Array       Back up [       Suggestide RV power       757       Wp fr         1       Pre-scing suggestions are based on the Monthly meteo and the user's needs definition       1.       Pre-scing       Suggestide RV value       757       Wp fr         2       Storage       Define the battery pack. (defauld checkboxes will approach the pre-scing)       3       74       74       74       74       74       74       72       74 <t< th=""><th></th><th>-</th><th>n, Variant "BUS_SHELTER</th><th></th><th></th><th></th><th>- 0</th></t<>		-	n, Variant "BUS_SHELTER				- 0
2.3 KWh/day       Exter requested automory       40(1)       Suggested EX space       451 Ah         recedure       The Pre-sizing suggestions are based on the Monthly meteo and the user's needs definition       1. Pre-sizing       Define the desized Pre-sizing       2.3 KWh/day       External external external external exterior       757 Work         recedure       The Pre-sizing suggestions are based on the Monthly meteo and the user's needs definition       1. Pre-sizing       Define the battery pack. (default checkboxes will approach the pre-sizing)       2. Stronge       Define the battery pack. (default checkboxes will approach the pre-sizing)         3. FV Aray (design)       Define an eventual Genet       Performed automory (DE DDD)       Performed automory (DE DDD)       Performed automory (DE DDD)       2. Stronge       2.4 V         2. Stronge       Define an eventual Genet       Manufacturer       Battery pack voltage       2.4 V         2. Stronge       C capacity       Manufacturer       Stonde energy (DB DDD)       364 kg         3. FV Aray (BB DCk SB 12/130 A       Number of elements       48       Number of elements       48         4. Stolar Block SB 12/130 A       Manufacturer       Somereschein       5056 kW       364 kg         9 Definitions of a Battery       —       —       —       —       —         9 Definitions of a Battery       — <td< th=""><th></th><th>Specified User's</th><th>'s needs Pre-sizing sugge</th><th>stions System</th><th>summary</th><th></th><th></th></td<>		Specified User's	's needs Pre-sizing sugge	stions System	summary		
Eth Detailed pre-tiong       Suggested PV power       757 Wp fr         arge       PV Array       Back-up       Schema       757 Wp fr         tracedure       The Pre-ticing suggestions are based on the Monthly meteo and the user's needs definition       1 Pre-ticing       Define the battery power (defuel checkboxes will approach the pre-ticing)         2 Storage       Define the battery pack. (defuel checkboxes will approach the pre-ticing)       Define the battery pack. (defuel checkboxes will approach the pre-ticing)       Imanufacturer         are VArray design       Define an overticul Benet       Define an overticul Benet       Battery pack. voltage       24 V         each-oid       It2V       105 Ah       Pb Sealed Gel       Solar Block SB 12/130       Imanufacturer         ormenschein       It2V       105 Ah       Pb Sealed Gel       Solar Block SB 12/130       Imanufacturer         add-oid       It2V       105 Ah       Pb Sealed Gel       Solar Block SB 12/130       Imanufacturer         add-oid       It2V       105 Ah       Number of batterys       8       Stored energy doing the battery bank sizi         add-oid       It2V       105 Ah       It2V       It2A Ah       It2A Ah         add-oid       It2V       105 Ah       It2A Ah       It2A Ah       It2A Ah         add-oid		Av. daily needs	: Enter accepted LO	L 5.0	% ?	Battery (user) voltage	24 ÷ V
race       PV Array       Back-up       Schema         tracedue       The Pre-sizing suggestions are based on the Monthly mateo and the use's needs definition         1 Pre-sizing       Define the desired Pre-sizing conditions (LOL, Autonomy, Batey voltage)         2 Storage       Define the batey pack. (default checkboses will approach the pre-sizing)         3. FV Array Vestign       Define the batey pack. (default checkboses will approach the pre-sizing)         3. FV Array Vestign       Define an eventual Generic         pecify the Battery set       orden an eventual Generic         orden and the control mode. You are advised to begin with a universal controller.         Define an eventual Generic         active       Define an eventual Generic         active       C capacity       manufacturer         commenchein       I 12 V 105 Ah       Pb Seeled Gel       Solar Block SB 12/130       24 V         2 If Battery in seale       Number of batterys       8       Batery pack voltage       24 V         2 If Battery in seale       Number of batterys       8       Battery back voltage       24 V         3 - If Z       Number of elements       48       No. cycles at 500: DDD       36 k kg         gue 5 The cut section of the PVSyst screenshot for the system components selection and battery back sisising to the size 20: DDD       36		2.3 kWh/d	lay Enter requested au	tonomy 4.0	day(s) 🥐		<b>451</b> Ah
tracedure       The Pre-sizing suggestions are based on the Monthly meteo and the user's needs definition         1 Pre-sizing       Define the desired Pre-sizing conditions (LOL, Autonomy, Battery voltage)         2 Storage       Define the battery pack. (default checkbooks will approach the pre-sizing)         3 RV Aray design       Design the PV array (FV module) and the control mode. You are advised to begin with a universal controller.         4 Back will be battery pack. (voltage       C appacity (C manufacture)         orderenschein       122/105 Ah         Pb       Sealed Gel         Stored energy (R0X DDD)       81.1 kW         Global capacity       364 kg         Stored energy (R0X DDD)       81.1 kW         4 - If Battery is in parallel       Number of batterys       8         Stored energy (R0X DDD)       364 kg         Number of battery       8       Stored energy (R0X DDD)         Global capacity       364 kg         Number of a Battery       -       -         Definitions of a Battery       -       -         Definitions of a Battery       Sizes and technology   Commercial data   Graphs         -         Model       Solar Block SB 12/130A       Manufacturer       Sonnenschein         File name       Sonnenschein       Bioc Capacity at C10       - <th></th> <th></th> <th>Detailed</th> <th>l pre-sizing</th> <th></th> <th>Suggested PV power</th> <th>757 Wp (r</th>			Detailed	l pre-sizing		Suggested PV power	757 Wp (r
1. Pre-sizing       2. Storage       Define the desired Pre-sizing conditions (LCL, Autonomy, Batery voltage)         2 Storage       Define the batery pack. (default checkbooks will approach the pre-sizing)       3. eV Anay design         3 VAray design       Define the batery pack. (default checkbooks will approach the pre-sizing)	rage PV Array	y Back-up Sch	nema				
1 Presiding       Define the deside Presiding conditions (LCL_Autonomy, Battery voltage)         2 Strage       Design the PV array (PV module) and the control mode. You are advised to begin with a universal controller.         3. FW Array (Weign)       Design the PV array (PV module) and the control mode. You are advised to begin with a universal controller.         pecify the Battery set       order of working       Capacity       manufacturer         ormenschein       12V       105 Ah       Pb Seeded Gel       Solar Block SB 12/130       42 V         2       If P Batterys in serie       Number of batterys       8       Storde energy (B0% DDD)       63 46 kg         4       If P Batterys in parallel       Number of elements       48       Total weight       364 kg         9       Definitions of a Battery       Ist kwing       Ist kwing       Ist kwing       Ist kwing         9       Definitions of a Battery       Ist kwing       Ist kwing       Ist kwing       Ist kwing         9       Definitions of a Battery       Ist kwing       Ist kwing       Ist kwing       Ist kwing         9       Definitions of a Battery       Ist kwing       Ist kwing       Ist kwing       Ist kwing         9       Definitions of a Battery       Ist kwing       Ist kwing       Ist kwing       Ist kwing	rocedure						
2 - Strage       Define the battery pack. (default checkboxes will approach the pre-sting)         3 - FV Any design       Design the FV any (FV module) and the control mode. You are advised to begin with a universal controller.         4 - Back-up       Define an eventual Geneet         advised to begin with a universal controller.         addid       Imanufacturer         ornenschein         I = 12 V       105 Ah         Pb Sealed Gel       Solar Block SB 12/130         2 - i IV       Battery in serie         Number of batterys       8         Stored energy (80% DDD)       81 kW/         4 - i IV       Batterys in serie         Number of elements       48         Number of elements       48         Number of elements       49         Definitions of a Battery       -         Pofinitions of a Battery       -         Paritions       6 able Solar Block SB 12/130A         Model       Solar Block SB 12/130A         Model       Solar Block SB 12/130A         Manufacturer       Sonnenschein         Portinitions of a Battery       -         Pofinitions       For all decide sealed. Gel         V       C Per element         Basice Data       Gel Bloc					-		
3 FVAriay design Design the FV array (FV module) and the control mode. You are advised to begin with a universal controller. 4 Back-up Define an eventual Genest pecify the Battery set ordenenschein ● 12V 105 Ah Pb Sealed Gel Solar Block SB 12/130 ● 100 per ead-acid ● Battery set ordenenschein ● 12V 105 Ah Pb Sealed Gel Solar Block SB 12/130 ● 100 per ead-acid ● Battery is serie Number of batterys 8 Global capacity 420 Ah Stored energy (80% DOD) 3 KV All weight Batterys in serie Number of elements 48 Total weight 364 kg 1170 Total stored energy (80% DDD) Total stored energy (80% DDD) Stored energy at DDD [80] × 1.09 kWh Total stored energy (727 cycles) 794 kWh Specific energy 20	-		—				
ort Batteries by          voltage		design Design	n the PV array (PV module)				ersal controller.
ommenschein       I2V       105 Ah       Pb Sealed Get       Solar Block SB 12/130       Image: Constraint of the Consthe Constraint o	pecify the B	attery set					
ead-acid <ul> <li>Battery pack voltage</li> <li>Global capacity</li> <li>Stored energy (80% DOD)</li> <li>Battery in parallel</li> </ul> Number of elements       Battery pack voltage     22 4 4 7 20 Ah           2         Image: Stored energy (80% DOD)         Battery in parallel         Number of elements         48         Total weight         364 kg           4         Image: Stored energy during the battery life         Detailed model parameters         Sizes and technology         Commercial data         Graphs           Definitions of a Battery <ul> <li>Image: Detailed model parameters</li> <li>Sizes and technology</li> <li>Commercial data</li> <li>Graphs</li> </ul> Model     Solar Block SB 12/130A     Manufacturer     Sonnenschein     Image: Detailed model parameters     Sizes and technology     Commercial data     Graphs     Image: Detailed model parameters     Image: Detailed model parameters     Image: Detailed model parameters     Image: Detailed model parameters      Image: Detailed model parameters      Image: Detailed model parameters      Image: Detailed model parameters      Image: Detailed model parameters         Image: Detailed model parameters         Image: Detailed model parameters         Image: Detailed model parameters         Image: Detailed model parameters         Image: Detailed model parameters         Image: Detailed model parameters         Image: Detail	ort Batteries by	🤍 💽 voltage	C capacity	O manu	lfacturer		
Participact Voltage       24         2       Image: State	onnenschein	•	12 V 105 Ah	Pb Sealed Ge	el Solar Block	: SB 12/130	
12       Image: Contract of the serie       Number of batterys       8       Stored energy (80% DOD)       8.1 kWl         4       Image: Contract of the series       48       Total weight       364 kg         4       Image: Contract of the series       48       Total weight       364 kg         10       Total stored energy during the battery life       6386 kWh         2       Image: Contract of the PVSyst screenshot for the system components selection and battery bank sizi       Definitions of a Battery       -       -       >         2       Definitions of a Battery       -       -       >       >       >         3       Definitions of a Battery       -       -       >       >       >         3       Definitions of a Battery       -       -       >       >       >         4       Solar Block SB 12/130A       Manufacturer       Sonnenschein       -       >       >         6       Solar Block SB 12/130A.       Manufacturer       Sonnenschein       -       >	ead-acid	•				Battery pack voltage	<b>24</b> V
Image: Second energy (802 000)       8.1 kWh         Image: Second energy (802 000)       1170         Image: Second energy (802 000)       1100	2 2	Ratterus in serie	Number	of batterus	8		
Image: Partery in parallel       Number of elements       48       Nb. cycles at 50% DDD       1170         Total stored energy during the battery life       6386 kWH         gure 5 The cut section of the PVSyst screenshot for the system components selection and battery bank sizit       0         Definitions of a Battery       —       —       —         Basic Data       Detailed model parameters       Sizes and technology       Commercial data       Graphs         Model       Solar Block SB 12/130A       Manufacturer       Sonnenschein       —       #				-			
gure 5 The cut section of the PVSyst screenshot for the system components selection and battery bank sizi Definitions of a Battery – – – × Basic Data] Detailed model parameters Sizes and technology Commercial data Graphs Model Solar Block SB 12/130A Manufacturer Somenschein File name Somenschein_Block_SB_12_130A.BTR Data Source Datasheets 2011 Original PVsyst database Technology Lead-acid, sealed, Gel • • <b>Basic parameters</b> Nb of elements in Series 6 Nominal Voltage 12.0 v Capacity at C10 105.00 Ah Internal Resistance @ Ref. Temp. 57.14 mOhm V Reference temperature 20.0 °C Coulombic Efficiency ? 97.0 °Z <b>For information (Lithium-ion only)</b> Datasheet Nominal Capacity 0.0 Ah Defined for the discharging rate of 0.00 Hours • 0/2 Set Second C 510 001 Hours • 0/2 Second C 510 001 Hours • 0/2 Second C 510 001 Hours • 0/2 Second C 5	4	Batterys in parall	el Number	of elements	48	-	-
Definitions of a Battery     Basic Data     Definitions of a Battery     Model     Solar Block SB 12/130A        Model     Solar Block SB 12/130A        Manufacturer     Somenschein     Bie name        Sonnenschein     Bie name        Sonnenschein            Model   Solar Block SB 12/130A   Manufacturer   Sonnenschein   Diginal PVsyst database <td></td> <td></td> <td></td> <td></td> <td>Total sto</td> <td>red energy during the batter</td> <td>ylife <b>6386</b> kWł</td>					Total sto	red energy during the batter	ylife <b>6386</b> kWł
File name       Sonnenschein_Block_SB_12_130A.BTR       Data Source       Datasheets 2011         Original PVsyst database       Technology       Lead-acid, sealed, Gel       Image: Control of the discharging rate of         Technology       Lead-acid, sealed, Gel       Image: Control of the discharging rate of       Image: Control of the discharging rate of       Per element         Basic parameters       Image: Control of the discharging rate of       Image: Control of the discharging rate of       Image: Control of the discharging rate of       Per element         For information on parameters       Image: Control of the discharging rate of       Image: Control of the dis	Model	Solar Block SB	) 12/130A	 Manufac	turer Sonnens	chein	
Original PVsyst database         Technology       Lead-acid, sealed, Gel         Image: Sealed acid, sealed, Gel       Image: Sealed acid, sealed, Gel         Basic parameters       Image: Sealed acid, seal				_			
Basic parameters       6       No of elements in Series       7       No of elements in Series       7       No of elements in Series       7       7       No of elements       No of elements       7       7       1       No of elements       7       7       1       No of elements       7       1       No of elements       No of elements <td></td> <td>,</td> <td></td> <td></td> <td></td> <td></td> <td></td>		,					
Basic parameters         Nb of elements in Series       6         Nominal Voltage       12.0         V       Capacity at C10         Internal Resistance @ Ref. Temp.       57.14         Internal Resistance @ Ref. Temp.       57.14         Reference temperature       20.0         Coulombic Efficiency       ?         97.0       %    For information (Lithium-ion only) Datasheet Nominal Capacity          0.0       Ah         Defined for the discharging rate of       0.00         900       Hours         200       ?         201       Cat Secondary	Technology	Lead-acid, se	ealed, Gel	-			
Basic parameters         Nb of elements in Series       6         Nominal Voltage       12.0         V       Capacity at C10         Internal Resistance @ Ref. Temp.       57.14         Internal Resistance @ Ref. Temp.       57.14         Reference temperature       20.0         Coulombic Efficiency       ?         97.0       %    For information (Lithium-ion only) Datasheet Nominal Capacity          0.0       Ah         Defined for the discharging rate of       0.00         900       Hours         2010       Call		,				G. ) (hele helter)	C. Per element
Nb of elements in Series       6         Nominal Voltage       12.0         Capacity at C10       105.00         Internal Resistance @ Ref. Temp.       57.14         m0hm       ✓         Reference temperature       20.0         Coulombic Efficiency       ?         97.0       %         Full battery Indicators         Stored energy at D0D       80       %       1.09       kWh         Defined for the discharging rate of       0.00       Hours       Total stored energy (727 cycles)       794       kWh         Specific energy       24       Wh/kg       24       Wh/kg	n i					Whole ballely	
Nominal Voltage       12.0       ∨         Capacity at C10       105.00       Ah         Internal Resistance @ Ref. Temp.       57.14       m0hm       ✓         Reference temperature       20.0       °C       ⊂         Coulombic Efficiency       ?       97.0       %         For information (Lithium-ion only)         Datasheet Nominal Capacity       0.0       Ah         Defined for the discharging rate of       0.00       Hours       Stored energy (727 cycles)       794       kWh         Specific energy       24       Wh/kg       Yh/kg       Yh/kg	-		6				
Capacity at C10       105.00       Ah         Internal Resistance @ Ref. Temp.       57.14       m0hm       ✓         Reference temperature       20.0       °C       ⊂         Coulombic Efficiency       ?       97.0       %         Full battery Indicators         Datasheet Nominal Capacity       0.0       Ah         Defined for the discharging rate of       0.00       Hours       Stored energy (727 cycles)       794       kWh         Specific energy       24       Wh/kg	. to or cionici						
Internal Resistance @ Ref. Temp.       57.14       m0hm       ✓         Reference temperature       20.0       °C       □         Coulombic Efficiency       ?       97.0       %         For information (Lithium-ion only)       ?       97.0       %         Datasheet Nominal Capacity       0.0       Ah       Stored energy at D0D       80       %       1.09       kWh         Defined for the discharging rate of       0.00       Hours        794       kWh         Specific energy       24       Wh/kg	Nominal Volt						
Reference temperature       20.0 °C         Coulombic Efficiency       ?         97.0 %         For information (Lithium-ion only)         Datasheet Nominal Capacity       0.0 Ah         Defined for the discharging rate of       0.00 Hours •         203 Set Second to \$10       \$210		-	105.00 Ab				
Coulombic Efficiency       97.0       %         For information (Lithium-ion only)       Full battery Indicators         Datasheet Nominal Capacity       0.0       Ah         Defined for the discharging rate of       0.00       Hours       Stored energy (727 cycles)       794       kWh         201 Set Separative © S10       Image: Second stored energy       24       Wh/kg	Capacity at (	C10					
Datasheet Nominal Capacity       0.0       Ah       Stored energy at DOD       80       %       1.09       kWh         Defined for the discharging rate of       0.00       Hours       Total stored energy (727 cycles)       794       kWh         2/3 Set Second to the discharging rate of       0.00       Hours       24       Wh/kg	Capacity at ( Internal Resi	- C10 istance @ Ref. T	Femp. 57.14 mOhr				
Datasheet Nominal Capacity       0.0       Ah       Stored energy at DOD       80       %       1.09       kWh         Defined for the discharging rate of       0.00       Hours       Total stored energy (727 cycles)       794       kWh         2/3 Set Second to the discharging rate of       0.00       Hours       24       Wh/kg	Capacity at ( Internal Resi Reference te	C10 istance @ Ref. T emperature	remp. 57.14 mOhr 20.0 °C				
Defined for the discharging rate of 0.00 Hours Total stored energy (727 cycles) 794 kWh Specific energy 24 Wh/kg	Capacity at ( Internal Resi Reference to Coulombic E	C10 istance @ Ref. T emperature (fficiency	Femp. 57.14 mOhr 20.0 ℃ ? 97.0 %		⊤Full batte	ry Indicators	
201 Cat Canadia O C10	Capacity at ( Internal Resi Reference to Coulombic E For informa	C10 istance @ Ref. T emperature ifficiency ation (Lithium-i	Femp. 57.14 mOhr 20.0 °C ? 97.0 %				<b>1.09</b> kWh
Specific weight 42 kg/kWh	Capacity at ( Internal Resi Reference to Coulombic E For informa Datasheet N	C10 istance @ Ref. T emperature ifficiency ation (Lithium-i lominal Capacity	remp.         57.14         mOhr           20.0         *C           ?         97.0         %           ion only)         0.0         Ah		Stored ener	gyatDOD 80 %	
	Capacity at ( Internal Resi Reference to Coulombic E For informa Datasheet N Defined for th	C10 istance @ Ref. T emperature ifficiency ation (Lithium-i lominal Capacity he discharging ra	Femp.         57.14         mOhr           20.0         °C           ?         97.0         %           ion only		Stored ener Total stored Specific ene	gy at DOD 80 % energy (727 cycles) ergy	<b>794</b> kWh <b>24</b> Wh/kg

Figure 6 The PVSyst screenshot showing the details of the selected battery used for the battery bank

	L DOGOTOL L OT						The nominal	power doesn't
lodel	LPC235SM-05		Manur	facturer Samsun	g SDI. Co. Li	id.	match the Vn	hpp*lmpp_data
ile name	Samsung_LPC	_235SM_05.PAN	Data	source Manufa	oturer 2010			y of 0.26%). distort the
2	Original PVsyst	database		Prod. fro	m 2010		Performance	e Ratio result
lom. Pow (at STC)	ver 235.0 W	p Tol/+ 3	0 3.0 :	% Technology	Si-mono	•		y accepts up to 2%)
anufact	urer specificat	ions or other	Heasuren	nents			Model summary	1
Reference	e conditions:	GRef 1000	W/m²	TRef	25 °C		Main paramete R shunt	rs <u>?</u> 250 ohm
Short-circ	uit current	lsc 8.470	A O	Ipen circuit Voc	37.20 V		Rsh(G=0)	1000 ohm
Max Powe	er Point:	Impp 7.880	A	Vmpp	29.90 V		R serie model	0.36 ohm
Temperati	ure coefficient	mulse 2.5	mA/°C				R serie max.	0.44 ohm
		or mulse 0.030	%/°C	Nb cells	60 in serie	es	R serie apparent	0.54 ohm
		or marse [0:030	~~~ C				Model paramet	
nternal m	nodel result too	bl					Gamma IoRef	1.016 0.40 nA
Operating	conditions	GOper 1000		r TOper 2	. <b>5</b> –}℃	· · · · · ·		-131 mV/*C
Max Powe	er Point:	· · · · · ·	5 w 🥐	Temper, coe	ff <b>0.45</b> %	«/°C	muPMax fixed	-0.46 /*C
		rent Impp 7.92	2 A 👘	Voltage Vmp	•			
	Short-circuit c	urrent Isc 👘 8.43	7 A 4 %	<ul> <li>Open circuit Vo</li> </ul>	oc <b>37.2</b> V a <b>14.72</b> %			

Figure 7 The PVSyst screenshot showing the details of the selected PV module used for the PV array of the SPV system

	rging Controller Definitions		- 🗆 ×
General Data	Thresholds MPPT converter Efficiency p	rofile   Other data / Sizes	
Model U	Universal controller with MPPT converter	Manufacturer Generic	;
File name	Jniversal_Controller_LA_MPPT.RLT	Data Source Adapta	ble for any system
0	Iriginal PVsyst database		
✓ Universal Device gene Technology	default controller	Electrical characteristic Max. charging current Max. discharging current	23.5 A 4.0 A acc.to Load
Data Display	No display	Max. back-up current	3.2 A Genset
Control mo	deBack-up genset	Converter nom, power	564 W
○ Battery V		Self comsumption	0.0 mA
SOC bas	ed Effectively used	Night comsumption	0.0 mA
Battery Tem	perature compensation	Associated Battery Pack	k
Туре	Internal sensor 💌 Default	Technol. Lead-acid, seal	ed, Gel 💡
Correction co	efficient -5.0 mV/*C 🔽	Battery pack voltage	24 V
Reference te	mperature 20 °C 🔽	Default controller: nominal vo pack of the system	oltage acc. to the battery
Battery contr	rol _ead-Acid batteries		
	Lithium batteries		
In Blue: value	ues defined for the system		
	Export to table	Print Can	cel 🗸 🖉 K

Figure 8 The PVSyst screenshot showing the details of the selected battery charger controller used for the SPV system

The PVSyst screenshot showing the details of the simulation parameters used for the SPV system analysis are shown in Figure 9 while Table 2 shows the results of the different performance parameters of the SPV system. The screenshot in Figure 8 also shows the details of the SPV components as obtained from the PVSysts simulation. Notably, Figure 8 shows the details of the PV module, the PV array, the battery and battery controller details.

The results in Figure 10 shows the normalized performance ratio (PR) expressed in %. The results shows that the average performance ratio is 0.652 (0r 65.2%) and in about five months of the year, the system operates at performance ratio below the yearly average. The best performance ratio of 80 % occurred in the month of June.

The results in Figure 11 produced useful energy or normalized final yield (Yf) expressed in kWh/kWp/day.

The results shows that the average produced useful energy is 3.09 and in about four months of the year, the system produced useful energy are below the yearly average. The maximum produced useful energy occurred in about 8 the months.

The results in Figure 12 normalized array losses or array collection losses (Lc) expressed in kWh/kWp/day. The

results shows that the average array collection losses is **1.315** and in about six months of the year, the array collection losses are above the yearly average. The minimum array collection losses occurred in the month of August.

PVSYST V6.70			:	30/12/22	Page 1/4
S	Stand Alone System:	Simulation par	ameters		
Project : B	US_SHELTER_SIZING				
Geographical Site	AKWA IBOM STATE		Country	Nigeria	
Situation Time defined as	Latitude Legal Time Albedo	Time zone UT 0.20	Longitude Altitude	9 56 m	
Meteo data:	AKWA IBOM STATE	NASA-SSE satellite	data, 1983-20	005 - Synth	netic
Simulation variant : B	US_SHELTER_SIZING_1				
	Simulation date	30/12/22 00h08			
Simulation parameters	System type	Stand-alone syste	m		
Collector Plane Orientation	Tilt	9°	Azimuth	0°	
Models used	Transposition	Hay	Diffuse	e Perez, I	Meteonorm
PV Array Characteristics PV module Original PVsyst database Number of PV modules Total number of PV modules Array global power Array operating characteristics Total area	Si-mono Model Manufacturer In series Nb. modules Nominal (STC) s (50°C) U mpp Module area	Samsung SDI. Co. I 1 modules 3 Ui 705 Wp At o 26 V	Ltd. In parallel nit Nom. Power operating cond. I mpp Cell area	235 Wp 626 Wp 24 A	
PV Array loss factors					
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/n	n²K / m/s
Wiring Ohmic Loss Serie Diode Loss Module Quality Loss Module Mismatch Losses Strings Mismatch loss Incidence effect, ASHRAE pa	Global array res. Voltage Drop rametrization IAM =		Loss Fraction Loss Fraction Loss Fraction Loss Fraction Loss Fraction bo Param.	2.4 % a 1.5 % 1.0 % a 0.10 %	t STC
System Parameter	System type	Stand Alone Syste	em		
Battery	Model				
Battery Pack Characteristics	Manufacturer Voltage Nb. of units Temperature	2 in series x 4 in pa	ominal Capacity rallel	420 Ah	
Controller	Model Technology Maxi and EURO efficiencies	Universal controller MPPT converter 97.0 / 95.0 %	with MPPT con Temp coeff.		//°C/elem.
Battery Management control	Threshold commands as Charging Discharging	SOC calculation SOC = 0.90 / 0.75 SOC = 0.20 / 0.45	i.e. approx. i.e. approx.		
User's needs :	Daily household consumers average	Constant over the ye 2.3 kWh/Day	ear		

Figure 9 The PVSyst screenshot showing the details of the simulation parameters used for the SPV system analysis

Table 2 The results of the different performance parameters of the SPV System								
	Yr Lu Yu Lc Ya Ls Yf							PR
	kWh/m².day		kWh/kWp/day		kWh/kWp/day		kWh/kWp/day	
January	5.91	0.911	5.91	2.133	3.77	0.514	3.26	0.552
February	5.81	0.962	5.81	2.177	3.63	0.37	3.26	0.561
March	5.35	0.708	5.35	1.802	3.55	0.29	3.26	0.609
April	4.97	0.416	4.97	1.43	3.54	0.28	3.26	0.656
May	4.5	0.019	4.5	0.901	3.6	0.34	3.26	0.724
June	4.07	0.001	4.07	0.784	3.29	0.031	3.26	0.8
July	3.68	0.001	3.68	0.681	3	0.334	2.67	0.724
August	3.67	0	3.67	0.63	3.04	0.269	2.77	0.755
September	3.92	0.001	3.92	0.741	3.18	0.468	2.71	0.692
October	4.35	0.285	4.35	1.157	3.19	0.263	2.93	0.673
November	5.1	0.358	5.1	1.364	3.74	0.479	3.26	0.639
December	5.7	0.899	5.7	2.039	3.66	0.398	3.26	0.572
Year	4.75	0.377	4.75	1.315	3.43	0.336	3.09	0.652

The Table 2 legend is as follows: the reference yield  $(Y_r)$ , the normalized array yield  $(Y_a)$ , the normalized final yield  $(Y_f)$ , the normalized performance ratio (PR), Normalized unused/loss energy (Lu), Normalized potential production (Yu), Normalized array losses or array collection Losses (Lc) and Normalized system losses (Ls).

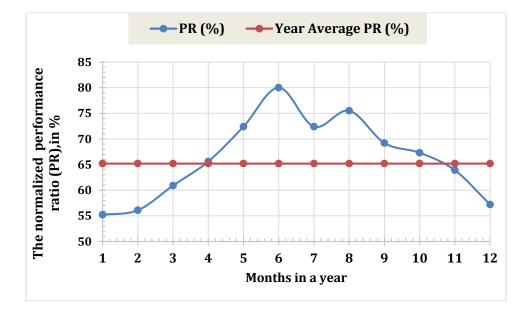


Figure 10 The normalized performance ratio (PR) expressed in %

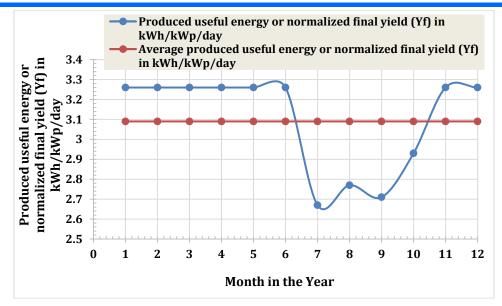


Figure 11 Produced useful energy or normalized final yield (Yf) expressed in kWh/kWp/day

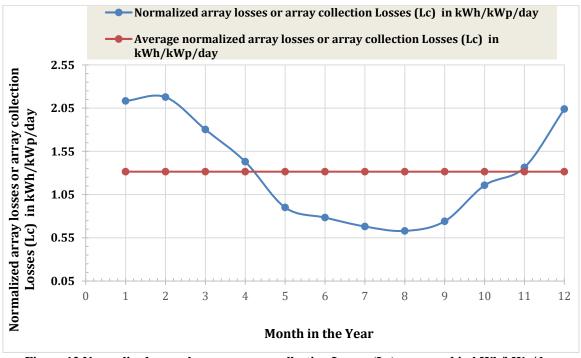


Figure 12 Normalized array losses or array collection Losses (Lc) expressed in kWh/kWp/day 4. Conclusion addition, the results identified the yearly aver

The paper presents the mathematical model for sizing an off-grid solar PV power system designed using the daily load demand of a bus shelter built with requisite sensors and internet connectivity for smart city applications. Also, the paper used PVSyst simulation software to implement the actual sizing of the off-grid solar PV power system and also to determine the various essential performance parameters of the system. The meteorological data of the SPV installation site is downloaded from NASA portal via PVSyst meteorological data import dialogue box. The various PVSyst screenshots showing the system simulation parameter selection and settings, as well as the results obtained from the simulation are presented along with some graphical plots and discussions of the system performance parameters. In all, the key system components (PV module, battery, battery charger, etc.) sizes are presented. In

addition, the results identified the yearly average and the values of the different system performance parameters for the different months in the year.

### Reference

- 1. Anttiroiko, A. V., Valkama, P., & Bailey, S. J. (2014). Smart cities in the new service economy: building platforms for smart services. *AI* & *society*, *29*(3), 323-334.
- 2. Sun, J., Yan, J., & Zhang, K. Z. (2016). Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financial Innovation*, 2(1), 1-9.
- Hashem, I. A. T., Chang, V., Anuar, N. B., Adewole, K., Yaqoob, I., Gani, A., ... & Chiroma, H. (2016). The role of big data in smart

city. International Journal of information management, 36(5), 748-758

- Sanchez, L., Muñoz, L., Galache, J. A., Sotres, P., Santana, J. R., Gutierrez, V., ... & Pfisterer, D. (2014). SmartSantander: IoT experimentation over a smart city testbed. *Computer Networks*, *61*, 217-238.
- 5. Vermesan, O., & Friess, P. (Eds.). (2013). Internet of things: converging technologies for smart environments and integrated ecosystems. River publishers.
- Ozuomba, Simeon, and Etinamabasiyaka Edet Ekott. (2020). "Design And Implementation Of Microcontroller And Internet Of Things-Based Device Circuit And Programs For Revenue Collection From Commercial Tricycle Operators." Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 8, August – 2020
- 7. Long, T. B., Blok, V., & Coninx, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. *Journal of cleaner production*, *112*, 9-21.
- 8. Otumdi, Ogbonna Chima, Kalu Constance, and Ozuomba Simeon (2018). "Design of the Microcontroller Based Fish Dryer." Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 4 Issue 11, November - 201
- Chandra, A., Dargusch, P., McNamara, K. E., Caspe, A. M., & Dalabajan, D. (2017). A study of climate-smart farming practices and climateresiliency field schools in Mindanao, the Philippines. *World Development*, *98*, 214-230.
- Thompson, E., Simeon, O., & Olusakin, A. (2020). A survey of electronic heartbeat electronics body temperature and blood pressure monitoring system. Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 8, August – 2020
- 11. Jog, Y., Singhal, T. K., Barot, F., Cardoza, M., & Dave, D. (2017). Need & gap analysis of converting a city into smart city. *International Journal of Smart Home*, *11*(3), 9-26.
- 12. Chikezie, Aneke, Ezenkwu Chinedu Pascal, and Ozuomba Simeon. (2014). "Design and Implementation Of A Microcontroller-Based Keycard." International Journal of Computational Engineering Research (IJCER) Vol, 04 Issue, 5 May – 2014
- 13. Simeon, Ozuomba. (2018) "Sliding Mode Control Synthesis For Autonomous Underwater Vehicles" Science and Technology Publishing (SCI & TECH
- 14. Samarajiva, R. (2010). How the developing world may participate in the global Internet economy: Innovation driven by competition. The Development Dimension ICTs for Development Improving Policy Coherence: Improving Policy Coherence, 75.

- 15. Ozuomba Simeon, S.T. Wara, C. Kalu and S.O. Oboma (2006); Computer Aided design of the magnetic circuit of a three phase power transformer, Ife Journal of Technology Vol.15, No. 2, November 2006, PP 99–108
- 16. Archibong, E. I., Ozuomba, Simeon, & Ekott, E. E. (2020). Life Cycle Cost And Carbon Credit Analysis For Solar Photovoltaic Powered Internet Of Things-Based Smart Street Light In Uyo. International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 1, January - 2020
- 17. Fuchs, C. (2009). Information and communication technologies and society: A contribution to the critique of the political economy of the Internet. *European journal of communication*, 24(1), 69-87.
- 18. Ozuomba, Simeon, Ekaette Ifiok Archibong, and Etinamabasiyaka Edet Ekott (2020). Development Of Microcontroller-Based Tricycle Tracking Using Gps And Gsm Modules. Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 1, January - 2020
- 19. Archibong, Ekaette Ifiok, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Design And Construction Of The Circuits For An Iot-Based, Stand-Alone, Solar Powered Street Light With Vandalisation Monitoring And Tracking Mechanism." Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 7, July - 2020
- 20. Maduka, N. C., Simeon Ozuomba, and E. E. Ekott. . (2020) "Internet of Things-Based Revenue Collection System for Tricycle Vehicle Operators." 2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS). IEEE, 2020.
- 21. Gungor, V. C., & Hancke, G. P. (2009). Industrial wireless sensor networks: Challenges, design principles, and technical approaches. *IEEE Transactions on industrial electronics*, *56*(10), 4258-4265.
- Sheng, Z., Mahapatra, C., Zhu, C., & Leung, V. C. (2015). Recent advances in industrial wireless sensor networks toward efficient management in IoT. *IEEE access*, *3*, 622-637.
- 23. Rodrigues, J. J., & Neves, P. A. (2010). A survey on IP-based wireless sensor network solutions. *International Journal of Communication Systems*, 23(8), 963-981.
- 24. Khalil, N., Abid, M. R., Benhaddou, D., & Gerndt, M. (2014, April). Wireless sensors networks for Internet of Things. In 2014 IEEE ninth international conference on Intelligent sensors, sensor networks and information processing (ISSNIP) (pp. 1-6). IEEE.
- 25. Umoette, A. T., Ozuomba, Simeon, & Okpura, N. I. (2017). Comparative Analysis of the Solar Potential of Offshore and Onshore Photovoltaic Power System. *Mathematical and Software Engineering*, *3*(1), 124-138

- 26. Adejumobi, I. A., Oyagbinrin, S. G., Akinboro, F. G., & Olajide, M. B. (2011). Hybrid solar and wind power: an essential for information communication technology infrastructure and people in rural communities. *JJRRAS*, *9*(1), 130-138.
- 27. Usah, Emmamuel Okon, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Spatial Regression Models For Characterizing The Distribution Of Peak Sun Hours, PV Daily Energy Yield And Storage Battery Capacity For Standalone (PV) Photovoltaic Installations Across Nigeria." Delta 5, no. 5.808841: 4-53. Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 7, July – 2020
- 28. Idorenyin Markson, Simeon Ozuomba, Iniobong Edifon Abasi-Obot (2019) Sizing of Solar Water Pumping System for Irrigation of Oil Palm Plantation in Abia State. Universal Journal of Engineering Science 7(1): 8-19, 2019
- 29. Ikpe Joseph Daniel, Ozuomba Simeon, Udofia Kufre (2019) Google Map-Based Rooftop Solar Energy Potential Analysis For University Of Uyo Main Campus . Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 7, July - 2019
- 30. Simeon, Ozuomba.(2019) "An assessment of solarpowered soybean farm basin irrigation water supply system." Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 4, April - 2019
- 31. Deele, L. B., Ozuomba, Simeon, & Okpura, N. (2019). Design and Parametric Analysis of a Stand-Alone Solar-Hydro Power Plant with Pumped Water Storage Technology. *International Journal of Engineering & Technology*, 4(1), 9-23.
- 32. Nnadi, D. B., Odeh, C. I., & Omeje, C. (2014). Use of hybrid solar-wind energy generation for remote area electrification in South-Eastern Nigeria. *Journal of Energy in Southern Africa*, 25(2), 61-69.
- 33. Usah, Emmamuel Okon, Simeon Ozuomba, Enobong Joseph Oduobuk, and Etinamabasiyaka Edet Ekott. (2020). "Development Of Analytical Model For Characterizing A 2500 W Wind Turbine Power Plant Under Varying Climate Conditions In Nigeria." Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 6, June - 2020
- 34. Ozuomba, Simeon, Edifon, Iniobong, and Idorenyin Markson (2019). Impact of the optimal tilt angle on the solar photovoltaic array size and cost for A 100 Kwh solar power system In Imo State. International Journal of Sustainable Energy and Environmental Research, 8(1), 29-35.
- 35. Ajao, K. R., Oladosu, O. A., & Popoola, O. T. (2011). Using HOMER power optimization software for cost benefit analysis of hybrid-solar power generation relative to utility cost in Nigeria. *International Journal of Research and Reviews in Applied Sciences*, 7(1), 96-102.
- Oladigbolu, J. O., Ramli, M. A., & Al-Turki, Y. A. (2020). Feasibility study and comparative analysis of hybrid renewable power system for off-grid rural

electrification in a typical remote village located in Nigeria. *IEEE Access*, *8*, 171643-171663.

- 37. Simeon, Ozuomba, Kalu Constance, and Okon Smart Essang (2020). Assessment Of The Effect Of The Water Pump Connection Configuration On The Electric Power Demand For A Solar Powered Groundnut Farm Furrow Irrigation System International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 9, September - 2020
- 38. Lemene B. Deele, Ozuomba, Simeon, Nseobong Okpura (2020). Comparative Life Cycle Cost Analysis Of Off-Grid 200 KW Solar-Hydro Power Plant With Pumped Water Storage And Solar Power Plant With Battery Storage Mechanism International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 8, August - 2020
- 39. Usah, Emmamuel Okon, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Design And Construction Of Circuits For An Integrated Solar-Wind Energy System With Remote Monitoring And Control Mechanism." Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 6, June - 2020
- 40. Mishra<sup>1</sup>, M. S. P., Ali, S. M., Mohapatra, M. P., & Pradhan, M. A. (2012). A Hybrid System (Solar and Wind) Energy System for Remote Areas. *International Journal of Engineering Research and Development eISSN*, 64-68.
- 41. Lemene B. Deele, Ozuomba, Simeon, Okon Smart Essang (2020) SIZING OF AN OFF-GRID PHOTOVOLTAIC POWER SUPPLY SYSTEM WITH BATTERY STORAGE Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 8, August - 2020
- 42. Usah, Emmanuel Okon, Simeon Ozuomba, Enobong Joseph Oduobuk (2020). "Pvsyst Software-Based Comparative Techno-Economic Analysis Of PV Power Plant For Two Installation Sites With Different Climatic Conditions." International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 7, July - 2020
- 43. Hart, J. K., & Martinez, K. (2006). Environmental sensor networks: A revolution in the earth system science?. *Earth-Science Reviews*, *78*(3-4), 177-191.
- 44. .Kalu, C., Ozuomba, Simeon. & Udofia, K. (2015). Web-based map mashup application for participatory wireless network signal strength mapping and customer support services. *European Journal of Engineering and Technology, 3 (8)*, 30-43.
- 45. Mainwaring, A., Culler, D., Polastre, J., Szewczyk, R., & Anderson, J. (2002, September). Wireless sensor networks for habitat monitoring. In Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications (pp. 88-97).
- 46. Samuel, Wali, Simeon Ozuomba, and Philip M. Asuquo (2019). EVALUATION OF WIRELESS SENSOR NETWORK CLUSTER HEAD SELECTION FOR DIFFERENT PROPAGATION

ENVIRONMENTS BASED ON LEE PATH LOSS MODEL AND K-MEANS ALGORITHM. EVALUATION, 3(11). Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 11, November - 2019

- 47. Bonato, P. (2010). Wearable sensors and systems. *IEEE Engineering in Medicine and Biology Magazine*, 29(3), 25-36.
- 48. Atakpo, F. K., Simeon, O., & Utibe-Abasi, S. B. (2021) A COMPARATIVE ANALYSIS OF SELFORGANIZING MAP AND K-MEANS MODELS FOR SELECTION OF CLUSTER HEADS IN OUT-OF-BAND DEVICE-TO-DEVICE COMMUNICATION. Journal of Multidisciplinary Engineering Science Studies (JMESS).
- 49. Glasgow, H. B., Burkholder, J. M., Reed, R. E., Lewitus, A. J., & Kleinman, J. E. (2004). Real-time remote monitoring of water quality: a review of current applications, and advancements in sensor, telemetry, and computing technologies. *Journal of experimental marine biology and ecology*, *300*(1-2), 409-448.
- 50. Njoku, Felix A., Ozuomba Simeon, and Fina Otosi Faithpraise (2019). Development Of Fuzzy Inference System (FIS) For Detection Of Outliers In Data Streams Of Wireless Sensor Networks. International Multilingual Journal of Science and Technology (IMJST) Vol. 4 Issue 10, October - 2019
- 51. Simeon, Ozuomba. (2020). "APPLICATION OF KMEANS CLUSTERING ALGORITHM FOR SELECTION OF RELAY NODES IN WIRELESS SENSOR NETWORK." International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 6, June - 2020
- 52. Patel, S., Park, H., Bonato, P., Chan, L., & Rodgers, M. (2012). A review of wearable sensors and systems with application in rehabilitation. *Journal of neuroengineering and rehabilitation*, *9*(1), 1-17

- 53. Simeon, Ozuomba. (2020). "Analysis Of Effective Transmission Range Based On Hata Model For Wireless Sensor Networks In The C-Band And Ku-Band." Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 12, December - 2020
- 54. Ogbonna Chima Otumdi , Ozuomba Simeon, Kalu Constance (2020). Clustering Of 2100 Mhz Cellular Network Devices With Som Algorithm Using Device Hardware Capacity And Rssi Parameters Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 2, February – 2020
- 55. Samuel, W., Ozuomba, Simeon, & Constance, K. SELF-ORGANIZING MAP (2019). (SOM) CLUSTERING OF 868 MHZ WIRELESS SENSOR NETWORK NODES BASED ON EGLI PATHLOSS MODEL COMPUTED RECEIVED SIGNAL STRENGTH. Journal of*Multidisciplinary* Engineering Science and Technology (JMEST) Vol. 6 Issue 12, December - 2019
- 56. Ogbonna Chima Otumdi, Ozuomba Simeon, Philip M. Asuquo (2020) Device Hardware Capacity And Rssi-Based Self Organizing Map Clustering Of 928 Mhz Lorawan Nodes Located In Flat Terrain With Light Tree Densities Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 9, September -2020
- 57. Khamisani, A. A. (2019). Design methodology of off-grid PV solar powered system (A case study of solar powered bus shelter). *Goolincoln Avenue Charleston, IL: Eastern Illinois University*