Caliphate Journal of Science & Technology (CaJoST)

ISSN: 2705-313X (PRINT); 2705-3121 (ONLINE)

Research Article

Article Info

Received: 23rd March 2021

Revised: 15th July 2021

Accepted: 17th July 2021

Modeling the Availability and Reliability of a Solar Photovoltaic System and Evaluating Using the Gumbel-Hougaard Family Copula

Anas S. Maihulla,[1,2*] Ibrahim Yusuf ,[2] Zainab A. Dogon Daji,[1] and Mujitaba Usman[1]

[1]Department of Mathematics, Sokoto State University, Sokoto
[2]Department of Mathematical Sciences, Bayero University, Kano

*Corresponding author's email:
anasmaihulla@gmail.com

Cite this: *CaJoST,* 2021, 2, 173-181

This work provides models and simulation of a stand-alone photovoltaic (PV) device with a battery bank. The key goal was to create a library of basic mathematical models for each component of a stand-alone PV device, including solar cells, batteries, controllers, inverters, and loads. Copula, modeling software with a graphical interface for constructing models as modular block diagrams, is used to analyze availability, durability, mean time to failure (MTTF), and cost benefits. This study addresses the evaluation of component faults of the PV simulation. The objective of this paper is to obtain an optimal sizing of the PV system from the economical point of view, by imposing some constraints related to the desired reliability of the system. This is to guarantee a desired reliability in the continuity of the supply in the design of PV generation system. The result was numerically analyzed to extract relevant conclusions about the design process of PV systems, which reveals that Subsystem A (modules panels) has maximum effect on the availability of the complete system. In addition, the failure rate also has maximum effect on availability of complete system. Other subsystems are almost equally effective. Thus, we can make an inference that we should take the most care of these subsystems in order to improve the overall availability of the system.

Keywords: Photovoltaic, Copula, Solar-cells, modules, simulation.

1. Introduction

This study provides a variety of models and simulation of a stand-alone photovoltaic (PV) device with a battery bank consisting of two units batteries, which were tested against a system mounted at the Sokoto State University Mathematics library in Sokoto, Nigeria. The architecture of a stand-alone PV system is made up of blocks to make modeling of other PV system models easier. Many photovoltaic systems can run on their own. As seen in Figure 1, such systems include a PV generator, energy storage (for example, a battery), AC and DC users, and power conditioning components stand-alone machine, by definition, does not interfere with the power grid. A PV generator can have many arrays. Each array is made up of several arrays, each of which is made up of several solar cells. When the energy provided by the PV modules reaches load requirement, the battery bank stores it and releases it when the PV supply is inadequate. A stand-alone PV system's load can be of various forms, including both DC (television) and AC (lighting) (electric motors, heaters, etc.). The power conditioning system acts as a link between all of the PV system's components, providing safety and control. Blocking diodes, charge regulators, and DC-AC converters are the most common power conditioning system components. Yusuf et. At al [1] analyze the performance of multi computer system with three subsystems in series using copula. Singh and Lado [2] dealt with cost assessment of a system attended by human operator. For instance, in Idoko et al. [3] multi-concept cooling technique is used in reducing the overheating of PV module there by increasing the life span of the PV module as well as the system. Similarly, in Charfi et al. [4] presented experimental study self-cooled PV panel whose performance was improved in hot period of the day through natural ventilation. Gouda et al. [5] presented modelling and performance evaluation for a PV system based MPPT through advanced techniques. Jayanth and Venkatesh [6] analyzed the performance of solar PV cell through climate data. Ramya el al. [7] presented an experimental study for performance analysis of a self-cooled photovoltaic panel. Ates and Singh [8] analyze the performance of a rooftop solar photovoltaic plant. Cavalcante et al [9] dealt with performance measurement of solar photovoltaic power plant.

Chiacchio et al [10] studied the performance of photovoltaic power plant through stochastic hybrid fault tree automation model. De Lima et al [11] analyze the performance of a grid connected photovoltaic system in northern Brazil. Dondariya et al. [12] presented simulation modelling for performance of a grid connected rooftop solar PV system for small household. El-Kharaza et al. [13] studied different cooling methods of PV solar performance improvement. Fetyan and Hady [14] studied the performance evaluation of on grid PV systems in Egypt. Haji et al. [15] discuss the performance of installed solar PV system using homer in Tanzania. Kassim et al. [16] dealt with the application reflector in performance improvement of solar module. Mustafa et al. [17] studied the impact of environment on the performance of solar photovoltaic system. Prasad et al. [18] dealt with performance enhancement of rooftop solar photovoltaic system. Rehmana and Sahin [19] studied the distinction in performance between diesel and solar photovoltaic power systems for water pumping in Saudi Arabia. Savalia et al. [20] presented the performance evaluation of 190 k Wp rooftop solar photovoltaic plant. Yadav and Bajpaj [21] analyze the performance of a rooftop solar photovoltaic power plant in Northern India. Zulkafli et al. [22] reviewed the performance factors of photovoltaic system.

The application of solar photovoltaic (PV) technology, on the other hand, differs from country to country. Solar PV technologies were previously mostly used in rural off-grid areas as a feasible alternative for providing electricity to isolated populations. Grid-tied solar PV electricity generation has become more common in recent years, thanks to technical advances and learning that have resulted in lower device costs and better efficiency, as well as favorable investment policies and regulatory structures.

Residential customers without access to the electricity delivery network are rapidly installing micro-renewable energy sources in rural areas or remote villages in developed countries (DN). Off-grid photovoltaic (PV) systems for electrification of single residential households are the most popular micro-renewables in Spain. These stand-alone photovoltaic (SAPV) energy systems generally include batteries for energy storage [23], [24] and [25].

Self-consumption of energy has recently been limited by the Spanish government. This legislation was issued as a last-minute measure to promote clean energies and protect consumers. It has removed regulatory barriers for small-scale energy plants and, for the first time, it provides for mutual self-consumption.

This study addresses the evaluation of component faults of the PV simulation. The objective of the paper is to obtain an optimal sizing of the PV system from the economical point of view, by imposing some constraints related to the desired reliability of the system. The objective is to guarantee a desired reliability in the continuity of the supply in the design of PV generation system. To validate the results of the proposed method. The results were numerically analyzed to extract relevant conclusions about the design process of PV systems.

Many residential households have installed PV renewable generation to satisfy its own energy requirements. This generation is accompanied by batteries to storage energy when surpluses are available and to supply energy when the PV output is insufficient. Figure 1 shows a scheme of the installation of PV panels and batteries to supply a residential load without connection to the grid. The battery has a regulator or battery controller (BC) to control the maximum current, both in charge and discharge operations. The BC decides the power flows between the PV panel array and the battery. The PV system has been divided into two sections:

I-The generation section: PV panel array, BC and batteries.

II-The load section: inverter and loads.

The reliability analysis performed in this work will take into account the possible failures in the PV panel array and the BC considering the failure rate in a given time of these elements. These failures can be covered by the batteries that also present a specific failure rate. The possible failures in the inverter cannot be supported by other elements in the proposed scheme. Therefore, to include these failures in the analysis, this element should be considered in series with the generation section and the overall reliability would be the product of the reliability of both systems.

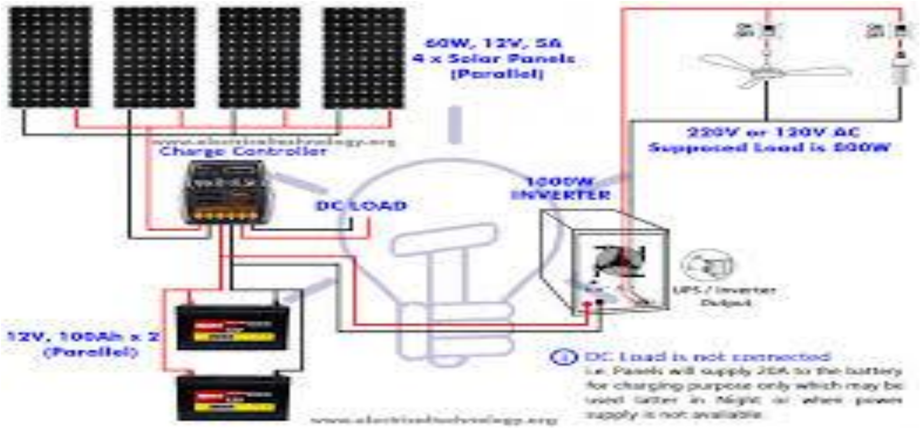

Figure I: Block diagram for the system

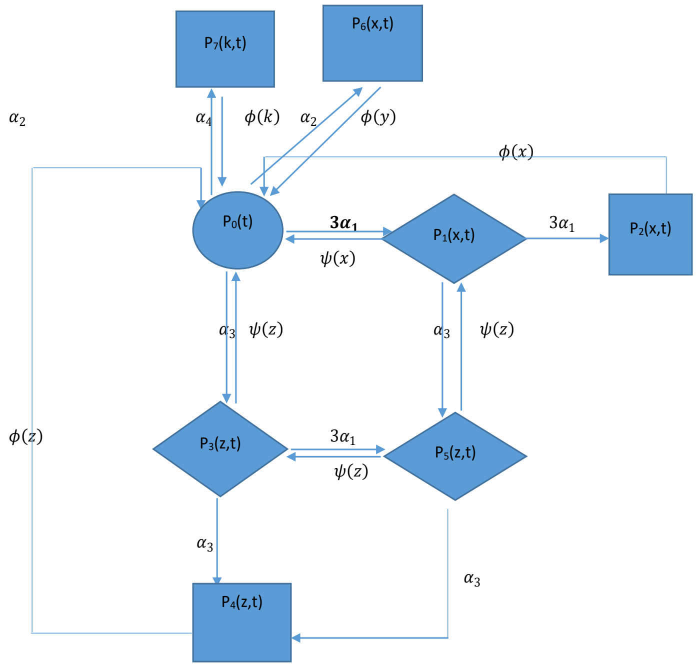

Figure II: System Transition Diagram

$$\left(\frac{\partial}{\partial x}+3\alpha_1+\alpha_2+\alpha_3+\alpha_4\right)P_0(t)=\int_0^\infty \psi(x)P_1(x,t)dx+\int_0^\infty \psi(z)P_3(z,t)dz+\int_0^\infty \psi(y)P_6(y,t)dy+$$

$$\int_0^\infty \psi(k)P_7(k,t)dk \quad (1)$$

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial x}+\psi(x)+\alpha_1+\alpha_3\right)P_1(x,t)=0 \quad (2)$$

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial x}+\phi(x)\right)P_2(x,t)=0 \quad (3)$$

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial x}+\psi(z)+3\alpha_1\right)P_3(z,t)=0 \quad (4)$$

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial x}+\phi(z)\right)P_4(z,t)=0 \quad (5)$$

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial z}+\alpha_3+2\psi(z)\right)P_5(z,t)=0 \quad (6)$$

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial y}+\phi(y)\right)P_6(y,t)=0 \quad (7)$$

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial k}+\phi(k)\right)P_7(k,t)=0 \quad (8)$$

Boundary conditions

$$P_1(0,t)=3\alpha_1 P_0(t) \quad (9)$$

$$P_2(0,t)=3\alpha_1^2 P_0(t) \quad (10)$$

$P_3(0,t) = \alpha_3 P_0(t)$ (11)

$P_4(0,t) = 3\alpha_3^2 P_0(t)$ (12)

$P_5(0,t) = 6\alpha_1\alpha_3 P_0(t)$ (13)

$P_6(0,t) = \alpha_2 P_0(t)$ (14)

$P_7(0,t) = \alpha_4 P_0(t)$ (15)

Initial condition $P_0(t)$ = 1 and other transition probability at t=0 are zero

Laplace transformation of equation (1) to (15)

$$(S + 3\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4)\bar{P}_0(S) = 1 + \int_0^\infty \psi(x)\bar{P}_1(x,s)dx + \int_0^\infty \psi(z)\bar{P}_3(z,s)dz + \int_0^\infty \psi(y)\bar{P}_6(y,s)dy + \int_0^\infty \psi(k)\bar{P}_7(k,s)dk \quad (15)$$

$$\left(S + \frac{\partial}{\partial x} + \psi(x) + \alpha_1 + \alpha_3\right)\bar{P}_1(x,s) = 0 \quad (16)$$

$$\left(S + \frac{\partial}{\partial x} + \phi(x)\right)\bar{P}_2(x,s) = 0 \quad (17)$$

$$\left(S + \frac{\partial}{\partial x} + \psi(z) + 3\alpha_1\right)\bar{P}_3(z,s) = 0 \quad (18)$$

$$\left(S + \frac{\partial}{\partial x} + \phi(z)\right)P_4(z,t) = 0 \quad (19)$$

$$\left(\frac{\partial}{\partial t} + \frac{\partial}{\partial z} + \alpha_3 + 2\psi(z)\right)\bar{P}_5(z,s) = 0 \quad (6)$$

$$\left(S + \frac{\partial}{\partial y} + \phi(y)\right)\bar{P}_6(y,s) = 0 \quad (20)$$

$$\left(S + \frac{\partial}{\partial k} + \phi(k)\right)\bar{P}_7(k,s) = 0 \quad (21)$$

Boundary conditions

$\bar{P}_1(0,s) = 3\alpha_1 \bar{P}_0(s)$ (22)

$\bar{P}_2(0,s) = 3\alpha_1^2 \bar{P}_0(s)$ (23)

$\bar{P}_3(0,s) = \alpha_3 \bar{P}_0(s)$ (24)

$\bar{P}_4(0,s) = \alpha_3^2 \bar{P}_0(s)$ (25)

$\bar{P}_5(0,s) = 6\alpha_1\alpha_3 \bar{P}_0(s)$ (26)

$\bar{P}_6(0,s) = \alpha_2 \bar{P}_0(s)$ (27)

$\bar{P}_7(0,s) = \alpha_4 \bar{P}_0(s)$ (28)

Solving equation (15) to (21) with the help of boundary condition (22) to (28) and applying the below shifting properties of Laplace:

$$\int_0^\infty [e^{-sx} . e^{-\int_0^x f(x)dx}]dx = L\left\{\frac{1-\bar{S}_f(x)}{s}\right\} = \frac{1-\bar{S}_f(x)}{s} \quad (29)$$

$$\int_0^\infty [e^{-sx} . f(x)\, e^{-\int_0^x f(x)dx}]dx = L\{\bar{S}_f(x)\} = \bar{S}_f(s) \quad (30)$$

And the identity; $\bar{P}_1(s) \int_0^\infty \bar{P}_1(x,s)dx$

$$\bar{P}_1(x,s) = \bar{P}_1(0,s)e^{-(s+\alpha_1+\alpha_3)x - \int_0^x \psi(x)dx}$$

We have the following;

$$\bar{P}_1(s) = \bar{P}_1(0,s)\left\{\frac{1-\bar{S}_\psi(S+\alpha_1+\alpha_3)}{S+\alpha_1+\alpha_3}\right\} \quad (31)$$

$$\bar{P}_2(s) = \bar{P}_2(0,s)\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\} \quad (32)$$

$$\bar{P}_3(s) = \bar{P}_3(0,s)\left\{\frac{1-\bar{S}_\psi(S+3\alpha_1)}{S+3\alpha_1}\right\} \quad (34)$$

$$\bar{P}_4(s) = \bar{P}_4(0,s)\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\} \quad (35)$$

$$\bar{P}_5(s) = \bar{P}_5(0,s)\left\{\frac{1-\bar{S}_{2\psi}(S+\alpha_1)}{S+\alpha_1}\right\} \quad (36)$$

$$\bar{P}_6(s) = \bar{P}_6(0,s)\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\} \quad (37)$$

$$\bar{P}_7(s) = \bar{P}_7(0,s)\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\} \quad (38)$$

Substituting (22) to (28) into (31) to (38)

$$\bar{P}_1(s) = 3\alpha_1\left\{\frac{1-\bar{S}_\psi(S+\alpha_1+\alpha_3)}{S+\alpha_1+\alpha_3}\right\}\bar{P}_0(s) \quad (39)$$

$$\bar{P}_2(s) = 3\alpha_1^2\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\}\bar{P}_0(s) \quad (40)$$

$$\bar{P}_3(s) = \alpha_3\left\{\frac{1-\bar{S}_\psi(S+3\alpha_1)}{S+3\alpha_1}\right\}\bar{P}_0(s) \quad (41)$$

$$\bar{P}_4(s) = \alpha_3^2\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\}\bar{P}_0(s) \quad (42)$$

$$\bar{P}_5(s) = 6\alpha_1\alpha_3 \left\{\frac{1-\bar{S}_{2\psi}(s+\alpha_1)}{s+\alpha_1}\right\}\bar{P}_0(s) \quad (43)$$

$$\bar{P}_6(s) = \alpha_2\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\}\bar{P}_0(s) \quad (44)$$

$$\bar{P}_7(s) = \alpha_4\left\{\frac{1-\bar{S}_\phi(S)}{S}\right\}\bar{P}_0(s) \quad (45)$$

$$\bar{P}_0(S) = \frac{1}{D(S)} \quad (46)$$

Where D(S) = $[(S + 3\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4)$- $3\alpha_1 \bar{S}_\psi(S + \alpha_1 + \alpha_3) + \alpha_3 \bar{S}_\psi(S + 3\alpha_1) +$ $\alpha_2\bar{S}_\phi(S) +$ $\alpha_4\bar{S}_\phi(S)$] (47)

$$\bar{P}_{up}(S) = \bar{P}_0(S) + \bar{P}_1(S) + \bar{P}_3(S) + \bar{P}_5(S) \quad (48)$$

$$\bar{P}_{up}(S) = [1 + 3\alpha_1\left\{\frac{1-\bar{S}_\psi(S+\alpha_1+\alpha_3)}{S+\alpha_1+\alpha_3}\right\} + \alpha_3\left\{\frac{1-\bar{S}_\psi(S+3\alpha_1)}{S+3\alpha_1}\right\} + 6\alpha_1\alpha_3\left\{\frac{1-\bar{S}_{2\psi}(S+\alpha_1)}{S+\alpha_1}\right\}]\bar{P}_0(S) \quad (49)$$

2. Materials and Methods

2.1 Availability

Setting all repairs to 1. i.e. $\phi(x) = \psi_0(x) = \psi_0(y) = 1$ (50)

$$\bar{S}_\phi(S) = \frac{2.7183}{S+2.7183}, \quad \frac{1-\bar{S}_\phi(S)}{S} = \frac{1}{S+\phi}$$

Taking the values of different parameters as $\alpha_1 = 0.01, \alpha_1 = 0.02, \alpha_3 = 0.03, \alpha_4 = 0.04$ In (48) then taking the inverse Laplace transform, we can obtain, the expression for availability as:

$$D(s) = S + 0.12- \left[\frac{0.03}{S+1.04} + \frac{0.03}{S+1.03} + 0.06\,.\left(\frac{2.7183}{S+2.7183}\right)\right] \quad (51)$$

$$\bar{P}_{up}(S) = \left[1 + \frac{0.03}{S+1.04} + \frac{0.03}{S+1.03} + \frac{0.0018}{S+1.03}\right] \quad (52)$$

$$0.02224471975\,e^{-2.780408155\,t} - 0.003427624317\,e^{-1.091429766\,t} - 0.000003931735619\,e^{-1.034581515\,t} + 0.9820494611\,e^{-0.001880564112\,t} - 0.0008626247588\,e^{-2.030000000\,t}$$

2.2 Reliability Analysis

Taking all repair rate. $\phi(x) = \psi_0(x) = \psi_0(y) = 0$ In equation (48) and for same values of failure rate as $\alpha_1 = 0.01, \alpha_1 = 0.02, \alpha_3 = 0.03, \alpha_4 = 0.04$

And then taking inverse Laplace transform, one may have the expression for reliability for the system. Expression for reliability of the system is given as;

D(S) = S + 0.019

$$\bar{P}_{up}(S) = 1 + \frac{0.03}{S+0.04} + \frac{0.03}{S+0.03} + \frac{0.0018}{S+0.03} \quad (53)$$

For different values of time t = 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100.

Unit of time, we may get different of $\bar{P}_{up}(t)$ with the help of (51) as shown in Table 1 and corresponding Figure.

2.3 Mean Time to Failure (MTTF) Analysis

Taking all repair rate $\phi(x) = \mu_0(x) = \mu_0(y) = 0$ in equation (60) and taking limit, as x tend to zero we obtain the expression for MTTF as:

MTTF = $\lim_{x\to 0} \bar{P}_{up}(S)$.,

Setting the values of failure rate as $\delta_2 = 0.002,\ \delta_3 = 0.003\ and\ \delta_4 = 0.004$ and varying δ_1 one by one respectively as 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, and 0.09.

Subsequently, we vary δ_2, δ_3 and δ_4 respectively by fixing the values of others.

Table I. Variation of Availability with respect to time

Time (t) In Days	$\bar{P}_{up}(t)$	$\bar{P}_{down}(t)$
0	1.000000000	0.0000000000
10	0.9637538974	0.0362461026
20	0.9457993024	0.0542006976
30	0.9281791386	0.0718208614
40	0.9108872371	0.0891127629
50	0.8939174822	0.1060825178
60	0.8772638727	0.1227361273
70	0.8609205184	0.1390794816
80	0.8448816394	0.1551183606
90	0.8291415635	0.1708584365
100	0.8136947239	0.1863052761

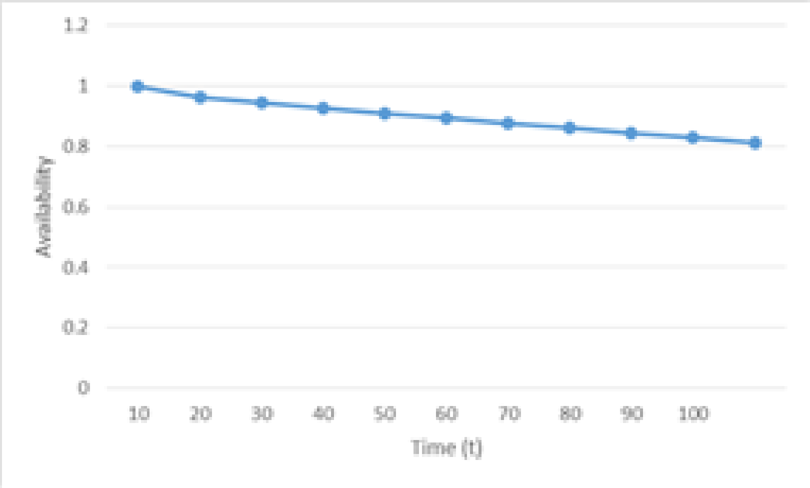

Figure III. Availability as function of time

Table II. Variation of Reliability with respect to time

Time(t)	Reliability R(t)
0	1.000000000
10	0.5949502161
20	0.3870568502
30	0.2640253872
40	0.1843688971
50	0.1302634487
60	0.09262766212
70	0.06613280045
80	0.04735790296
90	0.03399788562
100	0.02446146458

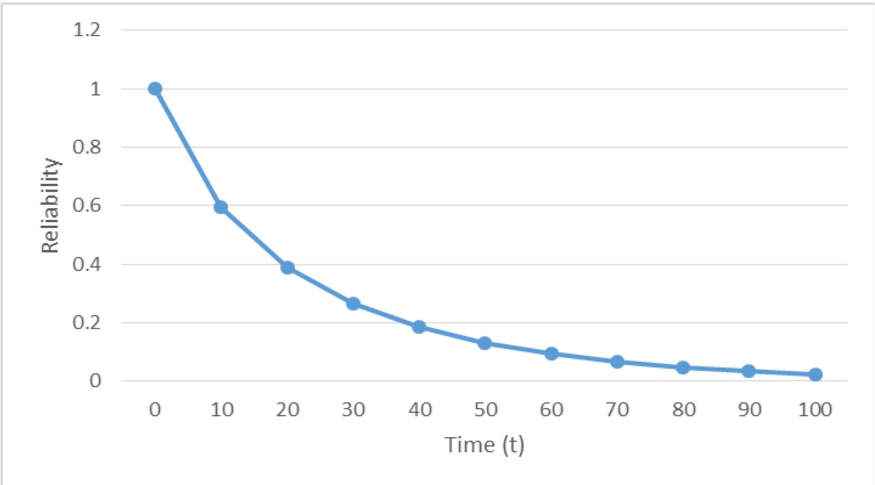

Figure IV: Reliability as a function of time (t)

Table III: Mean Time to Failure (MTTF) Analysis

Failure Rate	MTTF δ_1	MTTF δ_2	MTTF δ_3	MTTF δ_4
0.01	22.16666667	25.54545455	23.93333333	29.55555555
0.02	18.80000000	22.16666667	22.51515152	26.60000000
0.03	18.40740741	19.69230769	22.16666667	24.18181818
0.04	18.52380952	17.77551021	22.25641025	22.16666667
0.05	18.75000000	16.23333333	22.53741496	20.46153846

0.06	18.98765432	14.95833333	22.90000000	19.00000000
0.07	19.20952381	13.88235294	23.29166666	17.73333333
0.08	19.40909091	12.95959596	23.68627451	16.62500000
0.09	19.58641975	12.15789474	24.07070707	15.64705882

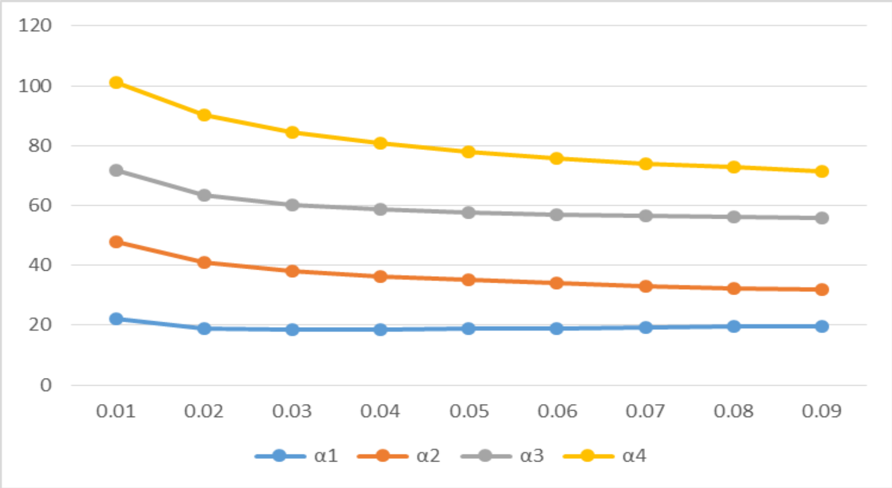

Figure V: MTTF as function of repair rate

Table IV: **SENSITIVITY ANALYSIS CORRESPONDING TO MTTF**

Repair Rate $\phi(x)$	$\frac{\partial(MTTF)}{\beta_1}$	$\frac{\partial(MTTF)}{\beta_2}$	$\frac{\partial(MTTF)}{\beta_3}$	$\frac{\partial(MTTF)}{\beta_4}$
0.01	-837.4999999	-402.6859505	-239.3333333	-328.3950617
0.02	-102.6666666	-284.7222222	-72.1074381	-266.0000000
0.03	-1.8518519	-215.5818540	-6.9444444	-219.8347107
0.04	19.8979592	-170.6997085	21.1045365	-184.7222222
0.05	23.9583333	-139.4722222	33.3819241	-157.3964497
0.06	23.1824417	-116.6377315	38.3055555	-135.7142857
0.07	21.1020408	-99.30795847	39.6122686	-118.2222222
0.08	18.8188705	-85.77186002	39.1003460	-103.9062500
0.09	16.6838135	-74.95383195	37.6849301	-92.04152248

Table below and corresponding graphs shown in the Figure.

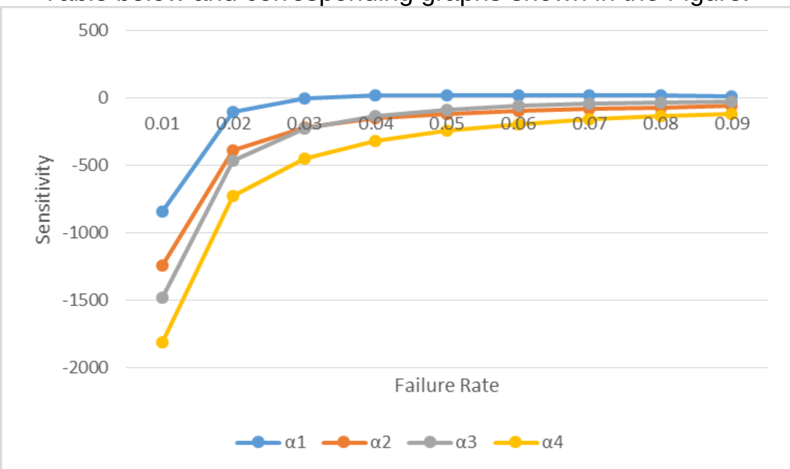

Figure VI: Sensitivity analysis corresponding to mean time to failure (MTTF)

2.4 Sensitivity Analysis Corresponding to MTTF

The sensitivity in MTTF of the system can be studied through the partial differentiation of MTTF with respect to the failure rate of the system. By applying the set of parameters as $\alpha_1 = 0.001$, $\alpha_2 = 0.002$ $\alpha_3 = 0.003$, $\alpha_4 = 0.004$, in the partial differentiation of MTTF, one can calculate the MTTF sensitivity as shown in the

3. Analysis of Results

Detailed study of Table I reveals that Subsystem A i.e. modules panels has maximum effect on the availability of the complete system. In addition, the failure rate also has maximum effect on availability of complete system. Other subsystems are almost equally effective. Thus, we can make an inference that we should take the most care of these subsystems in order to improve the overall availability of the system. Hence, it is recommended that management should pay more attention to these subsystems so that the overall performance of the system may improve.

The result shown in Table II presents the reliability of system computed by varying the time rate of mixture (t) from the initial 0 to100 and fixing other parameters as α1 = 0.01, α2 = 0.01, α3 = 0.03, α4=0.04. It indicates that with increase in time of the system (t) from 0 to 100, the Reliability of the system decreases approximately 13.01% whereas the availability decreases approximately 5.3–3.2% with increase in the time from 0 day to 100 days.

i. The results shown in the Table III present the MTTF of system computed by varying the Repair Rate $\phi(x)$ of PV system from 0.01 to 0.09 and fixing other parameters as α1 = 0.01, α2 = 0.02, α3 = 0.03, α4 = 0.04. It seems that increase in repair rate of the system from 0.01 to 0.09 increases the availability of the system by approximately 7.0–10.2%whereas the availability decreases approximately 3.3–0.01% with increase in the time from 20 days to 70 days.

4. Conclusion

Thus, we can make an inference that we should take the most care of these subsystems in order to improve the overall availability of the system. Hence, it is recommended that management should pay more attention to these subsystems so that the overall performance of the system may improve.

With the non-availability of data of the PV system, the present paper introduced a reliability modelling approach in order to study the overall strength, efficiency and performance of the PV system. The strength considered in this paper can be seen in terms of reliability, availability, MTTF and profit function. In this paper, we have introduced a new model of photovoltaic system consisting four subsystems namely, panel, inverter, and battery bank and control charger.

The finding of the paper, reliability modeling can be used to test the strength, efficiency and performance improvement of the PV system. Where strength, efficiency and performance improvement of the PV system are determined, the users will be able to serve the cost of kerosene, petrol, diesel etc. which expose to air and land pollution hazardous to human hearths for their domestic and commercial purposes.

Acknowledgements

The management of Sokoto State University is acknowledgement for funding our research work, and other necessary supports.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

References

[1] Yusuf, I., Ismail, A.L., Singh, V.V. (2020). Performance Analysis of Multi-computer System Consisting of Three Subsystems in Series Configuration Using Copula Repair Policy. SN COMPUT. SCI. 1, 241. https://doi.org/10.1007/s42979-020-00258-0

[2]. Singh, V and Lado, A, (2019). Cost assessment of complex repairable system consisting two subsystems in series configuration using Gumbel Hougaard family copula. International Journal of Quality & Reliability Management. Vol. 36 No. 10, pp. 1683-1698. https://doi.org/10.1108/IJQRM-12-2018-0322

[3]. Idoko, L, Anaya-Lara, O and McDonald, A. (2018). Enhancing PV modules efficiency and power output using multi-concept cooling technique, Energy Reports 4 (2018) 357–369. https://doi.org/10.1016/j.egyr.2018.05.004

[4]. Charfi, W., Chaabane, M., Mhiri, H and Bournot, P. (2018). Performance evaluation of a solar photovoltaic system, Energy Reports 4 (2018) 400–406. https://doi.org/10.1016/j.egyr.2018.06.004

[5]. Gouda, E. A., Kotb, M. K and Elalfy, D.A. (2019). Modelling and Performance Analysis for a PV System Based MPPT Using Advanced Techniques, European Journal of Electrical and Computer Engineering, Vol. 3, No. 1, htttps://doi.org/10.24018/ejece.2019.3.1.47

[6]. Jayanth K.G and Venkatesh B. (2017). Performance analysis of solar module with climatic data, International Journal of Advanced Research in Electrical, Electronics and Instrumentation

Engineering, 6(5), 3468-3476. DOI:10.15662/IJAREEIE.2017.0605049

[7]. Ramya, S., Duvvuru, R.R and Ramachander, N. (2020). Long term field performance analysis of 100KWp grid-connected rooftop solar PV power plant, Journal of critical review, 7(15), 2499-2511. DOI: http://dx.doi.org/10.31838/jcr.07.14.204

[8]. Ates, A.M, and Singh, H. (2020). Rooftop solar Photovoltaic (PV) plant – performance analysis and critical evaluation, Journal of King Saud University – Science, https://doi.org/10.1016/j.jksus.2021.101361

[9]. Cavalcante, M.M, Silva, J.L, D., Villalva, M.G and Lins, M.P.F. (2019). Performance analysis of a Solar Photovoltaic Power Plant," 2019 IEEE PES Innovative Smart Grid Technologies Conference - Latin America (ISGT Latin America), 2019, pp. 1-5, doi: 10.1109/ISGT-LA.2019.8894937.

[10]. Chiacchio, F.; Famoso, F.; D'Urso, D.; Brusca, S.; Aizpurua, J.I and Cedola, L.(2018). Dynamic performance evaluation of photovoltaic power plant by stochastic hybrid fault tree automaton model. Energies, 11, 306

[11]. De Lima, L. C., Ferreira, D, A. L., and De Lima Morais, F. H. B. (2017). Performance analysis of a grid connected photovoltaic system in northeastern Brazil. Energy for Sustainable Development, 37, 79–85. doi:10.1016/j.esd.2017.01.004

[12]. Dondariya, C., Porwal, D., Awasthi, A., Shukla, A.K., Sudhakar, K., Murali, M.M and Bhimte, A. (2018). Performance simulation of grid-connected rooftop solar PV system for small households: A case study of Ujjain, India. Energy Reports 4, 546–553. https://doi.org/10.1016/j.egyr.2018.08.002

[13]. El-Kharaza, H and Khallakib, K,Kadiric, M.S and Choukairy, K. (2021). Performance's improvement methods of PV solar panel by different cooling systems: A review of experimental and numerical studies, AIP Conference Proceedings 2345, 020039 (2021); https://doi.org/10.1063/5.0049573

[14]. Fetyan, K.M and Hady, R. (2021) Performance evaluation of on-grid PV systems in Egypt, Water Science, 35:1, 63-70, DOI: 10.1080/23570008.2021.1905347

[15]. Haji, M., Park, E and Kivevele, T. (2019). Performance Analysis of Installed Solar PV System Using Homer in Tanzania: A Case Study of Zanzibar and Arusha, American Journal of Electrical Power and Energy Systems, 8(1): 11-22 doi: 10.11648/j.epes.20190801.12

[16]. Kasim, N.K., Atwan, A.F, and Eliewi, F.M. (2018).Improve the performance of solar modules by reflectors, IOP Conf. Series: Journal of Physics: Conf. Series 1032 012031 doi :10.1088/1742-6596/1032/1/012031

[17]. Mustafa, R.J., Gomaa, M.R. Al-Dhaifallah, M and Rezk, H.(2019). Environmental Impacts on the Performance of Solar Photovoltaic Systems, Sustainability 2020, 12, 608; doi:10.3390/su12020608

[18]. Prasad, A.R., Shankar, R and Patil, C.K. (2021). Performance enhancement of solar photovoltaic system for roof top garden. *Environ Sci Pollut Res* (2021). https://doi.org/10.1007/s11356-021-14191-z

[19]. Rehmana, S and Sahin, A.Z. (2015). Performance Comparison of Diesel and Solar Photovoltaic Power Systems for Water Pumping in Saudi Arabiaâ€, International Journal of Green Energy, vol. 12, issue 7, pp. 702-713.

[20]. Savalia, R.J.,Yadav, S., Davda, A and Kanojia, S. (2016). Performance Evaluation of 190 kWp Rooftop Solar Photovoltaic Plant in CMPDI, Ranchi, International Journal of Advance Research in Engineering, Science &Technology, 1-8.

[21]. Yadav, S.K and Bajpai, U.(2018). Performance evaluation of a rooftop solar photovoltaic power plant in Northern India. Energy Sustain. Dev. 43, 130–138. https://doi.org/10.1016/j.esd.2018.01.006

[22]. Zulkafli, R.S, Abdulmajid, M.S., Roja, M.A and Zaman, I.(2018). Performance Factors of the Photovoltaic System: A Review. MATEC Web of Conferences 225, 03020 https://doi.org/10.1051/matecconf/201822503020 UTP-UMP-VIT SE

[23]. Mandelli, S.; Barbieri, J.; Mereu, R.; Colombo, E.(2016) Off-grid systems for rural electrification in developing countries: Definitions, classification and a comprehensive literature review. Renew. Sustain. Energy Rev. 58, 1621–1646. [CrossRef]

[24]. Luthander, R.; Widén, J.; Nilsson, D.; Palm, J. (2015,) Photovoltaic self-consumption in buildings: A review. Appl. Energy 142, 80–94. [CrossRef]

[25]. Evans, A.; Strezov, V.; Evans, T.J.(2012) Assessment of utility energy storage options for increased renewable energy penetration. Renew. Sustain. Energy Rev, 16, 4141–4147. [CrossRef].

