# Evaluation Of Off-Grid Solar Power System For Remote Self-Service Banking Kiosk In Cross River State

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Abstract— In this paper, the evaluation of off-grid solar power system for remote self-service banking kiosk in Cross River State is presented. The case study remote self-service banking kiosk is located at Odukpani in Cross River State with latitude of 5.082488, and longitude of 8.348434 and it has daily energy of 206.04 kWh per day. The meteorological data of the case study site consist of mean daily peak sun hour of 6.32 kWhr/m<sup>2</sup>/day and mean daily temperature of 26.00 °C. the results show that the PV system has annual energy yield of 91.9 MWh/yr, performance ratio of 62.7 % and system loss of 0.35 kWh/kWp/day. Also, the PV solar system satisfied the load demand for all the months except in the month of August with the lowest energy vield of about 6262 kWh where there is missing energy of 489.9 kWh with solar fraction of 0.923, loss of load probability of 7.6% and loss of load duration of 57 hour. Principally, in the month of August, over two days of power outage will be witnessed in the kiosk. Hence, some measures need to be taken to accommodate the two days of power outage. One option is to run the ATM at a fraction of the full load; that means, instead of all the 8 ATMs running 24 hours, the system can be scheduled whereby only 4 out of the 8 run for 24 hours, while the remaining 4 ATMs run 16 hours per day. In this way, power outage can be eliminated in the system all through the year.

Key words: Off-Grid Power, Self-Service Banking Kiosk, Solar Power System, Automatic Teller Machine, Photovoltaic Power

#### **1. INTRODUCTION**

Nowadays, many industries are embracing measures to minimize man hour by deploying robots and other self-service mechanisms for their clients. In this wise, banks are increasingly deploying automatic teller machines (ATMs) to provide self-service banking for the bank customers. Accordingly, many banks are deploying self-service banking kiosks to areas closer to their customers. Such areas like markets, city centers and some remote locations with significant customer base are possible locations that many banks do deploy self-service banking kiosks.

In any case, in Nigeria, the major challenge with such selfservice banking kiosk is power supply, notably, especially in the remote locations without access to the national grid, providing steady power supply for the self-service banking kiosk is a running challenge. In such situation, solar power has become a viable option for providing off-grid power supply to the self-service banking kiosk. Hence, in this paper, the evaluation of off-grid solar photovoltaic (PV) power system for remote self-service banking kiosk is presented. The evaluation is conducted using PVSyst simulation software. The emphasis of the evaluation is to assess the loss of load performance of the PV power system. Loss of load performance [16,17] parameters include determination of the missing energy, the loss of load probability and the loss of load duration. These parameters are determined using the PVSyst software.

### 2. METHODOLOGY

The case study remote self-service banking kiosk is located at Odukpani in Cross River State with latitude of 5.082488, and longitude of 8.348434, as shown in Figure 1. The meteorological data of the case study site consist of mean daily peak sun hour of 6.32 kW-hr/m^2/day and mean daily temperature of 26.00 °C. The electric load profile of the self service banking kiosk is given in Table 1 which shows a daily energy of 206.04 kWh per day. The PV system was simulated in the PVSyst software based on the given meteorological data and daily load demand.

The screenshot of PVSyst configuration of the PV power system for remote self-service banking kiosk is shown in Figure 2. The information in Figure 2 shows the selected PV module and the battery and it also shows that the system is designed to have maximum loss of load of 5% and 5 days of power autonomy from the battery bank. The screenshot of PVSyst details of selected PV module are shown in Figure 3. The screenshot in Figure 3 shows that 100 Wp 15 V module model PE 105 manufactured by Mereg is used. It has module area efficiency of 11.56%. Again, the screenshot of PVSyst details of selected battery are shown in Figure 4. The screenshot in Figure 4 shows that 105 Ah 12 V battery model MPG 12V 105 F manufactured by Norada is used. It has stored energy of 1.15kWh at 80 % depth of discharge (DoD).



Figure 1 the Google map location of the case study self-service banking kiosk site

S/N	Load Description	QTY.	Power (kW)	Duration of operation each day (h)	Total power (kW)	Energy consumption each day (kWh)
1	ATM	8	0.2	24	1.6	38.4
2	CCTV camera	10	0.015	24	0.15	3.6
3	AIR Conditioner	4	1.6	24	6.4	153.6
4	Light for ATM	8	0.03	24	0.24	5.76
5	Hub	1	0.015	24	0.015	0.36
6	Security light	4	0.09	12	0.36	4.32
				TOTAL	8.765	206.04

 Table 1 The electric load profile of the self-service banking kiosk

Stand-alone system definition, Variant "New sin	nulation variant", Variant "New simulation variant" — 🛛 🔿
Specified User"s needs Pre-sizing	suggestions System summary
Av. daily needs Enter accepte 206 kWh/day Enter request The De	ed PLOL     5.0     %     ?     Battery (user) voltage     96     V     ?       ted autonomy     5.0     +     day(s)     ?     Suggested capacity     12625 Ah       tailed pre-sizing     Suggested PV power     67921 Wp (nom
torage PV Array Back-Up Simplified Schema	
Sub-array name and Orientation Name PV Array	Presizing Help     O No sizing     Enter planned power      67.8     kWp
Orient. Fixed Tilted Plane Az	Tilt 14° Resize or available area C 0 m2
Select the PV module	
All modules   Sort modules   Po	wer C Technology
All manufacturers I 100 Wp 15V Si-poly	PE 105 Mereg Photon DB 2006 💌 🛅 Open
Sizing voltage	s: Vmpp (60°C) 15.1 V Voc (-10°C) 24.4 V
Select the control mode and the controller	MOT newsr converter
? 🔽 Universal controller Generic 👻	
Operating mode	Max. Charging - Discharging current
C Direct coupling	782 A 89 A Universal controller with MPPT conver
C DCDC converter adjusted according to the p	or the universal controller will automatically be properties of the system.
PV Array design	
Number of modules and strings	Operating conditions:
Mod. in series 8 🔆 🔽 No constraint	Vmpp (60°C) 120 V Vmpp (20°C) 144 V
Nbre strings 85 🔂 Ve between 68 and 102	Voc (-10°C) 195 V Plane irradiance 1000 W/m2
	Impo (STC) 482.4 Max operating power 60.9 MW
?	Isc (STC) 521 A at 1000 W/m <sup>2</sup> and 50°C)

Figure 2 The configuration of the PV power system for remote self service banking kiosk

asic data Sizes and Te	chnology   Model par	ameters Addition	onal Data   Comm	ercial   Graphs		
Model PE 105		Manufactur	er Mereg		The nomi	inal power
File name Mereg_PE1	05.PAN	Datasour	ce Photon DB 20	06	Vmpp*Ir (discrepance	mpp data
? Original PVs	yst database		Prod. from 200	4 to 2010	This will o	listort the
(at STC)	Wp Tol/+ -1	.5 1.5 %	Technology Si-p	oly _	(PVsyst usua to 0	lly accepts u .2%)
Reference condition	s GRef 1000	W/m <sup>2</sup>	TRef 25	- °C <mark>.</mark>	Model summary Main paramete R shunt	rs ? 220 ohm
Short-circuit current	Isc 6.100	A Open cir	rcuit Voc 21.9		Rsh(G=0)	900 ohm
Max Power Point	Impp 5.700	A	Vmpp 17.60	o v	R serie model	0.28 ohm
Temperature coeffic	or muIsc 0.020	mA/°C %/°C	Nb cells 36 i	n series	R serie max. R serie apparent Model paramet	0.35 ohm 0.43 ohm ers
Internal model resu	ilt tool				Gamma IoRef	0.994 0.27 nA
Operating condition	s GOper 1000	÷ ₩/m²	TOper 25	÷l•c -	muVoc	-71 mV/°C
Max Power Point	Pmpp 100.	3 W ? Ten	nper. coeff0	.43 %/°C		
Short-circuit	current Isc 6.1	O A Open	circuit Voc 2	1.9 V		
Efficiency	/ Cells area N/	A % / I	Module area 11	.56 %		
	Copy to	table	Print	🗶 Can	cel	и ок

Figure 3 The screenshot of PVSyst details of selected PV module

Definition	is for a battery					_		×
Basic data	Detailed model paramete	ers   Graphs   Size	es and Techno	ology   Con	nmercial data			
Model	MPG 12V 105 F		Manuf	acturer Na	arada			
File name	Narada_MPG 12V 105	F.BTR	Data	source Da	atasheets 2018			
	Original PVsyst databa	se		Pro	d. Since 2018			
Technology	Lead-acid, sealed, G	el	•					
					Whole battery	C P	er elemer	nt
Basic para	ameters							
Nb of eleme	ents in Series	6						
Nominal Vol	ltage	12.0 V						
Capacity at	t C 10	105.00 Ah						
Internal res	sistance @ ref. temp.	5.52 mOh	m 🗆					
Reference	temperature	25.0 °C						
Coulombic e	efficiency ?	97.0 %						
Info : Ren	ormalization to C10			Full bat	ttery Indicators			
Datasheet	Nominal Capacity	0.0 Ah		Stored e	energy at DOD 80	% 1.15	5 kWh	
Defined for	a discharging rate of	1.00 Hou	rs 💌	Total sto	ored energy (1000 cycles	) 1153	3 kWh	
=>Corresp	. C10 acc. to spec. prof	ile N	I/A ?	Specific	energy	34	4 Wh/kg	
				Specific	weight	29	9 kg/kWh	1
	D.	1	E.			1		
	📫 C	opy to table	E P	rint	X Cancel		OK	

Figure 4 The screenshot of PVSyst details of selected battery

💮 Results,	variant V	C0 "New simulation va	ariant"			_		Х
Simulation	ATM KTO	ters	System					
Site ODUKPANI 1 System type Stand alone		PV modules Nominal power	PE 105 68.0 kWp	Battery: Battery voltage	MPG 12V 96	105 F V		
Simulation	01/01 to (Generic	31/12 meteo data)	MPP Voltage MPP Current	17.6 V 5.7 A	Total capacity	12600	Ah	
Main resul	ts							
System Prod	luction	93.9 MWh/yr	Normalized prod.	3.01 kWh/kWp/	day			
Specific proc	ł.	1381 kWh/kWp/yr	Array losses	1.44 kWh/kWp/	day			
Performance	Ratio	0.627	System losses	0.35 kWh/kWp/	day			

Figure 5 The screenshot of PVSyst results showing the simulation parameters and main results

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m <sup>2</sup>	kWh	kWh	kWh	kWh	kWh	
January	173.9	189.2	10359	3152	0.0	6387	6387	1.000
February	158.5	165.0	9058	2955	0.0	5769	5769	1.000
March	165.9	162.5	8937	2207	0.0	6387	6387	1.000
April	152.7	141.7	7803	1399	0.0	6181	6181	1.000
May	148.2	130.7	7252	640	0.0	6387	6387	1.000
June	130.8	113.6	6335	92	0.0	6181	6181	1.000
July	120.6	105.9	5991	0	0.0	6387	6387	1.000
August	114.4	104.1	5884	0	489.9	5897	6387	0.923
September	120.3	114.7	6403	1	0.0	6181	6181	1.000
October	133.9	134.2	7368	0	0.0	6387	6387	1.000
November	145.2	153.8	8474	2106	0.0	6181	6181	1.000
December	165.2	181.9	10056	3033	0.0	6387	6387	1.000
Year	1729.5	1697.5	93919	15584	489.9	74715	75205	0.993

Table 2 The screenshot of PVSvst 1	esults showing the mis	ssing energy and solar fra	action

Table 3 The screenshot of PVSyst results showing the duration of loss of load and the loss of load probability

	EArray	E_Load	E_User	SolFrac	T_LOL	Pr_LOL
	kWh	kWh	kWh		Hour	%
January	7673	6387	6387	1.000	0	0.00
February	6498	5769	5769	1.000	0	0.00
March	7164	6387	6387	1.000	0	0.00
April	6818	6181	6181	1.000	0	0.00
May	7045	6387	6387	1.000	0	0.00
June	6652	6181	6181	1.000	0	0.00
July	6381	6387	6387	1.000	0	0.00
August	6262	6387	5897	0.923	57	7.62
September	6818	6181	6181	1.000	0	0.00
October	7846	6387	6387	1.000	0	0.00
November	6784	6181	6181	1.000	0	0.00
December	7480	6387	6387	1.000	0	0.00
Year	83421	75205	74715	0.993	57	0.65

The screenshot of PVSyst results showing the simulation parameters and main results are presented in Figure 5. Specifically, Figure 5 shows that the system has annual energy yield of 91.9 MWh/yr, performance ratio of 62.7 % and system loss of 0.35 kWh/kWp/day. The screenshot of PVSyst results showing the missing energy and solar fraction is shown in Table 2. The results in Table 2 show that the solar system satisfied the load demand for all the months except in the month of August where there is missing energy of 489.9 kWh with solar fraction of 0.923. The screenshot of PVSyst results showing the distribution of the energy yield over the year is shown in Figure 6 and it shows that the month of August has the lowest energy yield of about 6262 kWh per month.

The screenshot of PVSyst results showing the duration of loss of load and the loss of load probability is shown in Table 3. It shows that the loss of load duration of 57 hours (as shown also in Figure 7) occurred in the month of August. Now, on annual average, the mean annual loss of load probability of 0.65% was realized but the loss of load probability of 7.6% occurred in the month of August. This results exceeded the annual average of 5% set as the maximum. This shows that the PVSyst setting of maximum loss of load is for annual average and not the maximum for any month.

Principally, in the month of August, over two days of power outage will be witnessed in the kiosk. Hence, some measures need to be taken to accommodate the two days of power outage. One option is to run the ATM at a fraction of the full load; that means, instead of all the 8 ATMs running 24 hours, the system can be scheduled whereby only 4 out of the 8 run for 24 hours, while the remaining 4 ATMs run 16 hours per day. Essentially, load scheduling is required to eliminate the loss of load in the system.







## **3 CONCLUSION**

PVSyst software simulation of standalone solar power system for ATM machine kiosk is presented. The focus of the simulation is to carry out evaluation of the energy yield and loss of load performance of the PV power system. The results show that the system is able to supply the required daily load demand except in the month of August which has over two days of power outage. In such case, load scheduling can be used to achieve the desired PV system without any power outage.

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