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Impact of Temperature and Shading on Performance of Solar Photovoltaic Systems in Telecom Sites

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Abstract:- Nigeria's rural mobile network boom strains its power generation. Expensive and polluting diesel generators power off-grid base stations, prompting mobile network operators to explore solar PV systems. However, real-life performance under field conditions is a major concern, as manufacturer datasheets often fall short. This study highlighted the performance of a solar PV system powering a telecommunication station in Uli, Anambra State, Nigeria. We examined temperature, irradiance and shading effect. The findings highlight the impact of shading and temperature on energy yield and performance ratio (PR). While stand-alone and solar tracking systems had similar PRs (66 to 68 percent), tracking systems generated the most energy (4.53 energy yield) due to increased solar exposure. However, this benefit came with a trade-off; higher temperature losses (1559 kWh) caused by temperature rise from direct sunlight. Additionally, the nearby structures significantly impacted tracking systems by causing shading. In conclusion, well-designed solar PV systems for telecommunication stations must consider mitigating factors like shading and temperature. This can achieve substantial advantages: lower operational expenses for operators, improved network availability for rural users, and a reduced environmental impact, aligning with UN Sustainable Development Goals.

Keywords:- *Solar Photovoltaic (PV), Temperature, Shading, Telecommunication, Nigeria, Performance RatioEnergy Yield.*

I. INTRODUCTION

The growth of mobile subscribers in rural areas has presented unprecedented opportunities for mobile network operators to expand their cellular networks and provide mobile service to subscribers in those areas. However, comparing Nigeria with other countries reveals we are grossly underserved in power generation. The United Kingdom, with a population of fewer than 60 million, has installed an Electric Power Capacity of 80,000MW. Our South African brothers have over 40,000MW for just over 45 million people [1]. The lack of reliable power supply, operational expenditures, and greenhouse gas emissions are critical concerns for mobile network operators, who typically use diesel generators to power off-grid cellular base stations.

To address these concerns, mobile network operators are exploring eco-friendly and cost-effective power sources. A photovoltaic power system can provide a sustainable and reliable alternative source of electrical power by directly converting solar irradiance into electricity. The process involves designing, selecting, and determining the specifications of the different components employed in the system.

As the renewable energy sector progresses, the key features of a power source, such as cost-effectiveness, sustainability, reliability, and reduction of greenhouse gas emissions, can be achieved. Therefore, the adoption of photovoltaic power systems can be a viable solution for mobile network operators to meet the growing power demand while reducing environmental impact.

A. *Statement of Problem*

The gap between manufacturer datasheet performance and real-world performance under field conditions, particularly the impact of temperature and shading. Although there are several photovoltaic (PV) systems, more information about their technical performance under field operations still needs to be available. Since values estimated during the initial design differ from values achieved under field conditions, it is essential to monitor and measure data from these systems for more accurate analysis.

B. *Objectives*

The study aims to investigate the effect of temperature and shading on the performance of solar photovoltaic (PV) systems installed at telecom sites. The study focuses on the evaluation of the impact of temperature and shading on the performance ratio and energy yield of the PV systems.

II. LITERATURE REVIEW

In a study by Kumar and Shudakar 2015, a 10 MW grid-connected solar photovoltaic power plant in Ramagundam, India, was analyzed. The study focused on various aspects of the installation, including its viability

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regarding geographical data, solar panel design, and system interfacing. The study examined the system performance ratio and energy final yield by looking into system losses caused by temperature, internal network, inverter, and ohmic wiring. The results showed that the final yield ranges from 1.07 to 1.96 hours per day, with an annual performance ratio of 86.12%. The authors compared the performance results with the simulated values from the PVsyst and PV-GIS software [2]. A similar study was carried out by Attari et al. (2016) on a 5kW PV grid-connected system installed in Tangier, Morocco. The system was installed on top of a government building and made up of 20 modules of 250W. This study assessed the system's energy output, final yield, module temperature, plant efficiency, and system performance ratio. Various power losses were also investigated [3].

According to a study conducted by Shukla et al. (2016) in Manit, India, the performance of an 110kW solar rooftop photovoltaic plant was simulated to evaluate the potential of implementing solar PV systems within the vicinity. The study used four modules to evaluate the system's performance ratio and energy yield, and the Solar GIS PV Planner software was utilized to assess the system's efficiency. The study assessed several parameters, such as overall in-plane radiation, shading impact, surface reflection at different angles, system inefficiencies, and power efficiency. The study found that a-Si and CdTe PV systems are the most efficient, with performance ratios exceeding 75% [4].

Another study by Allouhi et al. (2016) analyzed the performance and economic and environmental impact of two 2kW solar power plants installed in the High School of Technology of Meknes, Morocco. Poly-Si and mono-Si modules were used in the study, while PVsyst software was employed for the simulations [5].

Some studies also looked at the effect of shading and temperature on PV systems. As solar cell temperature increases, the efficiency of converting sunlight into electricity decreases. This is because higher temperatures cause increased internal resistance within the solar cell, leading to a voltage drop and lower power output [6]. As solar cell temperature rises, the bandgap (energy difference between valence and conduction bands) narrows, reducing the voltage produced by the cell. This effect is well documented, with a typical decrease in efficiency of 0.4-0.5% per degree Celsius increase in cell temperature [7].When part of a solar panel is shaded, and the entire electrical circuit of the panel can be affected. This is because solar panels are typically connected in series, and a shaded cell can act like a resistor, reducing the current flow through the entire panel and lowering its power output [8]. The negative impacts of temperature and shading can be compounded. For example, high ambient temperatures combined with shading can significantly reduce the overall energy output of a PV array.

A. Relevant Studies on PV Systems in Telecom Applications

The following are some studies and review papers that focus on the performance evaluation, techno-economic analysis, and design and simulation of photovoltaic (PV) power systems for telecom stations;

Akpakwu and Ongunleye (2020) investigated the performance of a grid-connected PV system for a telecom base station in Nigeria [9]. Chowdhury et al. (2014) analyzed a grid-independent hybrid renewable energy system using solar PV for remote telecom base stations [10]. Hong et al. (2016) focused on the techno-economic analysis of a PV/battery hybrid system for telecom base stations [11]. Ibrahim et al. (2014) explored the design and simulation of a standalone PV system for a remote cellular base station [12].

Finally, Ishaq and El-Naggar (2019) provided a comprehensive overview of using solar PV systems to power cellular base stations in developing countries, discussing challenges and opportunities [13]. This study looks to provide insight on irradiance and array losses of PV systems installed in telecom sites not looked at by most relevant studies and papers. It will also compares PV system performance and energy yields citing the effect of temperature and shading on the performance.

B. Type of Photovatalic Systems

Solar photovoltaic (PV) systems can vary in complexity, ranging from basic systems designed to power small loads to highly complex PV plants. The fundamental components of a standalone PV system are PV modules, a charge controller, an inverter, and a battery. PV systems to be compared in this study are the Off-grid or standalone and Tracking systems;

- Off-grid PV systems are independent solar PV systems that don't rely on the local grid. They use battery storage to supply energy to local users, making them useful in remote areas. A control strategy for voltage control is necessary to regulate voltage and ensure stable operation. These systems consist typically of fixed tilt solar PV panels.
- The tracking system has become one of the research studies conducted to improve electricity collection more efficiently and lower energy losses. It is done by orienting the solar PV system surface in the sun's direction at all times to maximize the effective use of solar radiation [14]. The tracking system comprises a versatile pyramidal stand, both fixed and mobile components, a rotating unit with solar modules, a DCM, DC-DC converter, DCAC inverter, battery, and distribution board. It can operate as a single-axis or two-axis tracking mechanism.

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III. METHODOLOGY

Telecom site used as case study is T4153. The telecommunication station is located in Uli, Anambra State, Nigeria. It is a conventional lattice site with a 9.81kW off-grid fixed tilt PV system connected to the base transceiver station, BTS, with backup diesel generators. PV system design and configuration was evaluated, load characteristics of the site was collected for a period of one year. Collected data is simulated using PVsyst and irradiation data was culled from satellites using PVGIS. The results of the performance parameters for both off-grid fixed tilt and tracking systems are compared.

The Solar panels feed the required energy to the telecommunication base station site, which comprises the base station (BTS) and transmission equipment (TX). They run on -48VDC minimum. The diesel generator and PV array simultaneously power the site. The PV arrays are designed to carry about 75% of the total site load. When the output of solar panels is low due to rainfall or lack of sunlight, the backup diesel generator runs longer to compensate for the system's power requirement. This simultaneous supply is controlled by the rectifier system's Centralized Supervision Unit (CSU). When the batteries reach a peak state of charge (SOC), or peak allowed DC voltage (-56V to -58V) as set by the BMS or CSU, the diesel generator goes off via dry contacts on the generator control panel as signaled by the CSU, via an I/O interface. The photovoltaic distribution unit (PVDU) ensures that charges keep feeding the system from the PV array. The system remains in this state until the battery reaches its maximum depth of discharge (DOD) or minimum set DC voltage (-43.2V to -47V) and loses the ability to supply the telecommunication base station. The charging goes on at a slower rate in this state. At this stage, another charge cycle starts at a set charging coefficient (CC). The AC loads are fed from the inverter system.

A. *Technical Details of the PV System*

- Module Type and Technology: Monocrystalline solar panels are installed at the telecommunication site. This is an obvious choice by the mobile operator due to their high efficiency and conversion rate. Silicon solar panels are widely used across telecommunication sites in Nigeria.
- System Size and Capacity: The array consists of 545W Jinkosolar panels connected in a 3S3P configuration to make up 18 panels; spanning 46.4m2 nominal capacity is 9.81kW. The array is connected to a 48V, 400AH lithium ion battery rack. The backup diesel generators are also connected to a 30kW rectifier. Load on site varies based on cellular traffic, equipment load and battery load.
- Inverter Type and Capacity: The 6kVA inverter module converts DC power into 220V AC to power the HVAC and shelter lights.
- Mounting System: The array is a fixed tilt. Structure on which the solar panels lie is at 15° tilt and 0° azimuth. They are mounted close to the lattice telecommunication tower.

B. *Energy Monitoring System*

The energy monitoring system used was AIO. It comprises computer monitoring software, hardware, which unifies site components into one manager interface, and sensors, such as AC, DC, fuel, battery, environment, and security. It will monitor energy generation, storage, consumption and power on the telecommunication site. The parameters and sensors measured or used by Energy Monitoring System;

- Battery Backup: Amp Hours, Voltage, Forward power, Reverse power, Short Circuit Current.
- Solar: Amp Hours, Voltage, Forward power, Short Circuit Current
- Load or Consumption: Amp Hours, Voltage, Reverse Power
- Sensors: Various sensors used by the monitoring system include DPP – Digital Power Probes, temperature and humidity probes
- DC Monitoring Unit: This monitors and stores the generator, battery, solar, tenant load and other passive parameters. It stores and monitors the Solar DC, battery current, Total DC Current, and Load consumption.

C. *Load or Consumption of the Telecommunication Site*

The Average site consumption data is obtained from the remote computer monitoring system connected to the site.

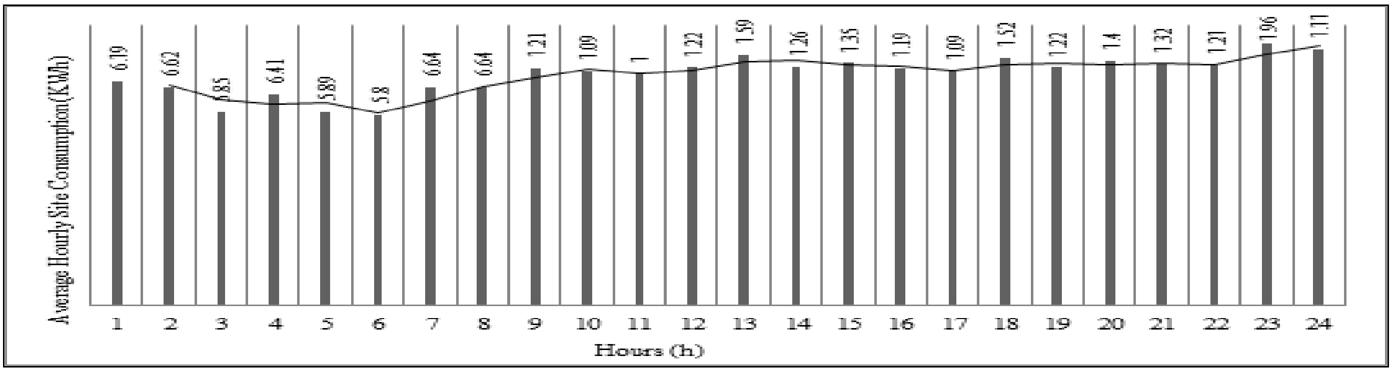

Fig 1: Chart Showing Average Consumption Distribution Per Hour on T4153, a Telecommunication Station in Uli

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D. Performance Parameters and Losses

Performance parameters to be discussed are energy yield factor and performance ratio, PR. Losses in the system includes irradiance losses, array losses and converter losses. This study will look at irradiance losses caused by shading and array losses due to increased temperature.

The International Energy Agency (IEA) and IEC 61724:1998 standard specify the PV performance parameters: performance ratio, energy efficiency, capacity factor, and yield factor [15]. The total energy of the photovoltaic system is produced during a specified time (period) and can be determined as;

$$Y_A = E_a / P_o \quad (1)$$

$$Y_r = H_t / G_o \quad (2)$$

$$Y_f = E_{AC}^{out} / P_{max}, STC \quad (3)$$

$$A_F = T_{output} / T_t \quad (4)$$

Where, Y_A is the array yield
Y_r is the reference system yield
Y_f is the system yield factor
A_F is the availability factor
E_a is the Energy produced by installed PV system;
P_o is the DC power of the installed PV array
H_t is the total in-plane irradiation,
G_o the PV's reference irradiance, usually 1 kW/m2

Then the system efficiency can be given as:

$$\eta_{PV} = (100 \times E_{DC}) / (H_t \times Aa)\ (\%) \quad (5)$$

$$\eta_{inv} = 100 \text{ x } E_{AC} / E_{DC}\ (\%) \quad (6)$$

$$PR = Y_f / Y_r\ (\%) \quad (7)$$

$$C_f = \frac{(\text{Estimated Energy production } Y_f)}{(\text{Installed capacity 24 hours} \times \text{365 Days})} \quad (8)$$

Where,
η_{inv} is the inverter efficiency
η_{PV} is the PV module efficiency

PR is the performance ratio

C_f is the capacity factor; it is defined as the ratio of the estimated energy of the generating system to be produced against the actual energy over the period at continuous operation at full rated power.

➢ *Performance Ratio (PR):*

The PR is a dimensionless quantity that indicates the overall effect of losses on the rated output. It does not represent the amount of energy produced because a system with a low PR in a high solar resource location might produce more energy than a system with a high PR in a low solar resource location. However, for any given system, location, and time, if a change in component or design increases the PR, the Y_f increases accordingly. The performance ratio is demonstrated as a unit of percentage, which shows the energy connection between the actual output and the PV system's target output based on the module's efficiency. It is given as;

$$PR = \frac{EE\ [kwh] \times 1000 \left[\frac{kwh}{m^2}\right]}{POA_{irradiation} \left[\frac{kwh}{m^2}\right] \times DC\ Power} \quad (9)$$

$$\alpha + \beta = \chi$$

Where PR is stated as a performance ratio, energy exported (EE) (the value is taken from the energy meter on the CSU). For a given month, the Plain of Array (POA) irradiation is obtained from the Photovoltaic Geographical Information System, which gives readings from the SARAH2 satellite orbiting the Earth. The DC power is the PV system's power capacity, also called the installed capacity.

The annual PR based on the data noted from the PV Array for a year. The PR formula is defined in (9) and it can be transformed and expressed as;

$$PR = E / (POA \times P) \quad (10)$$

E is Energy in MWh

POA irradiation in the plane of an array in kWh/m2;

P is the PV Array design power

➢ *Energy Yield factor (Y_f):*

The energy yield factor is a measure used to evaluate how well a photovoltaic (PV) system generates energy in relation to its installed capacity affiliation lines.

- Energy Yield: The total electrical energy generated by the photovoltaic (PV) system during a defined timeframe, usually expressed in kilowatt-hours (kWh).
- Installed Capacity: This is the maximum power output potential of the PV system under standard test conditions (STC), usually expressed in kilowatts (kW).

$$Y_f = E / P_o \quad (11)$$

Where
Y_f = Energy Yield Factor
E = Energy Yield (kWh)
P_o= Installed Capacity (kW)

The energy yield factor offers a standardized method for comparing the actual energy output of various photovoltaic (PV) systems, irrespective of their size. The energy yield factor typically falls between 0 and 1, with higher values indicating better performance. The actual amount of energy produced may be less than the maximum expected due to factors like temperature and shading effects.

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A yield factor of 0.8 (80%) might be considered suitable for a rooftop solar system, while a telecom site with higher energy demands might require a yield factor closer to 0.9 (90%) for optimal performance.

- *Losses:*

Losses to be studied are those caused due to shading and temperature. Losses due to shading are irradiance losses, while temperature losses are categorized as array losses. These losses mentioned are crucial in assessing the solar power system's effectiveness in efficiently generating energy and harnessing solar resources. The collected data will be simulated in PVsyst. The results and losses will be compared. Losses include; PV loss due to temperature and near Shadings irradiance loss. It will be seen to what extent these losses affect overall PR and energy yield factor.

IV. RESULTS

The results were obtained from readings carried out at a telecommunication station in Uli, and the results were simulated via PVSyst. In contrast, irradiance, temperature and wind data were obtained from PVGIS.

The PV System is a 3S3P | 3S3P PV array arrangement connected to a telecommunication site with four strings of 100Ah, 48V lithium-ion hybrid batteries and a backup generator designed to compensate for power. Results for this PV system was analysed when connected as an off-grid fixed tilt, and off-grid tracking system.

A. Off-grid Fixed Tilt System

Table 1: Off-Grid Fixed Tilt PV System - PvSyst Simulation Summary

Simulation Summary	
Stand-alone system	Stand alone with back-up generator
PV Field Orientation	Fixed plane
Tilt/Azimuth	15 / 0 °
Load requirement	Average 168 kWh/Day
Nb. of modules	18 units
Pnom total	9.81 kW

Table 2: Off-Grid Fixed Tilt PV System - Simulation Results

Result Summary	
Available Energy	14232 kWh/year
Used Energy	61479 kWh/year
Specific production	1451 kWh/kW/year
Performance Ratio PR	66.84%
Energy supplied to the user	61479 kWh
Back-up generator (44.37%)	49039 kWh
Energy need of the user (Load)	61356 kWh
Global effective energy on an area of 46.4m²	1681 kWh/m²

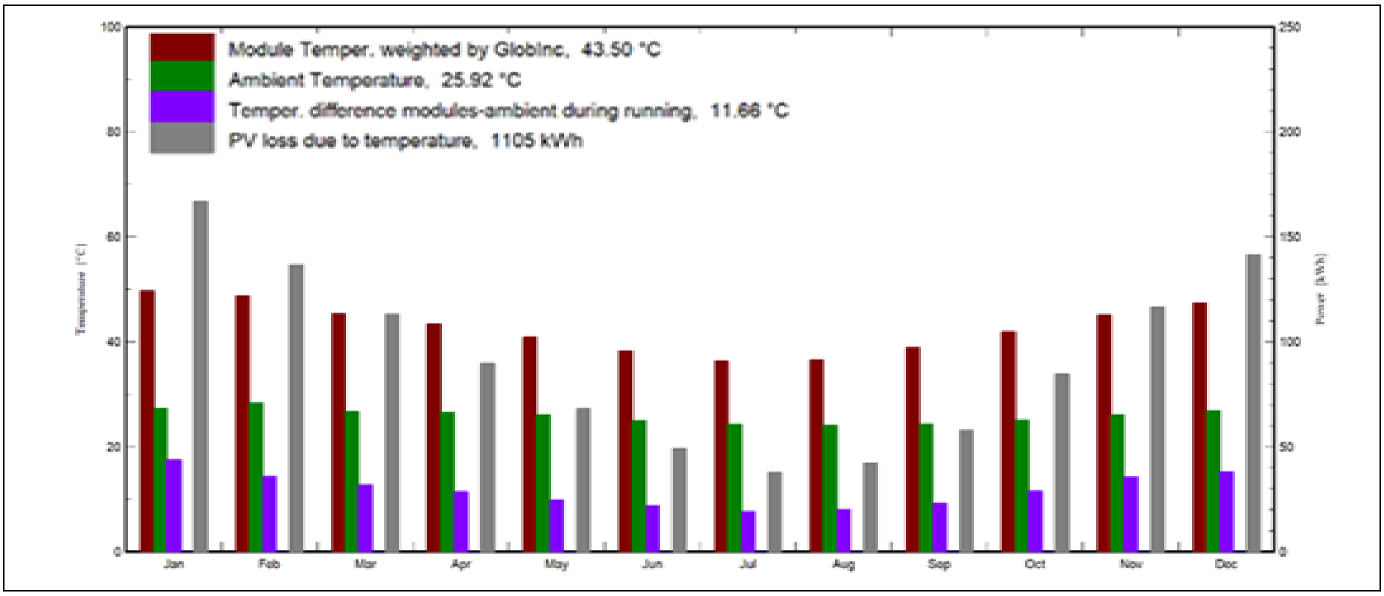

Fig 2: Off-Grid Fixed Tilt System – Average Ambient to Module Temperature Difference as Compared to PV Energy Losses Due to Temperature

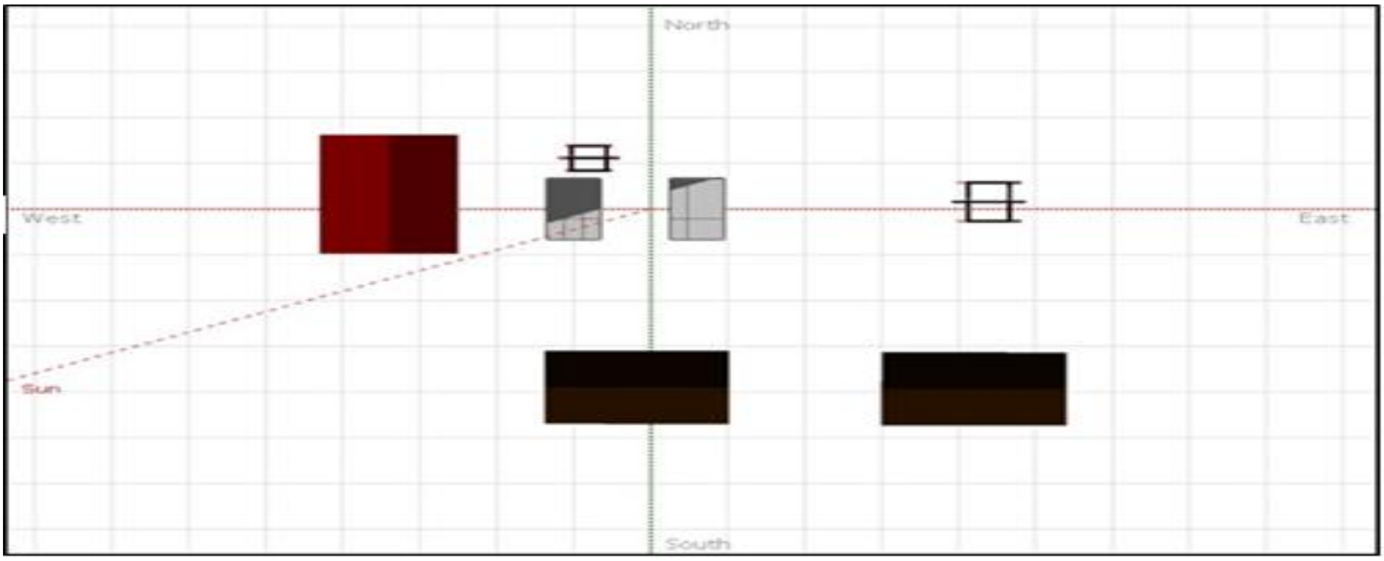

Fig 3: Off-Grid Fixed Tilt System - Pvsyst 3D Modelling Interface - Top View Showing Nearby Shading From Structures in and Around the Telecommunication Site

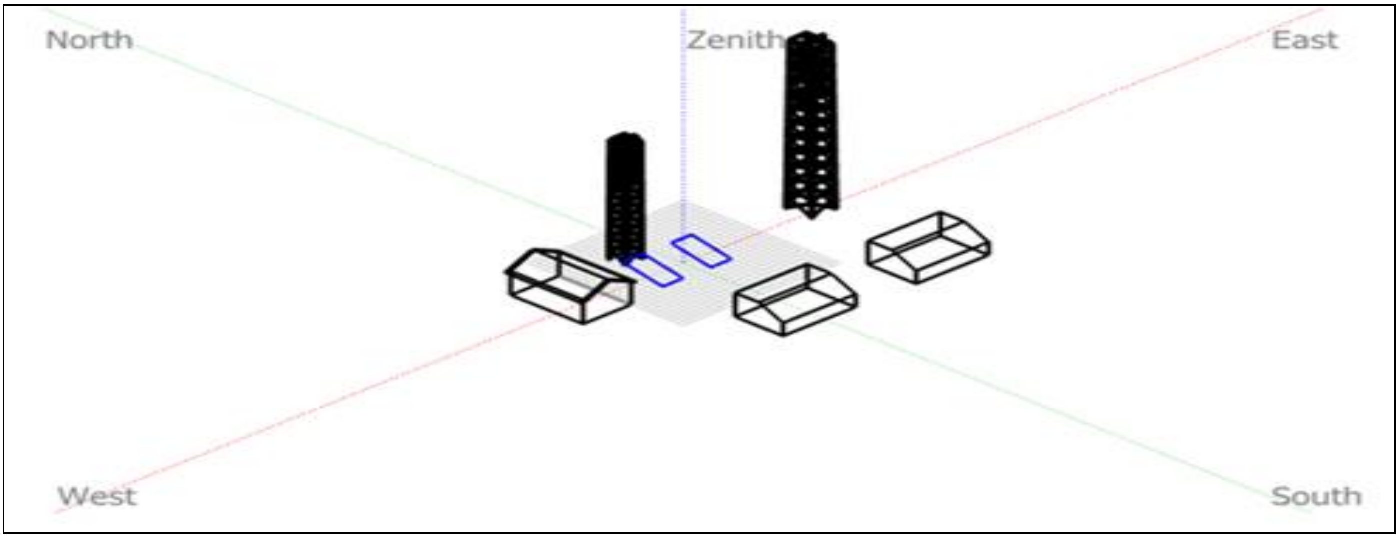

Fig 4: Off-Grid Fixed Tilt System - Near Shadings Perspective of the PV-field and Surrounding Shading Scene

Table 3: Off-Grid Fixed Tilt PV System – Performance Result

Month	**Y_f**	**PR**
	kWh/kW/day	***ratio***
January	4.86	0.728
February	4.53	0.719
March	3.96	0.696
April	3.39	0.634
May	2.79	0.587
June	2.35	0.540
July	2.21	0.591
August	2.44	0.627
September	2.85	0.640
October	3.52	0.698
November	4.28	0.722
December	4.57	0.730
Year	3.47	0.659

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Table 4: Off-Grid Fixed Tilt PV System – Summary of Results Showing the Losses in the PV System

Loss Type	Variable	Loss [%]	Energy after
Global horizontal irradiation, for 46.4 m² of Solar panels			
Global horizontal irradiation	GlobHor		1878.6 kWh/m²
Global incident in coll. plane	GlobInc	0.99%	1897.2 kWh/m²
Near Shadings: irradiance loss	FShdGl	-6.73%	1769.6 kWh/m²
IAM factor on global	FIAMGl	-2.07%	1733 kWh/m²
Soiling loss factor	FSlgGl	-3.00%	1681 kWh/m²
Effective irradiation on collectors	GlobEff		1681 kWh/m²
Array losses			
Array nominal energy (at STC efficiency.)	EArrNom		16494 kWh
PV loss due to irradiance level	GIncLss	-0.76%	16369 kWh
PV loss due to temperature	TempLss	-6.75%	15264 kWh
Module quality loss	ModQual	0.75%	15378 kWh
Mismatch loss, modules and strings	MisLoss	-2.10%	15055 kWh
Ohmic wiring loss	OhmLoss	-1.58%	14817 kWh
Unused energy (battery full)	EUnused	-13.02%	12889 kWh
Effective energy at the output of the array	EArray		12889 kWh

B. Tracking System

Table 5: Tracking PV System - PvSyst Simulation Summary

Simulation Summary	
Stand-alone system	Tracking two axis system with back-up generator
PV Field Orientation	Tracking plane, two axes
Tilt/Azimuth	Linear shadings
Load requirement	Average 168 kWh/Day
Nb. of modules	Tracking two axis system with back-up generator
Pnom total	Tracking plane, two axes

Table 6: Tracking PV System - Simulation Results

Result Summary	
Available Energy	18039 kWh/year
Used Energy	61478 kWh/year
Specific production	1839 kWh/kW/year
Performance Ratio PR	67.20%
Energy supplied to the user	61478 kWh
Back-up generator (44.37%)	45257 kWh
Energy need of the user (Load)	61356 kWh
Global effective energy on an area of 46.4m²	2138.8 kWh/m²

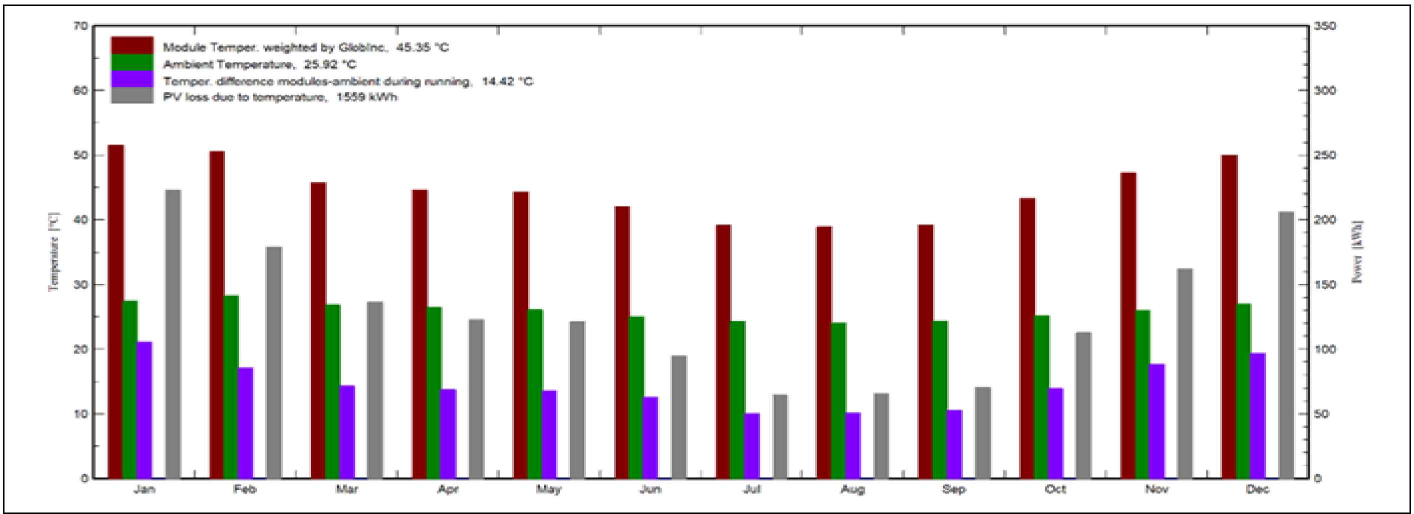

Fig 5: Tracking System – Average Ambient to Module Temperature Difference as Compared to PV Energy Losses Due to Temperature

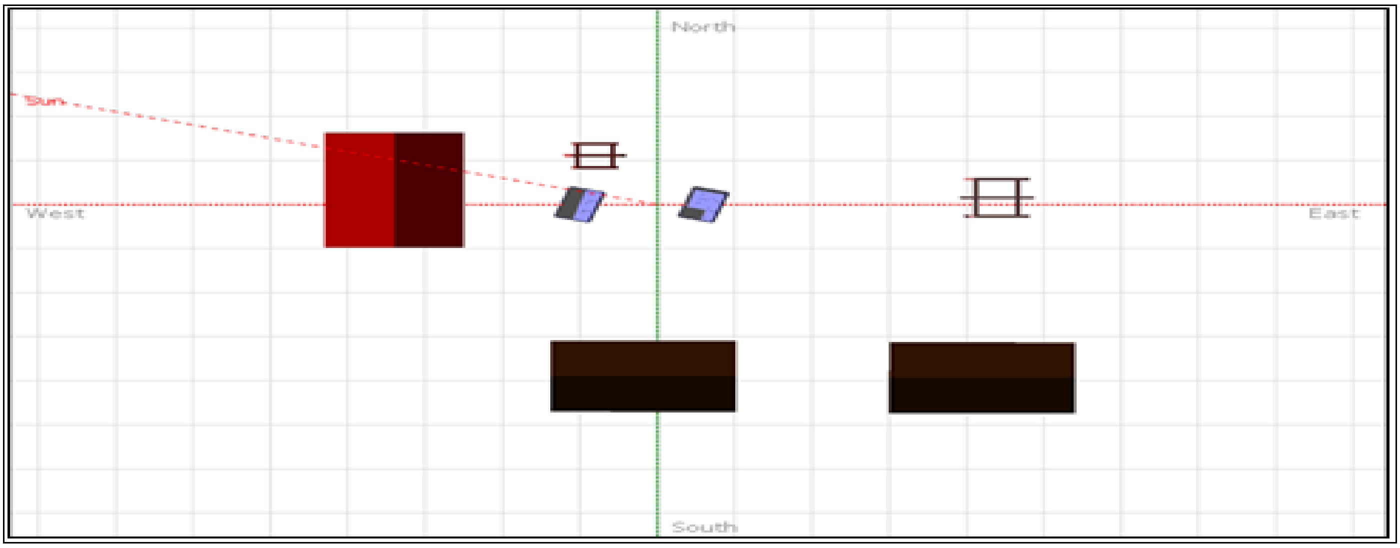

Fig 6: Tracking System - PVsyst 3D Modelling Interface - Top View Showing Nearby Shading from Structures in and Around the Telecommunication Site

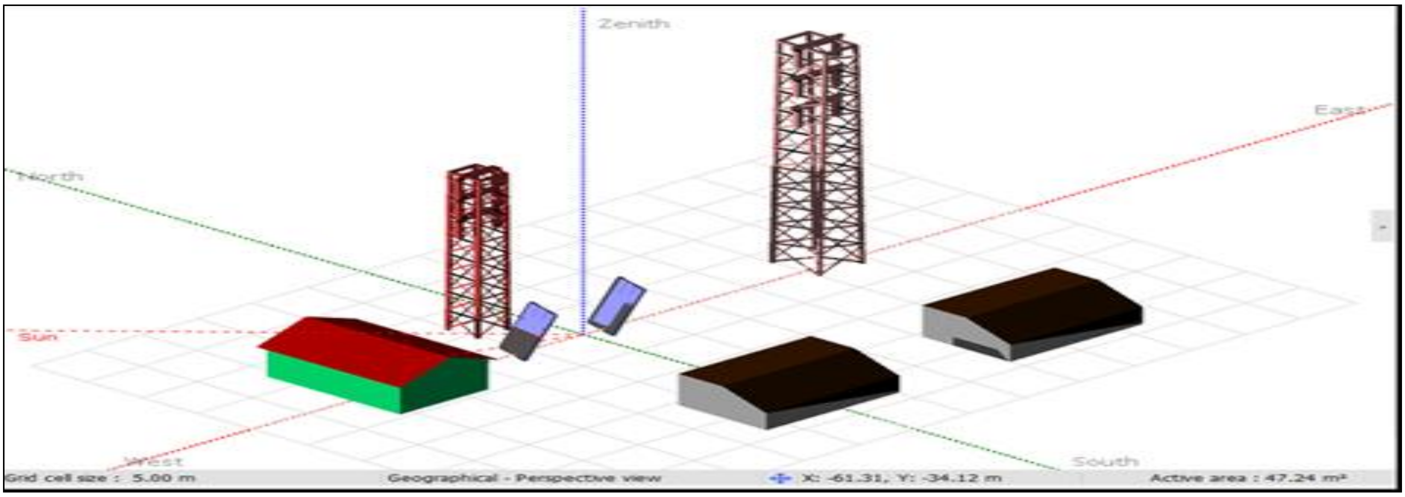

Fig 7: Tracking System - Near Shadings Perspective of the PV-Field and Surrounding Shading Scene

Table 7: Tracking PV System – Performance Result

Month	Y_f	PR
	kWh/kW/day	***ratio***
January	6.14	0.738
February	5.48	0.7
March	4.59	0.656
April	4.11	0.581
May	4.29	0.634
June	4.19	0.668
July	3.09	0.617
August	3.46	0.674
September	3.04	0.547
October	4.37	0.685
November	5.43	0.723
December	6.2	0.764
Year	4.53	0.666

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Table 8: Tracking PV System – Summary of Results Showing the Losses in the PV System

Loss Type	Variable	Loss [%]	Energy after
Global horizontal irradiation, for 46.4 m² of Solar panels			
Global horizontal irradiation	GlobHor		1878.6 kWh/m²
Global incident in coll. plane	GlobInc	30.98%	2460.5 kWh/m²
Near Shadings: irradiance loss	FShdGl	-9.73%	2221 kWh/m²
IAM factor on global	FIAMGl	-0.73%	2204.9 kWh/m²
Soiling loss factor	FSlgGl	-3.00%	2138.8 kWh/m²
Effective irradiation on collectors	GlobEff		2138.8 kWh/m²
Array losses			
Array nominal energy (at STC efficiency.)	EArrNom		20986 kWh
PV loss due to irradiance level	GIncLss	-0.42%	20898 kWh
PV loss due to temperature	TempLss	-7.46%	19339 kWh
Module quality loss	ModQual	0.75%	19484 kWh
Mismatch loss, modules and strings	MisLoss	-2.10%	19075 kWh
Ohmic wiring loss	OhmLoss	-1.58%	18741 kWh
Unused energy (battery full)	EUnused	-11.10%	16660 kWh
Effective energy at the output of the array	EArray		16657 kWh

C. Performance Ratio, Yield Factor and Losses

Below is a comparison of the performance parameters and losses for the evaluated system. Here, we compare the losses of each system; it shows the temperature loss (templss) and total near shading loss (shdloss). The near shading loss is the summation of four losses near shading losses; near shading beam loss (ShdBlss), near shading circumsolar loss (ShdClss) and near shading aldedo loss (ShdAlss) and near shading diffuse loss (ShdDlss). The temperature losses are measured in kWh, while the near shading losses are in kWh/m^2.

The performance ratio for each month is also compared to the yield factor for each month. The PR is a ratio and can be measured in percentile. The yield factor Y_f is measured in kWh/kW/day.

Table 9: Performance Ratio, Yield Factor and Total Losses due to Temperature and Shading for each PV System

PV system →	Off-grid Fixed Tilt System				Off-grid Tracking system			
	PR	***Y_f***	***Losses***		***PR***	***Y_f***	***Losses***	
	ratio	***kWh/kW/day***	***Templss kWh***	***Shdloss kWh/m²***	***ratio***	***kWh/kW/day***	***Templss kWh***	***Shdloss kWh/m²***
January	0.73	4.86	167	5.3	0.74	6.14	223	9.26
February	0.72	4.53	136.6	5.27	0.7	5.48	179	12.58
March	0.7	3.96	113.3	11.95	0.66	4.59	136.5	30.54
April	0.63	3.39	89.9	15.89	0.58	4.11	122.8	34.04
May	0.59	2.79	68.2	17	0.63	4.29	121.4	24.54
June	0.54	2.35	49.3	16.62	0.67	4.19	94.6	23.18
July	0.59	2.21	37.9	13.78	0.62	3.09	64.7	19.29
August	0.63	2.44	42.1	12.59	0.67	3.46	65.7	21.39
September	0.64	2.85	57.9	11.63	0.55	3.04	70.5	30.06
October	0.7	3.52	84.8	7.44	0.69	4.37	112.9	18.86
November	0.72	4.28	116.5	5.33	0.72	5.43	162.3	9.03
December	0.73	4.57	141.8	4.81	0.76	6.2	205.6	6.74
Year	0.659	3.47	1105.4	127.62	0.666	4.53	1558.9	239.5

Table 10: Further Results - Monthly Temperature and Shading Losses – Fixed Tilt System

Month	TempLss	TArray	T_Amb	ShdLoss	ShdBLss	ShdCLss	ShdALss	ShdDLss
	kWh	***°C***	***°C***	***kWh/m²***	***kWh/m²***	***kWh/m²***	***kWh/m²***	***kWh/m²***
January	167	44.98	27.37	5.3	0.643	0.259	0.36	4.036
February	136.6	42.62	28.29	5.27	0.479	0.171	0.321	4.304
March	113.3	39.57	26.83	11.95	4.264	1.876	0.34	5.466
April	89.9	37.89	26.52	15.89	7.629	3.196	0.325	4.743
May	68.2	35.94	26.12	17	8.391	3.505	0.312	4.795
June	49.3	33.87	25.02	16.62	8.215	3.358	0.282	4.77
July	37.9	32.08	24.33	13.78	5.028	2.946	0.245	5.564
August	42.1	32.1	24.05	12.59	4.292	2.441	0.249	5.611
September	57.9	33.73	24.39	11.63	4.039	1.979	0.263	5.353

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October	84.8	36.8	25.22	7.44	1.526	0.563	0.291	5.058
November	116.5	40.39	26.08	5.33	0.445	0.146	0.315	4.423
December	141.8	42.29	26.98	4.81	0.35	0.114	0.333	4.009
Year	1105.4	37.58	25.92	127.62	45.302	20.553	3.637	58.131

Table 11: Further Results - Monthly Temperature and Shading Losses – Tracking System

Month	**TempLss**	**TArray**	**T_Amb**	**ShdLoss**	**ShdBLss**	**ShdCLss**	**ShdALss**	**ShdDLss**
	kWh	***°C***	***°C***	***kWh/m²***	***kWh/m²***	***kWh/m²***	***kWh/m²***	***kWh/m²***
January	223	48.5	27.37	9.26	2.36	0.932	2.289	3.676
February	179	45.41	28.29	12.58	5.1	1.883	1.666	3.93
March	136.5	41.13	26.83	30.54	15.83	7.854	1.433	5.424
April	122.8	40.29	26.52	34.04	19.76	8.032	1.245	5.007
May	121.4	39.72	26.12	24.54	12.98	4.927	1.26	5.37
June	94.6	37.55	25.02	23.18	12.04	4.779	1.113	5.242
July	64.7	34.41	24.33	19.29	7.94	4.362	1.013	5.978
August	65.7	34.24	24.05	21.39	9.29	5.137	1.026	5.929
September	70.5	34.88	24.39	30.06	15.71	7.901	1.109	5.337
October	112.9	39.13	25.22	18.86	9.68	3.091	1.447	4.646
November	162.3	43.76	26.08	9.03	2.41	0.927	1.878	3.811
December	205.6	46.36	26.98	6.74	0.86	0.254	2.228	3.399
Year	1558.9	40.34	25.92	239.5	113.96	50.078	17.708	57.75

V. CONCLUSION

This study discussed Impact of Temperature and Shading on Performance of Solar Photovoltaic Systems installed in Telecom Sites. The loss due to shading and temperature was discussed. It was carried out by identifying the location and type of solar cell. A technical survey and analysis were conducted to check the design and ensure the system design was appropriate. Finally, these data were simulated in PVsyst, and the meteorological data was obtained from PVGIS. Results were obtained for the fixed tilt and tracking systems, keeping certain conditions, such as shading, fixed plane, and etcetera, constant. Below are the deductions from the simulation results.

- PV array energy yield is primarily affected by level irradiation on its surface.
- In addition, the performance ratio of the stand-alone and tracking systems shows close similarity and value.
- The tracking system produced more energy yield but had higher losses than the stand-alone system, mainly due to the higher solar cell temperature recorded caused by prolonged exposure to incident irradiation.
- The tracking system is the most affected by shading from nearby structures at the location of the telecommunication site.

All the systems used a diesel generator as a backup power source to prevent downtime due to malfunctions, energy loss, and planned maintenance. Surface irradiation is the primary factor influencing PV array energy yield, but it is just the tip of the iceberg. This study delves into the intricate web of factors, such as temperature and shading, which significantly impact overall performance, inviting you to explore the depths of PV system dynamics.

Stand-alone and tracking systems exhibited similar performance ratios, but a key difference emerged. Despite generating more energy, tracking systems experienced higher losses than fixed-tilt systems. This is primarily attributed to the increased solar cell temperature caused by prolonged direct sunlight exposure in tracking systems. PV array energy yield is primarily affected by level irradiation on its surface. In addition, the performance ratio of the stand-alone and tracking systems shows close similarity and value. The tracking system is the most affected by shading from nearby structures at the location of the telecommunication site.

Moreover, the study revealed that tracking systems, particularly at the telecom site, are highly vulnerable to shading from nearby structures. This shading significantly reduces their energy output, highlighting the urgent need to consider shading patterns in real-world PV system design and implementation.

Further research is encouraged in the aspect of providing stability to these PV systems connected to telecommunication sites and equipment. Telecommunication research has led to implementation of techniques and use of BTS equipment with less power consumption. The 5G wireless network uses massive MIMO as its exciting area that promises significant gains, which provide the ability for more users to be accommodated at higher data rates with improved reliability even as less power is consumed [16]. Suggested further work can show how these improved telecommunication techniques are affected by the performance of PV systems connected to the base stations.

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REFERENCES

[1]. J. Atuchukwu. (2022). Fault Analysis of Nigerian 330kv Power System. Scholar Publishing SSE-UK. https://doi.org/10.14738/eb.283.2022.
[2]. A, Kumar, and S. Shudakar. (2015). Performance study of a 10 MW grid-connected solar photovoltaic power plant installed at Ramagundam, India. *Energy Procedia*, 88, 339– 346.
[3]. Attari, M. Haddadi, and A. Fekri. (2016). Performance evaluation of a 5 kW grid-connected PV system installed in Tangier, Morocco. *Energy Procedia*, 93, 465–470.
[4]. Shukla, and G. N. Tiwari. (2016). Simulated performance of a 110-kW solar rooftop photovoltaic plant connected to a distribution network for a residential hostel building in Manit, India. *Energy Reports*, 2, 149–160.
[5]. Allouhi, M. H. Albadi, and A. Elhadrami. (2016). Performance analysis of two 2 kW grid-connected photovoltaic systems installed at High School of Technology of Meknes, Morocco. *Energy Procedia*, 92, 176–182.
[6]. G. Singh, A. Tiwari, and S. Chandra. (2017). Impact of dust accumulation on performance of photovoltaic modules. Renewable and Sustainable. *Energy Reviews*, 74, 1031-1041.
[7]. M. G. Villalva, J. R. Gazoli, and E. R. Filho, "Comprehensive approach to modeling and simulation of photovoltaic arrays," *IEEE Transactions on Power Electronics*, 24(12), 2895-2904, 2009.
[8]. Skowron, A. Pietrzykowski, and M. Grabowiecki. (2018). The influence of shading on the efficiency of a photovoltaic module. *Renewable Energy*, 113, 1127-1132.
https://doi.org/10.1016/j.renene.2017.06.052
[9]. Akpakwu, C, and A. A. Ongunleye. (2020). Performance evaluation of a grid-connected photovoltaic power system for a Base Transceiver Station (BTS) site in Nigeria. *International Journal of Electrical and Computer Engineering*, 14(3), 122-130.
[10]. S. Chowdhury, S. Rahman, and A. M. T. Oo. (2014). Grid-independent hybrid renewable energy system for mobile phone base station in remote areas. *Renewable and Sustainable Energy Reviews*, 31, 567-579.
[11]. Y. Y. Hong, B. H. Kang, and J. H. Kim. (2016). Techno-economic analysis of a PV/battery hybrid power system for a remote telecommunication base station. *Renewable Energy*, 86, 798-805.
[12]. H. Ibrahim, H. Ramadan, and A. A. Mohamed. (2014). Design and simulation of a standalone photovoltaic power system for a remote cellular base station. *Energy Procedia*, 50, 522-529.
[13]. M. Ishaq, and A. M. El-Naggar. (2019). A comprehensive overview of solar PV energy systems for powering cellular base stations in developing countries. *Renewable and Sustainable Energy Reviews*, 114, 109283.
[14]. R. Eke, and I. F. Senturk. (2012). Modelling and optimization of the performance of solar photovoltaic power systems. *Renewable and Sustainable Energy Reviews*, 16(8), 6025– 6036.
[15]. Photovoltaic (PV) systems - Performance characterization of terrestrial PV modules under uniform spectral irradiance and temperature conditions, IEC standard 61724:1998.
[16]. A.J. Okoye, C.B. Mbachu, S.A Akaneme and C.A. Nwabueze. (2022). Maximizing the Capacity of Large Scale MIMO Based on Maximal Ratio Combining. *International Journal of Innovative Science and Research Technology*.
7(6), 378-383.