Simulated Performance Analysis Of Medical Laboratory Solar Pv Power Installation Across Nigeria

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***Abstract*— Over the years, medical laboratories have been crucial in both curative and preventive health care service delivery. Today, medical laboratories increasingly rely on electronic and communication technologies that require electricity to function. In the developing countries with limited access to effective electricity, photovoltaic solar power has become the preferred alternative power source. The performance of such power system is critical to cost, affordability and sustainability. Consequently, performance analysis of a standalone solar power system for a case study medical laboratory located in six different States across Nigerians six geopolitical zones is presented. The results show that the annual average of daily normalized system production (Yf) for the PV installation in Akwa Ibom State is 2.89 kWh/kWp/day, the annual average of daily normalized array production (Ya) is 3.25 kWh/kWp/day and the annual average of daily reference incident energy in the PV Array Plane (Yr) is 4.77 kWh/m^2/day. Also, the annual average of normalized array loss (Lc), annual average of normalized system loss (Ls) and annual average of performance ratio (PR) for the PV power installation in Akwa Ibom State are 1.516, 0.361 and 0.606 respectively. Among the six States considered in the study, Sokoto State gave the highest Yf value of 2.92 kWh/kWp/day , the highest Ya value of 3.32 kWh/kWp/day and the highest Yr value of 6.16 kWh/m^2/day while Akwa Ibom State had the lowest values of all the three parameters. On the other hand, the PV installation in Akwa Ibom has the lowest normalized array loss (lc) of 1.516, the lowest Normalized System Loss (Ls) of 0.361 and the highest performance ratio (PR) of 0.606 while the PV installation in Sokoto State has the highest normalized array loss (Lc) of 2.833, the highest Normalized System Loss (Ls) of 0.406 and the lowest performance ratio (PR) of 0.474. In essence, there are more energy losses in the PV installation in Sokoto than the one in Akwa Ibom State. In all, the results show that the minimum value of Yf , Ya , and Yr occurred within the months with the lowest monthly average solar radiation for the State.**

Keywords— Medical Laboratories, Solar PV Power, Normalized Array Loss, Normalized System Loss, Performance Ratio, Normalized System Production , Normalized Array Production , Reference Incident Energy

1. INTRODUCTION

Globally, medical laboratories are critical components of curative and preventive health care service delivery system [1,2,3,4,5,6,7,8,9,10]. Also, advances in technologies have given rise to robust medical laboratory systems that rely on sophisticated electronic and mart systems for their effective operations [11,12,13,14,15,16,17,18,19,20]. In addition, many modern medical laboratory equipment are electronic in nature, and many of the equipment require connectivity and communication with other electronic systems [13,14,15,16,17,18,19,20]. In such cases, electric power supply and internet connectivity are required. However, in Nigeria, there is perennial challenge of poor access to electricity from the national grid, as well as poor quality of the available power from the national grid [21,22,23,24,25,26,27]. Consequently, most medical laboratory owners rely on alternative power supply system, such as fossil fuel-based power generators or fast growing photovoltaic (PV) power supply system [28,29,30,31,32,33].

In this paper, the focus in on the PV power systems which researches have shown are preferred over the fossil fuel energy supply systems due to the negative environmental impact of fossil fuel. Particularly, the performance analysis of PV power installation for medical laboratory is examined for a case study medical laboratory load demand and PV system components configuration. The performance of the same PV system components configuration is studied and the performance of the PV system under different climatic condition in the various geopolitical zones in Nigeria is evaluated. The ideas presented in this paper will assist medical laboratory owners in the selection of PV power system component configuration for the laboratory facility.

2. METHODOLOGY

2.1 PV System Performance parameters

In order to compare different PV power installations, some performance parameters have been defined by experts. Some of the key performance parameters are presented here for the performance analysis of the solar power system for medical laboratories located in different States across Nigeria.

i) Array yield (expressed in kWh/kWp):

Array yield per annum $\left(Y_{a\_AN}\right)$ is the ratio of the energy production over a year (E_{DCAN}) to the PV array rated power $(P_{PVrated})$, hence [33];

$$Y_{a\_AN} = \frac{E_{DC\_AN}}{P_{PVrated}} \quad (1)$$

ii) Final yield (expressed in kWh/kWp):

Final yield per annum $\left(Y_{f\_AN}\right)$ is the ratio of the AC energy production of the whole PV system over a year $\left(E_{AC\_AN}\right)$ to the PV array rated power ($P_{PVrated}$), hence [33];

$$Y_{f\_AN} = \frac{E_{AC\_AN}}{P_{PVrated}} \quad (2)$$

iii) Reference yield (expressed in kWh/kWp):

The reference yield , Y_r is expressed as the ratio of the total daily solar irradiation H_t (kWh/m^2) on the horizontal plane of the PV module to the reference irradiation, H_r $(which\ is\ 1\ kWh/m^2)$, hence [33];

$$Y_r = \frac{H_t}{H_r} \quad (3)$$

iv) Performance ratio (expressed in %):

The performance ratio (PR) of a PV system is a function of the total system losses and it is given as [33];

$$PR = \frac{Y_{f\_AN}}{Y_r} \quad (4)$$

v) Array capture losses (expressed in kWh/kWp):

The array capture losses (L_C) is defined as [34];

$$L_C = Y_r - Y_a \quad (5)$$

vi) System losses (expressed in kWh/kWp):

The system losses (L_S) is defined as [34];

$$L_S = Y_a - Y_f \quad (6)$$

vii) Array efficiency (expressed in %):

The array efficiency (η_{PV}) is defined as [34];

$$\eta_{PV} = 100\left(\frac{E_{DC\_AN}}{H_t(A_a)}\right) \quad (7)$$

Where A_a is the surface area of the PV module (m^2)

viii) System efficiency (expressed in %):

The system efficiency $\left(\eta_{sys}\right)$ is defined as [34];

$$\eta_{sys} = 100\left(\frac{E_{AC\_AN}}{H_t(A_a)}\right) \quad (8)$$

The case study Medical laboratory daily energy demand profile is given in Table 1. The location data of the selected medical laboratory solar PV power installation sites across Nigeria is presented in Table 2 while the map plot of the selected medical laboratory solar PV power installation sites across Nigeria is presented in Figure 1. Also, the meteorological parameters data for the PV power installation in Akwa Ibom State is given in Table 3.

Table 1 Medical Laboratory Loads demand

S/N	LOAD	QTY	RATED OWER IN WATTS	TOTAL WATTS	HOURS	WH/DAY
1	Fluorescent Lamps (Day)	5	40	200	12	2400
2	Fluorescent Lamps (Night)	6	40	240	12	2880
3	CD4 Machine	2	200	400	6	2400
4	Hematology Analyzer	1	230	230	7	1610
5	Blood Chem. Analyzer	1	45	45	7	315
6	Microscope	4	30	120	5	600
7	Centrifuge	2	400	800	2	1600
8	Fan	1	150	150	12	1800
9	Efficient Refrigerator	2	60	120	24	2880
10	Air Conditioner	1	1000	1000	12	12000
11	Desk Top Computer	2	150	300	12	3600
Total				3605		32085

Table 2 The location data of the selected medical laboratory solar PV power installation sites across Nigeria

Name	Description	Latitude	Longitude
South South: Akwa Ibom State	University of Uyo	5.02894	7.97897
North Central : *Kogi State*	Kogi State university	7.48707	7.18023
South East: Ebonyi State	Ebonyi State University Abakaliki	6.32591	8.08055
North East: Adamawa State	Adamawa State University Mubi	10.2803	13.2772
South West: Ekiti State	Ekiti State University Ado Ekiti	7.71414	5.26004
North West: Sokoto State	Sokoto State University Sokoto Birnin Kebbi Rd	12.9425	5.19051

Figure 1 The map plot of the selected medical laboratory solar PV power installation sites across Nigeria

Table 3 The meteorological parameters data for the PV power installation in Akwa Ibom State

Interval beginning	GlobHor kWh/m^2.mth	GlobInc (Perez model) kWh/m^2.mth	T Amb °C
January	171.4	183.9	25.3
February	156.5	163.7	25.8
March	164.9	167.2	25.7
April	152.7	150.1	25.8
May	146.3	140.4	25.7
June	129.3	122.9	24.8
July	119.3	114.5	24.1
August	116.9	114.0	23.9
September	118.2	118.2	24.2
October	132.4	135.3	24.5
November	145.2	153.9	24.7
December	164.0	177.3	24.7
Year	1717.2	1741.5	24.9

3. RESULTS AND DISCUSSION

The PV power system simulation software, PVSyst was used to for the selection and computation of the number and capacities of the various components and various performance parameters of the PV power system based on the case study medical laboratory daily energy demand and the meteorological data of each of the selected six study sites across Nigeria. The result of key performance parameters for the PV power installation in Akwa Ibom State is shown in Table 4 and Figure 2. The results show that the annual average of daily normalized system production (Yf) for the PV installation in Akwa Ibom State is 2.89 kWh/kWp/day, the annual average of daily normalized array production (Ya) is 3.25 kWh/kWp/day and the annual average of daily reference incident energy in the PV Array Plane (Yr) is 4.77 kWh/m^2/day. Also, the annual average of normalized array loss (Lc), annual average of normalized system loss (Ls) and annual average of performance ratio (PR) for the PV power installation in Akwa Ibom State in Figure 3 and Table 4 show that Lc is 1.516 , Ls is 0.361 and PR is 0.606. The minimum value of all the stated performance parameters for the PV installation in Akwa Ibom State occurred within the months of July and August which corresponds to the months with the lowest monthly average solar radiation for the State.

Table 4 Some key performance parameters for the PV power installation in Akwa Ibom State

Simulation variant : New simulation variant

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Yr - Reference Incident Energy in coll. plane
Lu - Normalized Unused (Full battery) Loss
Yu - Normalized Potential production
Lc - Normalized Array Losses
Ya - Normalized Array Production
Ls - Normalized System Losses
Yf - Normalized System Production
PR - Performance Ratio

Normalized Performance Coefficients

	Yr kWh/m².day	Lu	Yu kWh/kWp/d	Lc	Ya kWh/kWp/d	Ls	Yf kWh/kWp/d	PR
January	6.21	1.672	6.21	2.740	3.47	0.548	2.92	0.470
February	5.99	1.641	5.99	2.679	3.31	0.395	2.92	0.487
March	5.39	1.197	5.38	2.098	3.29	0.371	2.92	0.542
April	4.87	0.762	4.87	1.567	3.30	0.382	2.92	0.600
May	4.31	0.394	4.31	1.071	3.24	0.321	2.92	0.677
June	3.86	0.050	3.86	0.644	3.22	0.303	2.92	0.755
July	3.52	0.000	3.52	0.516	3.00	0.206	2.80	0.795
August	3.56	0.000	3.56	0.476	3.08	0.164	2.92	0.820
September	3.89	0.026	3.89	0.615	3.28	0.526	2.75	0.707
October	4.40	0.551	4.40	1.270	3.13	0.211	2.92	0.663
November	5.32	1.024	5.32	1.883	3.44	0.520	2.92	0.548
December	6.02	1.705	6.02	2.703	3.32	0.400	2.92	0.485
Year	4.77	0.748	4.77	1.516	3.25	0.361	2.89	0.606

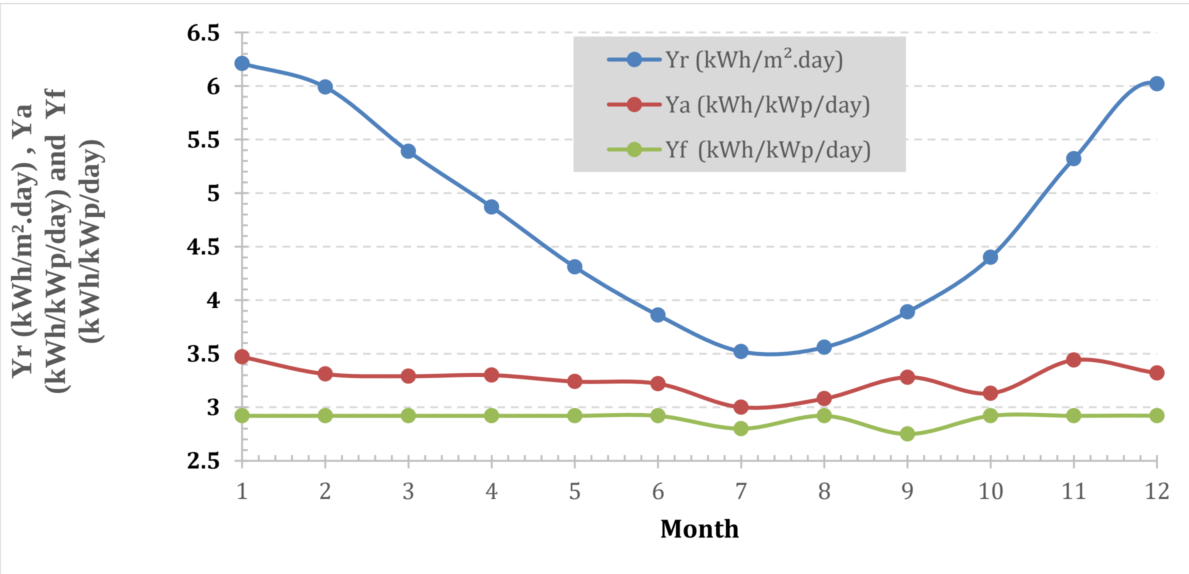

Figure 2 Normalized System Production (Yf), Normalized Array Production (Ya) and Reference Incident Energy in the PV Array Plane (Yr) for the PV power installation in Akwa Ibom State

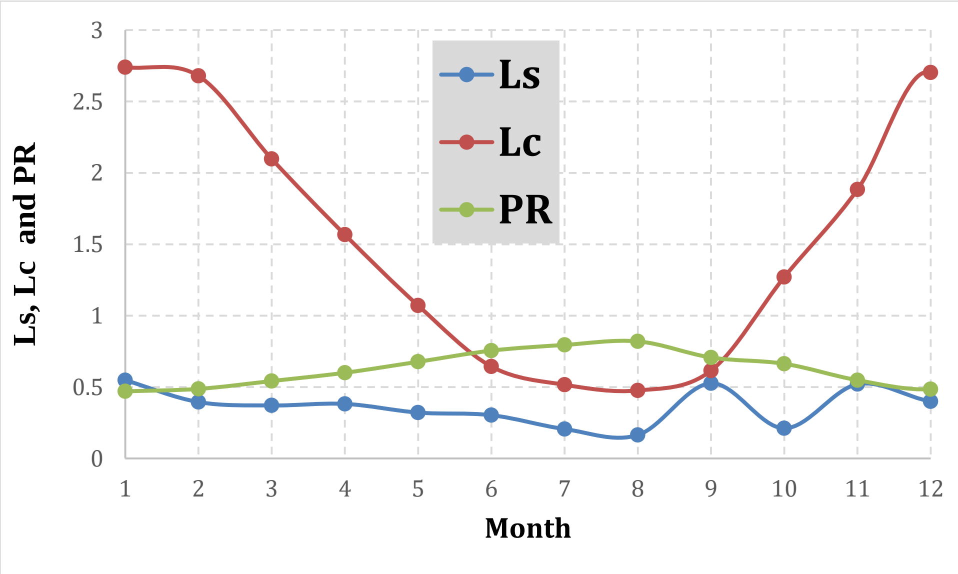

Figure 3 The Normalized Array Loss (Lc), Normalized System Loss (Ls) and Performance ratio (PR) for the PV power installation in Akwa Ibom State

The results in Table 5 and Figure 4 show that the annual average of daily normalized system production (Yf) for the PV installation in Akwa Ibom State with a value of 2.89 kWh/kWp/day is the lowest among the six states, while that of Sokoto State with a value of 2.92 kWh/kWp/day is the highest among the six states. Also, the annual average of daily normalized array production (Ya) for the PV installation in Akwa Ibom State with a value of 3.25 kWh/kWp/day is the lowest among the six states, while that of Sokoto State with a value of 3.32 kWh/kWp/day is the highest among the six states. Furthermore, the annual average of daily reference incident energy in the PV Array Plane (Yr) in Akwa Ibom State with a value of 4.77 kWh/m^2/day is the lowest among the six states, while that of Sokoto State with a value of 6.16 kWh/m^2/day is the highest among the six states.

On the other hand, the PV installation in Akwa Ibom has the lowest normalized array loss (lc) of 1.516, the lowest Normalized System Loss (Ls) of 0.361 and the highest performance ratio (PR) of 0.606 while the PV installation in Sokoto State has the highest normalized array loss (Lc) of 2.833, the highest Normalized System Loss (Ls) of 0.406 and the lowest performance ratio (PR) of 0.474. In essence, there are more energy losses in the PV installation in Sokoto than the one in Akwa Ibom State.

Also, the results in Table 6 and Figure 6 show that the PV installation in Akwa Ibom has the highest annual average array efficiency , EffArrR of 9.23 % and the highest annual average system efficiency , EffSysC of 9.14 % while the PV installation in Sokoto State has the lowest annual average array efficiency , EffArrR of 7.3 % and the lowest annual average system efficiency , EffSysC of 7.14 % .

Table 5 Annual Values of the selected key performance parameters for the PV installation in the six selected State across Nigeria

	Yr (kWh/m².day)	Ya (kWh/kWp/day)	Yf (kWh/kWp/day)	Lc	Ls	PR
Akwa Ibom	4.77	3.25	2.89	1.516	0.361	0.606
Adamawa	5.93	3.32	2.92	2.609	0.403	0.492
Ebonyin	5.14	3.29	2.91	1.857	0.379	0.565
Kogi	5.24	3.3	2.92	1.946	0.381	0.556
Ekiti	5.06	3.28	2.91	1.785	0.37	0.574
Sokoto	6.16	3.32	2.92	2.833	0.406	0.474

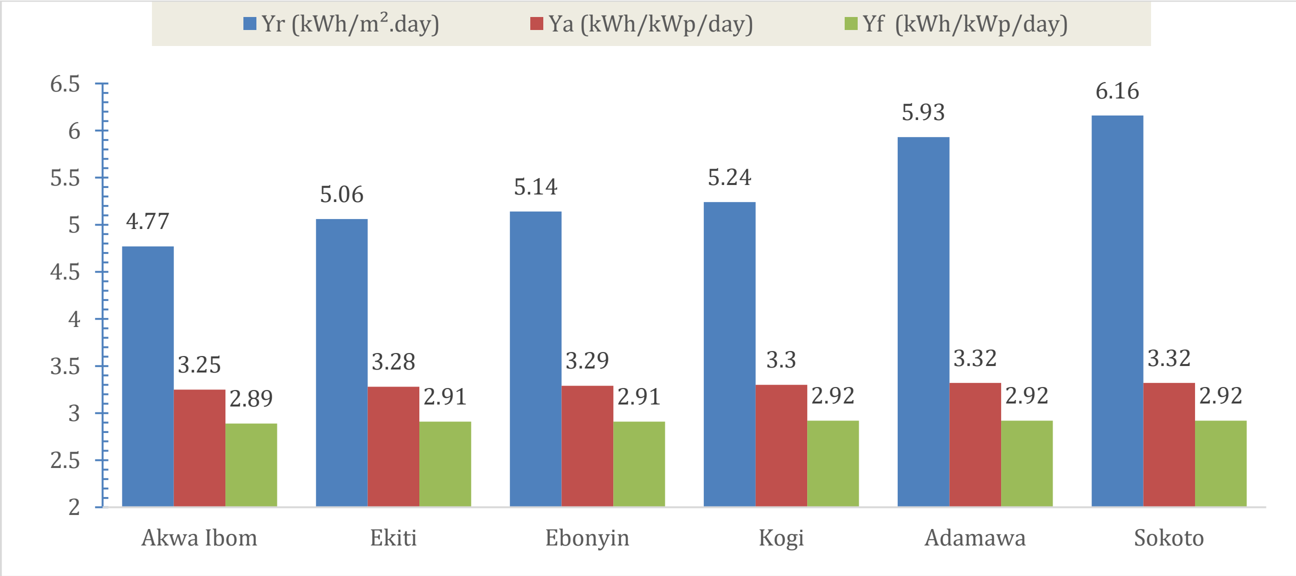

Figure 4 The bar chart of the Annual Values of the Normalized System Production (Yf), Normalized Array Production (Ya) and Reference Incident Energy in the PV Array Plane (Yr) for the PV installation in the six selected State across Nigeria

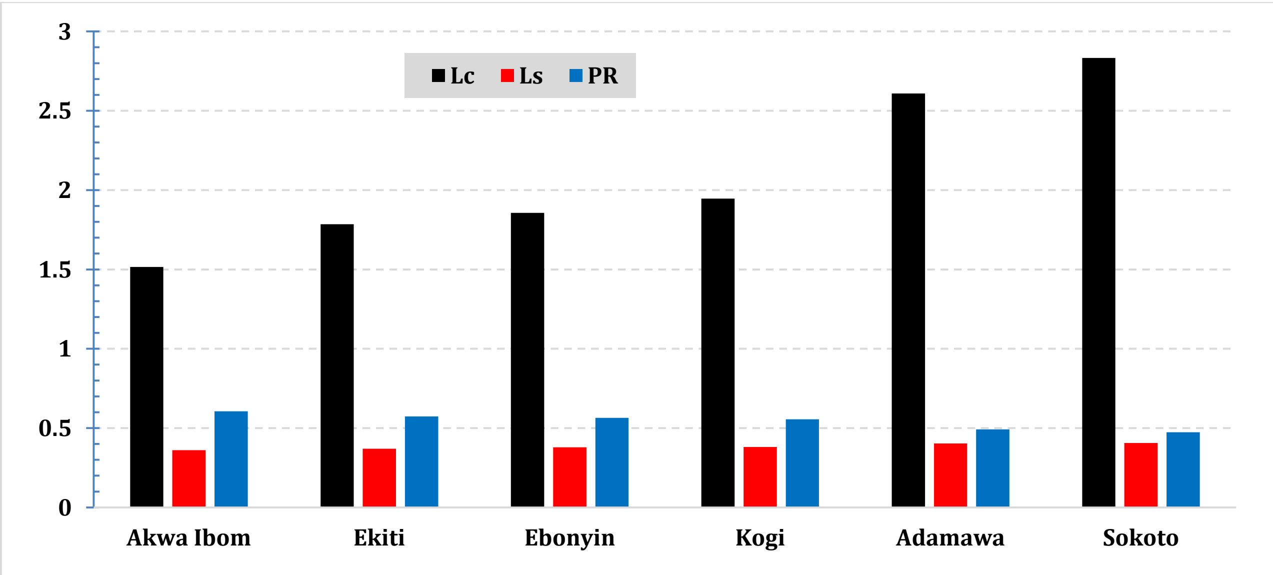

Figure 5 The bar chart of the Normalized Array Loss (Lc), Normalized System Loss (Ls) and Performance ratio (PR) for the PV installation in the six selected State across Nigeria

Table 6 The annual average array efficiency , EffArrR (%) and the annual average system efficiency , EffSysC (%) for the PV installation in the six selected State across Nigeria

Site Name (State)	EffArrR(%)	EffSysC (%)
Akwa Ibom	9.23	9.14
Ekiti	8.75	8.65
Ebonyi	8.64	8.52
Kogi	8.5	8.38
Adamawa	7.57	7.41
Sokoto	7.3	7.14

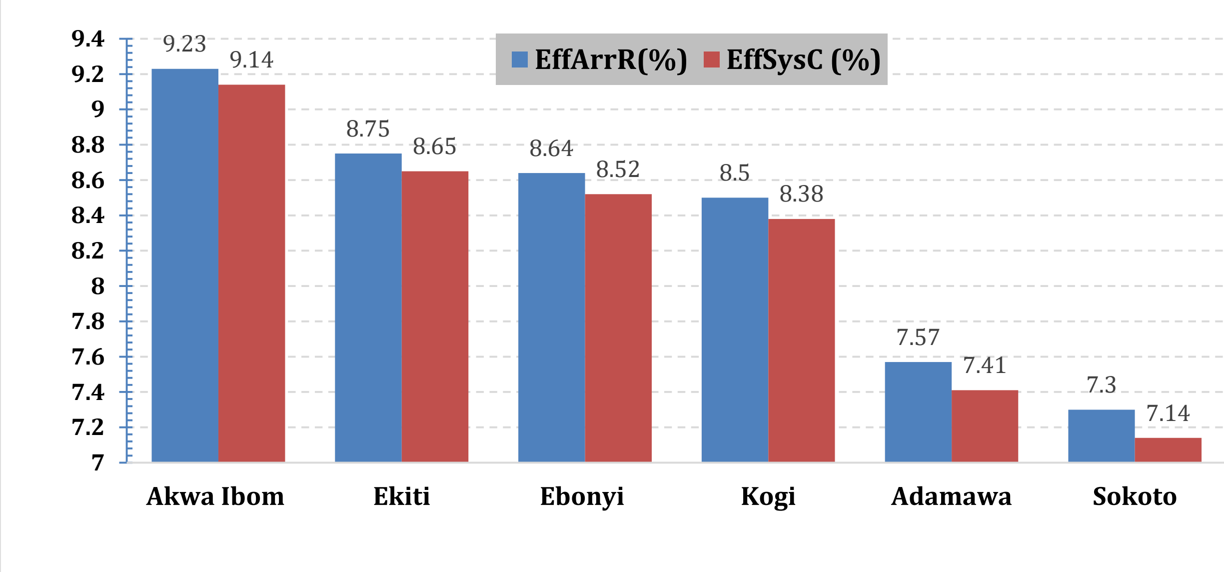

Figure 6 The bar chart of the annual average array efficiency , EffArrR (%) and the annual average system efficiency , EffSysC (%) for the PV installation in the six selected State across Nigeria

4. CONCLUSION

Performance analysis of a standalone solar power system is presented. The analysis is conducted using PVSyst simulation software and the daily load demand of a case study medical laboratory located in six different States across Nigerians six geopolitical zones. The key performance parameters considered are; the Normalized System Production (Yf), the Normalized Array Production (Ya) , the Reference Incident Energy in the PV Array Plane (Yr) , the Normalized Array Loss (Lc), the Normalized System Loss (Ls) , the Performance ratio (PR) , the array efficiency , EffArrR (%) and the system efficiency , EffSysC. In all, the results show that the minimum value of Yf , Ya , and Yr occurred within the months with the lowest monthly average solar radiation for the State.

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