Sizing and performance analysis of grid-connected solar power for electronic and communication laboratories using PVSYST Software

Aniekan James Ekpo

Department of Electrical /Electronic Engineering, University of Uyo, Akwa Ibom State, Nigeria aniboy2016@gmail.com

Abstract- In this paper, the sizing and performance analysis of grid-connected solar power for electronic and communication laboratories using PVSYST Software is presented. The work is focused on presenting the steps used in PVsyst software to size the solar power system for powering a set of laboratories used for electronics and communication in the faculty of Engineering located at the main campus of University of Uyo with geo-coordinate of 5.041294, 7.974573, annual mean solar radiation of 1717.2 kW/m² and mean temperature which has annual mean value of 24.9 °C. The results showed that with the 12 V 200 Wp PV panel, total of 213 PV module are required for the PV array while 147 battery units are required in the system. The result shows zero loss of load probability and zero duration of loss of load duration. As such, the system is sized to avoid any power outage which resulted in excess energy yield that led to as much unused energy loss of 16427 kWh per year. Also, the PV array operated with efficiency of 7.01 % annual average and thermal loss of about 12,57 % of the total energy yield.

Keywords— Grid-Connected, PVSYST Software, Solar Power, Loss of Load, Alternative Power

1. Introduction

Over the years, the power sector in Nigeria has witnessed chronic power challenges including grossly inadequate generation and losses on the system, as well as epileptic power supply due to load shading and scheduling [1,2,3]. This has affected the university community which rely on electric energy for most of their research works. Particularly, the department of electrical and communication engineering requires energy supply for a given number of hours every working day to attend to the laboratory works as required in the curriculum. Such practical works cannot be adequate conducted without the availability of electric power in the laboratories.

In view of the energy challenges, the university community has resulted in using diesel generators as the alternative energy source [4,5,6]. Such approach, though highly welcomed has suffered enormous setback due to recent increase in the prices of fossil fuel and their associated energy system [7,8]. The central diesel generator can no longer be powered as regular as required to meet up with the demands in the school. As such, alternative energy solutions are need. Accordingly, in this work, the solar power system for the laboratory is recommended and a simulated sizing and performance analysis of the standalone solar power for the electronic and communication laboratories are presented. The simulation is conducted using the PVSyst simulation software [9,10].

2. Methodology

The work is focused on presenting the steps used in PVsyst software to size the solar power system for powering a set of laboratories used for electronics and communication in the faculty of Engineering located at the main campus of University of Uyo. The first step in the study is the determination of the site geo-coordinates using Google Map. The case study laboratory is in the faculty of engineering located in university of Uyo main campus with geo-coordinate of 5.041294, 7.974573 and shown in Google map visualization of Figure 1.

The second step is that the geo-coordinate of 5.041294, 7.974573 was used in PVSyst to acquire the daily mean global solar radiation and temperature of the site [11]. The plot of the daily mean global solar radiation on the horizontal plane for the site is shown in Figure 2 with annual mean of 1717.2 kW/m^2 while Figure 3 shows the plot for the daily mean temperature which has annual mean value of 24.9 °C.

The third step is that the optimal tilt angle for the solar panel is determined using the PVSyst. The optimal tilt for the PV panel as captured using PVSyst software is shown in Figure 4. It shows that for annually fixed tilt, the site required tilt angle of about 13° to gain transposition factor of 1.02. This means that 2 % of solar radiation is captured by the optimally tilted PV panel when compared with that of the PV on a horizontal plane.

The fourth step is the determination of the daily energy demand of the case study laboratory which is shown in the load profile in Table 1. The schematic layout of the standalone solar power in PVSyst is captured and presented in Figure 5. The system configuration for the battery bank is presented in Figure 6 while the configuration for the PV array is shown in Figure 7.



Figure 1 The visualization of faculty of engineering which is the location of the case study laboratory



Figure 2 The plot for the daily mean global solar radiation on the horizontal plane for the site



Figure 4 The optimal tilt for the PV panel as captured using PVSyst software

Laboratory	Appliance	QTY.	Power Rating (W)	Total Power (W)	Hours/Day	Energy per day (Wh)
Flastrianland	Digital storage oscilloscope	10	50	500	6	3000
Electronic	Function generator	10	50	500	6	3000
Circuits Laboratory	DC power supply (dual)	10	120	1200	6	7200
	PC desktop	2	500	1000	6	6000
	PC desktop	10	500	5000	6	30000
Digital	Digital storage oscilloscope	10	50	500	6	3000
Electronics Laboratory	Microcontroller training kit	10	50	500	6	3000
	Digital analog training system	10	40	400	6	2400
	Digital storage oscilloscope	8	50	400	6	2400
	PC desktop	10	500	5000	6	30000
	Communications training kit EV	8	36	288	6	1728
Communications	Function generator (20GHz)	2	250	500	6	3000
Laboratory	Function generator (25MHz)	2	120	240	6	1440
	Network analyzer (20GHz)	1	350	350	6	2100
	Spectrum analyzer (20GHz)	1	450	450	6	2700
	Total power rating	104	3116	16828		100968

Table 1 The load profile for the three laboratories that make up the electronic and communication laboratory [12]



Figure 5 The layout of the standalone solar power in PVSyst

Stand-alone sy	ystem definition, Vari	ant "New simulati	ion variant", Varia	ant "New simul	ation variant" –	- 🗆 >
	Specified User"s nee	ds Pre-sizing sugge	stons System su	ummary		
	Av. daily needs 101 kWh/day	Enter accepted PLC Enter requested au The Detailed	DL 3.0	% <mark>?</mark> day(s) <mark>?</mark>	Battery (user) voltage Suggested capacity Suggested PV power	36 <u>↓</u> V 9899 Ah 36462 Wp (non
orage PV Array	y Back-Up Simplified	i Schema				
Procedure 1 Pre-sizing 2 Storage 3 PV Array de 4 Back-Up	The Pre-sizi Define the d Define the b sign Design the P Define an ev	ng suggestions are ba lesired Pre-sizing con attery pack (default V array (PV module) ventual Genset	ased on the Month ditions (LOL, Autor checkboxes will ap and the control mo	ly meteo and the nomy, Battery vo proach the pre-s ode. You are advi	user"s needs definition (tage) izing) ised to begin with a universal	controller.
Specify the Ba Sort batteries by Narada	v v voltage	C capacity	C man	NPG 12V 200	Since 2018	B Open
Lead-acid 3 V 49 V 100.0 % 100.0 %	batteries in series batteries in parallel Initial State of We Initial State of We	Number Number ar (nb. of cycles) ar (static)	ofbatteries 14	7 2 Total stored e	Battery pack voltage Global capacity Stored energy (80% DOD) Total weight Nb. cycles at 80% DOD nergy during the battery life	36 V 9800 Ah 282 kWh 9849 kg 1000 323 MWh
Operating bat Temper. mode Fixed t The battery tem battery. An incr by a factor of tw	Fixed (temperature Fixed (temperate low remperature 20 or perature is important f ease of 10 °C divides t vo.	cal)]			
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Figure 6 The configuration for the battery bank of the solar power system

	Specified User's ne	eds Pre-sizing su	uggestons Syst	tem summary		
	Av. daily needs	Enter accepted	PLOL 3.0	* % ?	Battery (user) voltage	36 ÷ V
	101 kWh/day	Enter requeste	d autonomy 3.0	day(s) ?	Suggested capacity	9899 Ah
		Deta	ailed pre-sizing		Suggested PV power	36462 Wp (nor
orage PV Array	Back-Up Simplifie	ed Schema				
Sub-array name a	and Orientation			Presizing Help		
Name PV Arra	y			No sizing	Enter planned power	35.8 kWp
Orient. Fixed	Tilted Plane	Azin	Tilt 13° nuth 0°	Resize	or available area	300 m2
Select the PV n	nodule					
All modules	 Sort mod 	ules 📀 Pow	er C Ted	hnology		
All manufacturers	▼ 200 Wp	24V Si-poly	SW 200 Poly	SolarW	/orld Photon Mag. 2	00' - 🖪 Open
a manana a cia		en orpory	511 2551 61,	Doidi 11		
		Cizing voltages	 Vmon (60°C) 	23.4 V		
		Sizing voltages	· • • • • • • • • • • • • • • • • • • •			
Select the cont	trol mode and the	controller	Voc (-10°C)	40.9 V		
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Figure 7 The configuration for the PV array of the solar power system

3. Results and Discussion

The simulation was conducted based on the system (PV array and battery bank) configuration of Figure 6 and Figure 7 and the summary of PVSyst simulation result for the load profile, the PV array configuration and the battery bank of the system is shown in Figure 8 while Figure 9

included the input and output energy diagram of the system generated by the PVSyst software. The results showed that with the 12 V 200 Wp PV panel, total of 213 PV module are required for the PV array while 147 battery units are required in the system.

PVSYST V6.88								14/	06/25	Page 1/6
Simulation parameters		System by	De S	and alc	ne svs	tem w	ith batt	eries		
Collector Blace Orientati		-,,					Anim		~	
Conector Plane Orientati	on			•			Adm			
Models used		Transposit	on P	0/02			Dn	use F	Perez, N	Aeteonorm
User's needs :		daily pro	ge 10	onstant (over the Day	year				
0 h	1h 2h	3h 4h	Sh	6 h	7 h	8 h	9h	10 h	11 h	
12	h 13 h 14 h	15 h 16 h	17	18 h	19 h	20 h	21 h	22 h	23 h	
Hourly load 0.00	0.00 00.0	0.00 00.0	0.00	0.00	0.00	0.00	0.00	16.83	16.83	kW
16.2	3 16.83 16.83	16.83 0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	KW .
L										
PV Array Characteristic										
PV module	Si-po	ly Mo	Del SI	W 200 P	Poly					
Number of PV modules		In ser	es 3	modules			In para	ild 7	71 string	5
Total number of PV module	s	Nb. modul	les 21	213 Unit Nom. Power 200 Wp						
Array global power		Nominal (ST	C) 43	42.6 kWp At operating cond. 37.6 kWp (50°C)					p (50°C)	
Array operating characteris	tics (50°C)	Um	PP 74	V			In	npp 5	506 A	
Total area		Module an	63 35	57 m*						
System Parameter		System by	pe SI	tand ale	one sys	tem				
Battery		Mo	del M	PG 12V	200					
Ballon, Back Characteristics		Manufactu	rer N	arada	- 40 In	manal				
Battery Pack Characteristic		ND. of un Volta	00 34	in series	X 49 E	Nomin	al Cana	cev s	9800 Ah	
	Discha	raina min. Si	oc 2	1.0 %		Sto	red ene	ray 2	290.9 ki	AD
		Temperatu	re R	xed (20*	(C)					
Controller		Mo	del La	iversal	control	er with	MPPT	onvert	ter	
		Technolo	gy M	PPT con	verter	T	emp co	eff	5.0 mV	/"C/elem.
Converter	Maxi and B	URO efficience	ies 97	1.0 / 95.1	0 %					
Battery Management control	I Threshol	d commands	as 50	OC calcu	lation					
		Chargi	ng Si	OC = 0.9	0/0.7	5 1	e. appr	OK. 4	40.3/3	8.0 V
		Discharg	ng S	DC = 0.2	20 / 0.4	5 1	.e. appr	юк. 3	35.4 / 3	6.8 V
PV Array loss factors										
Thermal Loss factor		Uc (con	st) 20	1.0 W/m	2K		Uv (wi	nd) (0.0 W/m	1 ² K / m/s
Wiring Ohmic Loss	(lobal array n	es. 2.	5 mOhm	1	Lo	ss Frad	tion 1	1.5 % a	t STC
Serie Diode Loss		Voltage Dr	op 0.	7 V		LO	ss Frad	tion (0.8 % a	t STC
Module Quality Loss						Lo	ss Frac	Son 1	1.5 %	
Strings Mismatch Losses						LO	ss Fract	tion f	1.0 % 3	I PAPP

Figure 8 The summary of PVSyst simulation result for the load profile, the PV array configuration and the battery bank of the system



Figure 9 The summary of the system configuration with the input /output energy diagram generated from the PVSyst simulation

The summery of the energy balance results from the PVSyst is shown in Table 2. It shows that the solar fraction (SolFrac in Table 2) is 1 in all the months meaning there is no power outage in all the months. However, there are used energy (EUnused in Table 2) in each of the months with annual total of 16427 kWh per annum. That is the toal of energy produced but not used and hence lost.

The result on the loss of load is shown in Table 3. It shows zero loss of load probability (Pr_LOL in Figure 3) and zero duration of loss of load duration (T_LOL in Figure 3). As such, the system is sized to avoid any power outage which

resulted in excess energy yield that led to as much unused energy loss of 16427 kWh per year, as witnessed in Table 2.

The summary of the PV array operating efficiency is shown in Table 4 while the loss diagram of the system is shown in Figure 10. The results show that the PV array operated with efficiency of 7.01 % annual average. The loss diagram showed thermal loss of about 12,57 % of the total energy yield.

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	
January	171.4	185.3	6230	2610	0.000	3130	3130	1.000
February	156.5	162.4	5436	2218	0.000	2827	2827	1.000
March	164.9	161.6	5445	1915	0.000	3130	3130	1.000
April	152.7	142.6	4833	1557	0.000	3029	3029	1.000
May	146.3	130.7	4458	1052	0.000	3130	3130	1.000
June	129.3	113.4	3917	444	0.000	3029	3029	1.000
July	119.4	106.0	3695	487	0.000	3130	3130	1.000
August	116.9	107.3	3748	198	0.000	3130	3130	1.000
September	118.2	112.4	3889	782	0.000	3029	3029	1.000
October	132.4	132.6	4495	930	0.000	3130	3130	1.000
November	145.2	153.3	5166	1722	0.000	3029	3029	1.000
December	164.0	179.3	6089	2513	0.000	3130	3130	1.000
Year	1717.2	1686.9	57401	16427	0.000	36853	36853	1.000

Table 2 The summery of the energy balance results

	EArray	E_Load	E_User	SolFrac	T_LOL	Pr_LOL
	kWh	kWh	kWh		Hour	%
January	3852	3130	3130	1.000	0	0.00
February	3427	2827	2827	1.000	0	0.00
March	3757	3130	3130	1.000	0	0.00
April	3485	3029	3029	1.000	0	0.00
May	3625	3130	3130	1.000	0	0.00
June	3698	3029	3029	1.000	0	0.00
July	3413	3130	3130	1.000	0	0.00
August	3777	3130	3130	1.000	0	0.00
September	3304	3029	3029	1.000	0	0.00
October	3797	3130	3130	1.000	0	0.00
November	3669	3029	3029	1.000	0	0.00
December	3806	3130	3130	1.000	0	0.00
Year	43610	36853	36853	1.000	0	0.00

Table 3 The summary	of the	loss	of load
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	EffArrR
	%
January	5.67
February	5.76
March	6.32
April	6.62
Мау	7.48
June	8.78
July	8.67
August	9.50
September	7.95
October	7.76
November	6.51
December	5.78
Year	7.01



Figure 10 The system loss diagram

4. Conclusion

A standalone solar power system was simulated using PVSysts software. The solar power was modeled for powering a set of laboratories used in the electronic and communication courses in the faculty of engineering located at the main campus of University of Uyo. The simulation steps are presented along with the set of input parameters and the results. The results showed that the sizing configuration of the PV array and battery banks gave solar fraction of 100 % without loss of load but with excess energy loss in the system. In all, the power need of the laboratory is fully met without any power outage.

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