Challenges of small-scale standalone solar energy supply in parts of Lagos via 39 years dataset

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Abstract. The adoption of solar energy as a sustainable clean type of energy can be seen globally by the patronage of solar devices. However, the high patronage photovoltaic (PV) module by the small-scale standalone user may be mitigated by the recent high maintenance cost via PV module damages by UV radiation. This study analyzed thirty-nine years (1980-2018) shortwave dataset in the tropics to chart the way forward for PV user, manufacturer, and regulatory organizations. It was observed that there is an increase in shortwave radiation in recent times that has led to more damages to PV modules. However, there is a statistical possibility that there may be lower shortwave radiation in the next decade, thereby reducing PV module damage. It is recommended that PV manufacture should modify the PV polymeric to shield the PV modules from UV radiation damage. Based on this research's finding, it is recommended that product regulatory organizations develop a new technique to monitor PV modules.

1 Introduction

Use The quest for improved energy supply has led to the development of various technologies. Some of these technologies have been proven to detrimental to life forms. For example, the fossil fuel generator is the most used in developing countries [1]. This technology has contributed significantly to the global carbon print [2-3]. Nuclear energy technology is still in use in most parts of the globe. The main shortcoming of nuclear energy technology is the toxic radioactive waste [4]. Radioactive waste includes solid, liquid, or gas material that consists of a radioactive nuclear substance. This waste can lead to air, land, and water pollutions if not correctly managed [5-7].

The cause of the energy crisis in most developing countries is insufficient government involvement in sustainable energy solutions. Unfortunately, the already established market for fossil-fuel generators has employed a significant number of the populace. Hence, the populace's reluctance to renewable energy options is justified, as there is no convincing evidence that it is viable. In recent times, the emphases of energy experts are to develop cleaner energy that would not pollute the environment. The most dominant form of renewable energy is solar power, whose source is the sun. The conversion of solar energy is done using a semiconductor device known as solar cells [8]. Also, a solar concentrator is used in recent times for heat and powering steam engines. Another popular renewable energy source is wind energy. However, wind energy is not suitable in all places or areas; wind energy will be more suitable in the desert and offshore locations.

Renewable energy technology has received huge patronage based on the global resolution to promote the sustainable development goal (SDG) number 7, i.e., provision of clean energy [9]. Among the renewable energy options, solar energy is the most prominent due to the sun's availability in sizeable parts of the globe. The solar devices convert solar irradiance to useable energies. Some solar devices include solar collectors, solar heater, photovoltaic, thermovoltaic, solar storage fluids, etc. The photovoltaic technology is the most used among solar devices based on its cost, availability, and flexibility to serve different users. The photovoltaic technology had experienced significant advancement since 1954 when the first photovoltaic was invented by Calvin Souther Fuller, Daryl Chapin, and Gerald Pearson [10]. Most photovoltaic are referred to as solar cells. A solar cell is a semiconducting device and can be classified into first, second, and third-generation cells.

This paper's hypothesis is that energy crisis in developing countries is far from being over because of the realities of corruption, low facility maintenance, inadequate legal framework, socio-cultural beliefs, and ignorance. Therefore, it is proposed that the temporal solution to the lingering energy crisis in developing is the improvement in the standalone technology. However, the tropics' standalone solar energy user's challenge is the severe damage solar cell or photovoltaic module via the

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UV radiation [11]. Scientists have proven that the in-built polymeric encapsulates that shield the photovoltaic module from mechanical stress and environmental corrosion is significantly affected by terrestrial solar UV radiation in the form of UVA (320–400 nm) and UVB (280–320 nm) [12]. IEC 61215 propounded that UV irradiance over the test plane should not exceed 250 W/m2. Solar energy enters our atmosphere as shortwave radiation in ultraviolet (UV) rays (the ones that give us sunburn) and visible light. Based on the above, shortwave radiation (visible light) was investigated using a live dataset so that users and photovoltaic companies can understand the climatic system's peculiarity.

2 Methodology

Shortwave radiation was used in this study. Shortwave radiation (SW) is radiant energy with wavelengths in the visible (VIS), near-ultraviolet (UV), and near-infrared (NIR) spectra. Thirty-nine years shortwave radiation dataset (1980-2018) was obtained from the MERRA-NASA database for Agege, Lagos, Nigeria. The Modern-Era Retrospective analysis for Research and Applications (MERRA) dataset is based on a version of the GEOS-5 atmospheric data assimilation system. MERRA data were produced on a $0.5° × 0.66°$ grid with 72 layers. MERRA was used to drive standalone reanalyses of the land surface (MERRA-Land) and atmospheric aerosols (MERRAero) [13].

The primary two climatic seasons in Nigeria is the wet and dry seasons. In this research, the early dry season (i.e., September, October, November- SON), late dry season (i.e., December, January February-DJF), early wet season (i.e., March, April, May – MAM), and late wet season (i.e., June, July, August-JJA) were considered. The dataset was statistically analyzed by considering the monthly averages of shortwave radiation. Thirty-nine years dataset was then separated based on the seasons defined earlier. The averages of the seasons were obtained for each year. Then the analysis was grouped into ten years. Group A was 1980-1989, Group B was 1990-1999, Group C was 2000-2009, and Group D was 2010-2018.

3 Results and discussion

The seasonal shortwave radiation between 1980 and 1989 was considered, as shown in Figure 1. It is observed that the shortwave radiation for DJF season had an imperfect sinusoidal curve with a unique high (1980, 1983, 1985, and 1989) and low (1981, 1984, and 1988). Three high shortwave radiation spikes were discovered in SON, DJF, and MAM. The MAM season also had an imperfect sinusoidal curve with a unique high in 1981 and 1988, and a unique low in 1982 and 1985. The shortwave in JJA season decreased over the years with a unique low in 1988. SON season had an imperfect sinusoidal curve with the high in 1981, 1984, and 1986, while the low was in 1983, 1985, and 1989. The year 1988 is seen to be unique all through the seasons i.e., it is high in MAM and low in DJF, and JJA. This trend is seen to occur in 1984 and 1985. Hence, when the PV module is installed within the decade, it is more likely that the module malfunction in 1984, 1985 and 1988.
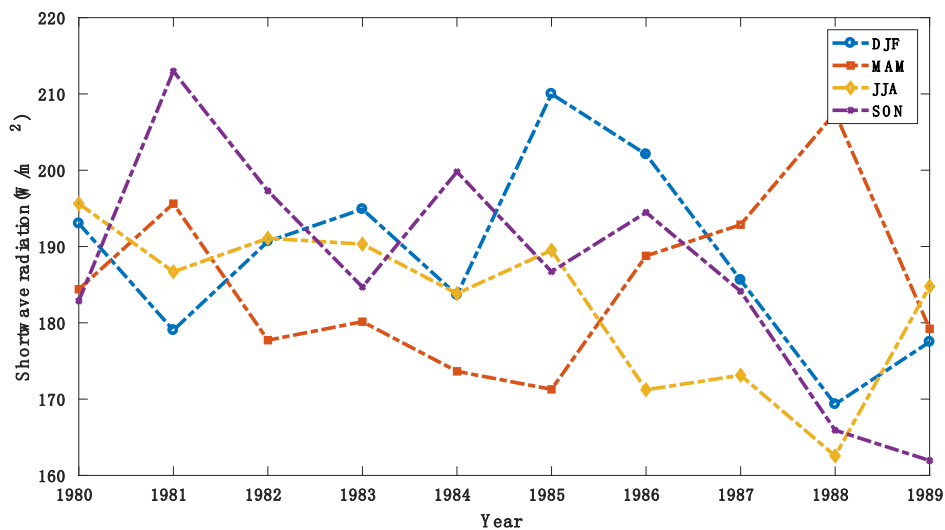

Fig. 1. Shortwave radiation of all-season between 1980 and 1989

Table 1. ANOVA Table of ten years of data (1980-1989)

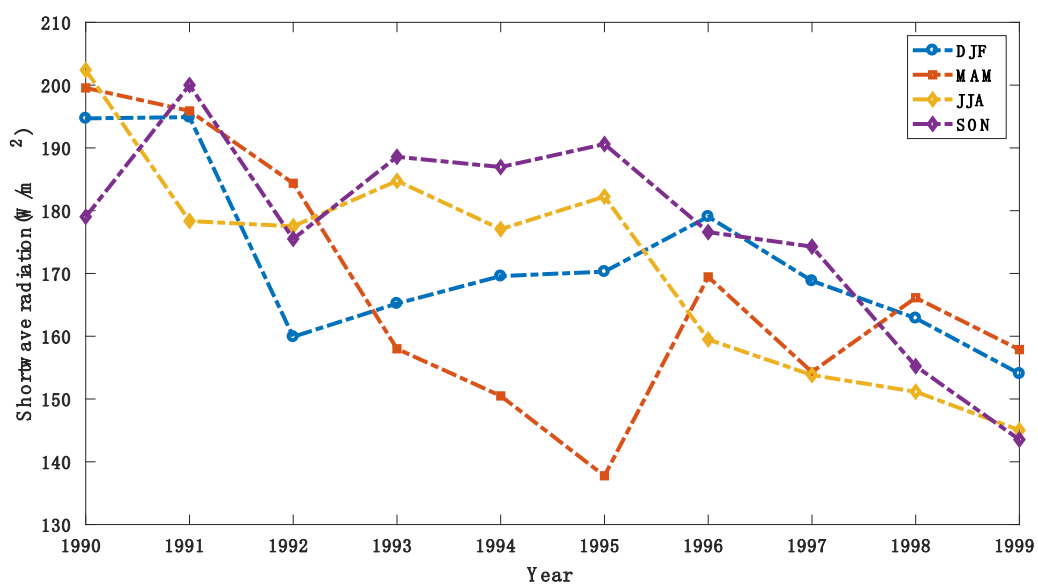| Source	df	Sum of Squares	Mean Square	F
Regression:	2	506.97	253.48	3.66
Residual:	7	484.75	69.25	
Total:	9	991.71		

Fig. 2. Shortwave radiation of all-season between 1990 and 1999

Table 2. ANOVA Table of ten years of data (1990-1999)

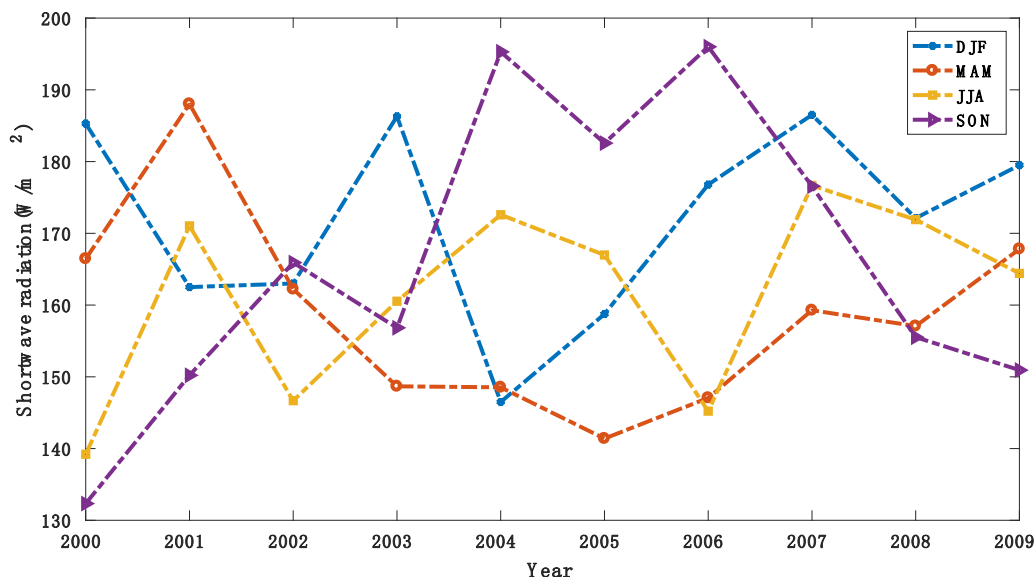| Source	df	Sum of Squares	Mean Square	F
Regression:	2	986.26	493.13	1.78
Residual:	7	1945.04	277.86	
Total:	9	2931.30		

Figure 3. Shortwave radiation of all-season between 2000 and 2009

Table 3. ANOVA Table of ten years of data (2000-2009)

Source	df	Sum of Squares	Mean Square	F
Regression:	2	132.70	66.35	0.32
Residual:	7	1441.19	205.88	
Total:	9	1573.89		

Fig. 4. Shortwave radiation of all-season between 2010 and 2018

Table 4. ANOVA Table of ten years of data (2010-2018)

Source	df	Sum of Squares	Mean Square	F
Regression:	2	1149.89	574.95	7.68
Residual:	6	449.03	74.84	
Total:	8	1598.92		

Table 5. Statistical summary of 39 years dataset

Year	1980-1989	1990-1999	2000-2009	2010-2019
Minimum:	162.56	145.02	139.19	161.29
25%-tile:	173.12	153.81	146.66	176.56
Median:	186.68	177.51	166.97	188.45
75%-tile:	190.31	182.24	171.9	194.96
Maximum:	195.62	202.40	176.66	204.36
Midrange:	179.09	173.71	157.93	182.82
Range:	33.06	57.38	37.47	43.07
Interquartile Range:	17.19	28.43	25.24	18.40
Median Abs. Deviation:	4.40	18.03	6.44	10.07
Mean:	182.87	171.18	161.51	184.24
Trim Mean (10%):	183.82	170.54	162.41	184.65
Standard Deviation:	9.96	17.12	12.55	13.33
Variance:	99.17	293.13	157.39	177.66
Coef. of Variation:	0.05	0.10	0.08	0.07
Coef. of Skewness:	-0.76	0.05	-0.59	-0.29

The ANOVA for the ten years data is presented in Table 1. The regression model shows that it can only explain 51.2% of all the variability in the dataset. The error in the regression model is seen to be as high as 48.8%. The coefficient of multiple determination (R^2.) is given as 0.51. Also, the F-significance shows that no significant relationship exists between dependent and independent variables. This high variability is clear evidence that climate change is noticeable since four decades ago. The implication for PV modules is its high susceptibility to damage. The shortwave radiation between 1990 and 1999 indicates a notable trend where all value decreased significantly all through the years (Figure 2). This trend may be very comfortable for the PV module has no significant climatic perturbations were seen. The ANOVA table shows that the variability between the dataset is low, with the coefficient of multiple determination (R^2) as 0.34 (Table 2). Like in Figure 1, the shortwave radiation between 2000 and 2009 is characterized by imperfect sinusoidal curves with high and low (Figure 3). However, the ANOVA table it has a lower variability than the previous decade, i.e., whose shortwave radiation declined throughout the year (Table 3). The coefficient of multiple determination (R^2) is given as 0.084. The F significance also proves that though the datasets' high and lows, the variability is low. Unfortunately, not only variability determines the effect of shortwave radiation on the PV module. More significant is the sinusoidal curve that shows how much the solar cells must undergo operational stress that results in its damage. The trend in Figure 4 is exactly the opposite in Figure 2, as the shortwave radiation increased significantly. This trend may be attributed to the upward trend in the average magnitude of sunspots and solar flares over time [14-15]. The high variability in Table 4

(i.e., the coefficient of multiple determination (R^2) of 0.72) shows that PV modules are more likely to damage more in this period. This fact is supported by reports on severe PV module damage within this period [16-18]. More disturbing is the upward trend that may likely mean that this trend may not change for a long time. The statistical summary of 39 years dataset is presented in Table 5. The general observation in Table 5 reveals that shortwave radiation has been the toughest between 2010 and 2018. However, the thirty-nine years trend shows that whenever there is high shortwave radiation (1980-1989), its magnitude decreases gradually through two other decades, i.e., 1990-1999 and 2000-2009. Based on the above, it is likely that PV modules may not experience much damage in the next decade.

4 Conclusion

Despite the severe damage of PV modules in recent times due to high variable shortwave radiation, there is a statistical possibility that the next decade may be better, i.e., with lower PV modules damaging. With these new facts on the trend of shortwave radiation, it is possible to make solar energy a focus to alleviate or mitigate the energy crisis in developing communities. The standalone solar system can significantly impact a matching solar device technology for developing countries, especially developing countries in the tropics. With the rise in photovoltaic patronage-globally, which has resulted in low solar panel cost so that the less privileged in society can afford it, it expedient for PV manufacturers to modify the PV manufacturers' polymeric module to withstand UV damage. Hence, when this challenge is subdued, there could be higher patronage of solar TV, solar radio,

solar lamp, solar refrigerator, etc. Based on this research's finding, it is recommended that product regulatory organizations develop a new technique to monitor PV modules.

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