Scientific Research Publishing

Energy and Power Engineering, 2022, 14, 477-490
https://www.scirp.org/journal/epe
ISSN Online: 1947-3818
ISSN Print: 1949-243X

Optimization of PV/Diesel Production through Data Monitoring

Bognini Y. Lucien[1]*, Jean B. Byiringiro[2], Bernard Zouma[3], Bognini W. Abraham[4]

[1]Génie énergétique et énergie renouvelable, Distance Production House University, Ouagadougou, Burkina Faso
[2]DeKUT SIEMENS Mechatronics Certification Center, Dedan Kimathi University of Technology, Nyeri, Kenya
[3]University of Ouagadougou, Ouagadougou, Burkina Faso
[4]Génie industriel et efficacité énergétique, Distance Production House University, Ouagadougou, Burkina Faso
Email: *bogninilucien@yahoo.com, jbbyiringiro@gmail.com, Bernard_zouma@univ-ouaga.bf, bogniniw@yahoo.fr

How to cite this paper: Lucien, B.Y., Byiringiro, J.B., Zouma, B. and Abraham, B.W. (2022) Optimization of PV/Diesel Production through Data Monitoring. *Energy and Power Engineering*, **14**, 477-490.
https://doi.org/10.4236/epe.2022.149025

Received: July 23, 2022
Accepted: September 26, 2022
Published: September 29, 2022

Abstract

The study PV/diesel system is a stand-alone microgrid powered by the PV/diesel combination without production storage. The study focused on optimising PV/diesel production by monitoring data. It also referred to a comparison of sensitive factors in PV/diesel production. This study implemented structural and non-structural factors of the said system. A literature search was conducted to determine the factors involved. So, factors such as system autonomy, energy quality, system stability and data monitoring were considered for the study. Thus, after a detailed presentation of the data monitoring, a comparison based on the method, Analysis of Failure Modes, their Effects and Criticalities (FMEA) was carried out. At the end of the comparison, a hierarchy of parameters in the exploitation of the energy production of autonomous microgrids was made. From its results, it emerges a good consideration of the factor "data monitoring" in the management of the system studied. The results obtained confirm the importance of data monitoring for a better optimization of energy production. A monitoring program or procedure has been developed according to the originality that the present study has identified. The study also made it possible to evaluate the performance of data monitoring for the energy production of photovoltaic systems in general and hybrid PV/diesel systems in particular.

Keywords

Microgrid, Data Monitoring, Criticality

1. Introduction

Since the advent of solar technology, Burkina Faso has registered installations in the field every year, which are the work of public structures or those of private individuals. The solar sector is experiencing technological innovations in view of the progress of research. Thus, nowadays, it is possible, through devices, to follow in real time, the operation of a photovoltaic solar installation. Previous research on data monitoring has revealed various theoretical or practicable methods. In fact, on the one hand, we differentiate the application of monitoring by the use of control boxes and on the other hand, its application through management. With the main aim of optimising energy via monitoring, this study focuses on an originality which I summarize below:

- An energy production is controlled by the box according to the prior request of the load to be supplied. Thus, when the box records the need for the load, it first controls the equivalent of this value in the PV, and as soon as there is a deficit with the PV, the diesel groups (whose total power is equivalent to the power of the dimensioned load), start gradually to compensate for the power solicited by the load whose PV is lacking at the desired time.
- The use of a data recording box of the main components (the load to be satisfied; the PV; the diesel groups).
- The main originality of the monitoring system we have developed is to control the system device and trigger each device according to demand. This originality, identified by the study, is developed to be applied more specifically in hybrid photovoltaic/diesel systems. On the other hand, it can be adapted according to various specific standards for any energy production system.

2. Optimization through Data Monitoring for the Photovoltaic/Diesel System

2.1. Characteristics of Data Monitoring

The ideal of monitoring is to provide a service to users to supervise and diagnose their installations against the main defects (heating of cells, different performance modules, degradation of interconnections) [1], and above all, to have optimal management between production and demand [2].

2.2. Aspect of a Suitable Configuration for Monitoring a Hybrid Photovoltaic/Diesel Microgrid

An adequate arrangement of all the elements of the hybrid PV/diesel microgrid device requires the implementation of an appropriate configuration. I give below, the illustrative **Figure 1** of a configuration [3] of hybrid PV/diesel microgrid subject to data monitoring.

Figure 1 gives a general arrangement of the various elements of the system studied.

2.3. Data Monitoring and Optimization of the Exploitation of Electrical Energy from an Autonomous Photovoltaic/Diesel Micro-Grid

Optimization is a process of improving the performance of the device in question,

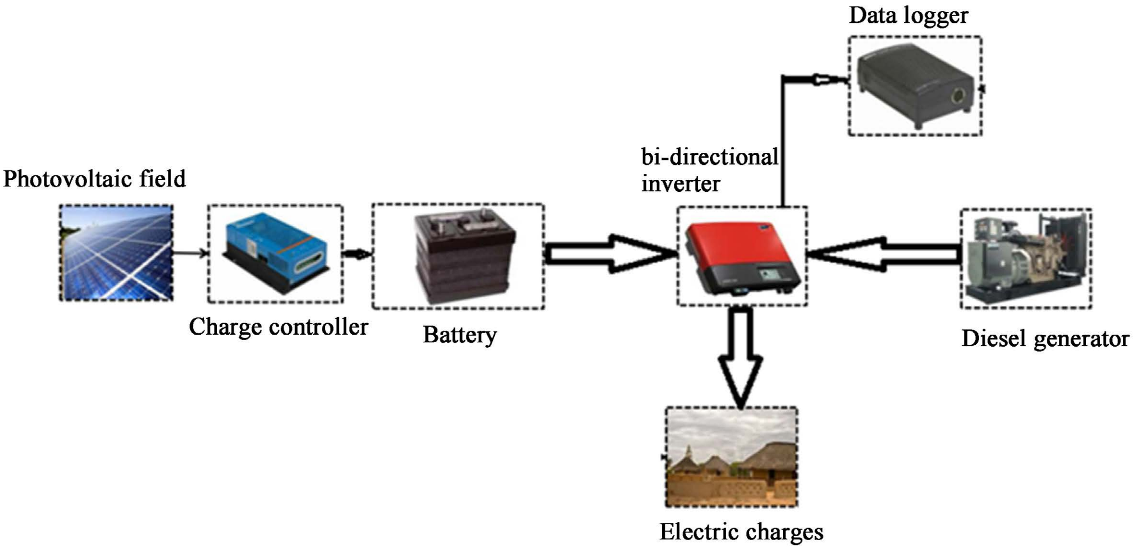

Figure 1. Diagram of a hybrid PV/diesel configuration subject to data monitoring.

it responds to a certain logic. This is how there are several criteria [4], which characterize optimization processes. Among these cases, I cite two major forms of optimization:

- Optimization based on an improvement in the efficiency of the internal structure of the system (manufacturing process of the components of the system).
- Optimization based on an improvement in the efficiency of the management or arrangement of the different elements of the system (operating process of the production of the system).

In the present study, it is the second form of optimization that is taken into account. In this practice of monitoring on PV/diesel, the control of a certain number of parameters is necessary for good monitoring. Table 1 below, gives an overview of its parameters.

The process must allow a good overall follow-up for a match between the power from the sunshine and the power calls on the hybrid generator (PV and generator). We give below, an illustration of the synoptic likely to guide a good practice of monitoring on the PV system.

Figure 2 illustrates the desired monitoring practice for an application on the hybrid PV/diesel system. Two phases of data collection or control of the system are envisaged. First, the installation of a data logger, which collects data from sunlight, the PV field and the battery. Then, the inverter, will be the second level of data collection. This inverter will have the ability to collect data from charges, battery and generator set. The inverter will be equipped with artificial intelligence [5], and will coordinate the power demand of the charges and the power inflows (of the PV and the generator). It must be able to control the start-up of the generator set in the event of a drop or lack of power of the PV and stop it in case of overproduction of the PV or a decrease in the power required by the loads.

Table 1. Electrical parameters followed by monitoring

Parameters	Acquisition method
Global illumination (W/m²)	Reading on the monitoring tables
The overall power received from the sun (W)	
Photovoltaic field voltage, VPV(V) DC side	
Photovoltaic field voltage, VPV(V) AC side	
Photovoltaic field intensity, IPV (A) DC side	
Photovoltaic field intensity, IPV (A) AC side	
Power of the photovoltaic field, PAC (W) DC side	
Power of the photovoltaic field, PAC (W) AC side	
Generator current on the photovoltaic injection phase (A)	
Network frequency (Hz)	
Diesel generator engine speed (r.p.m)	
Diesel generator exhaust temperature (°C)	
Power generated by the diesel generator (W)	
Power required by electrical loads (W)	
Diesel Generator Fuel Consumption	
Time	

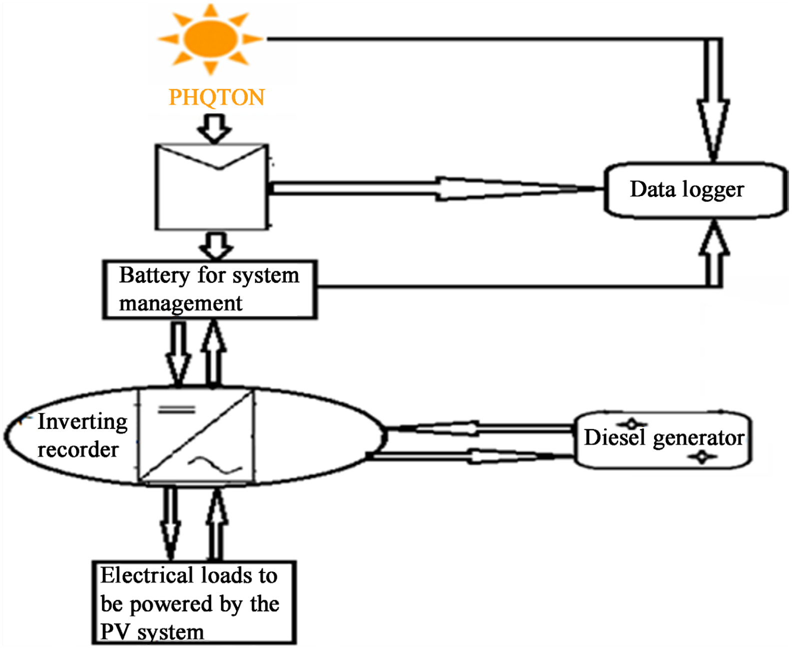

Figure 2. Synoptic of the PV/diesel system for monitoring.

3. Comparison between Data Monitoring and Important Factors of Electrical Energy Production of the PV/Diesel System with Management Energy Storage

This section highlights important factors or criteria points of the PV/diesel system. Their choice, no doubt rational, is the result of a careful bibliographic research on the factors that can influence the energy from the PV/diesel system. To structural factors of the system, I added another non-structural factor [6], such as data monitoring, to make the comparative study between its important factors. The study compares the following criteria or factors:

- The autonomy of the hybrid PV/diesel system;
- The quality of the energy produced by the hybrid PV/diesel system;
- The stability of the hybrid PV/diesel system;
- The contribution of data monitoring of the hybrid PV/diesel system.

3.1. Concept on Comparators

I briefly describe the key criteria determining the factors of the study.

The autonomy of the PV/diesel system: in the case of renewable energies, the installation of storage to compensate for off-peak periods (nights, climatic hazards, etc.) is subject to significant costs that depend on the storage technology. The costs of storing in a PV system with batteries as storage technology can represent 40% of the total investment [7]. It should be noted that the addition of storage can aim at a goal of stability or security for the installation, we speak of management storage. For example, the injection of PV energy into power lines can cause a disturbance. Indeed, the power lines being sized for a unidirectional flow direction, then, a large flow of energy in the opposite direction (the injections of a photovoltaic power plant) causes overvoltages and generates significant degradation of the network, it is the phase shift effect between production and consumption [8].

The quality of the energy exported by the PV/diesel system: The main role of a power interface is to preserve the quality of the energy exported to consumers, regardless of the nature of the loads to be supplied (linear or not, balanced or not). Although there are no international standards specific to stand-alone configurations, the quality of the energy to be guaranteed must be (at least) similar to that imposed in the case of interconnected networks. The quality of the energy exported amounts to ensuring a quasi-sinusoidal voltage (with fixed amplitude and frequency) with a minimal harmonic content at the point of connection of the consumers. The quality of this energy is quantified by the low harmonic distortion rate (THD) which summarizes the disturbances of this voltage [8].

The stability of the energy produced by the PV/diesel system: The stability of a power system is the ability of an electrical energy system, for a given initial operating condition, to return to a balanced operating state after experiencing a physical disturbance. All this, keeping most of the variables of the system in their bounds, so that the integrity of the system is preserved. System integrity is preserved when the entire electrical system remains virtually intact, without the need to trigger generators or loads [9].

The contribution of the monitoring of the data of the PV/diesel system: It is a set of devices upstream of the PV systems which is intended for the monitoring and surveillance of the energy production from the PV system. The idea is to provide a "service" to users to monitor and diagnose their installations against the main defects [10], as well as the phase shifts between demand and supply, which are the sources of energy losses.

3.2. Quantitative Analysis of Comparison Factors Used in the PV/Diesel System

This is the characterization phase of the comparison factors. It aims to prioritize the comparison factors in order of criticality index [11]. The criticality of an event corresponds to the product of gravity, occurrence and non-detection. Criticality can be expressed by the following equation:

$$C = G \times O \times ND \tag{1}$$

C: Criticality;

G: Severity;

O: Occurrence;

ND: Not detected.

The prioritization is given in order of increasing criticality, this means that the highest value corresponds to the strongest criticality. **Table 2** below reads the scoring tools that will be used to determine the criticality index values.

3.3. Analysis of Failure Modes of Their Effects and Criticality (FMEA)

In the rest of the work, the FMEA method (Analysis of failure modes of their Effects and Criticality) is used for the comparison. It is based on personal experience on the one hand, and on the other hand, on expert assessments as well as a bibliographic contribution. **Table 3** below summarizes the assessments.

The completion of **Table 3** shows the failure modes, causes and effects of the comparators. Regarding failure modes, it is noted that each of the factors is subdivided into two failure modes. The second factor, which is the quality of the energy produced by the system, also provides information on two failure modes. This factor suggests a failure on the high costs of storage means, as well as a failure in the choice of energy treatment filters.

For the autonomy factor, we note a failure on the costs for a production storage

Table 2. Rating of assessment tools.

Note	Severity Scale	Scale of Occurrence	Non-detection scale
1	No influence for failure	Failure very unlikely	Accurate detection during inspection
2	Decline in yield	Failure unlikely	High probability of detection during control
3	Slight system corruption	Possible failure	Moderate probability of detection during control
4	System Shutdown	Inevitable failure	Low probability of detection during control
5	System jeopardy	Very Probable Failure	Impossibility of detection during control

Table 3. FMEA assessment of comparison factors.

Criteria	Explication	Failure mode	Causes	Effets	G	O	ND	C	Total C
Autonomy	The energy holding capacity for continuity of operation	Expensive energy storage	Specificity of storage means	Storage makes the system financially undesirable in the short to medium term	2	2	2	8	17
		Management energy storage	Specificity of energy micro-grid sources	The storage has only a technical purpose and not an operating reserve	3	3	1	9	
Power quality	Quasi-sinusoidal power delivery to loads	Charges for power adaptation means	Power interfaces are not very affordable for everyone	The quality of the energy depends on the finances of the producer	4	3	2	24	36
		Choice of interconnect filters	Energy for sale or for national grids is dictated by standards	The quality of the interconnection energy is independent of the producer	4	3	1	12	
Power system stability	The ability of the system to preserve its integrity in the face of nuisance tripping	The Nature of Microgrid Power Sources	Not all sources produce directly consumable energy	The adaptation system (DC and AC side) is not exempt from tripping	2	3	1	6	15
		The nature of the loads to be supplied	Not all loads consume the same form of energy	Loads require matching nesting, trigger sources	3	3	1	9	
Production monitoring	The production monitoring and control system	Expensive means of work	The monitoring equipment is not accessible to all producers	The option without monitoring generates losses	2	3	3	18	27
		The quality of staff	Monitoring requires qualified personnel	Improper maintenance reduces the life of the system	3	3	1	9	

(reserve for bad periods) of the energy and that on the management storage or transition storage. For the stability factor of the PV/diesel network, the failures are at the level of the nature of the sources of energy production, on the one hand, and on the other hand, the sources of the loads to be supplied. Finally, for the last factor of the study, which is data monitoring, failures are localized on the expensive means of this factor, as well as on the quality of the personnel in charge of its application.

3.4. Evaluation and Prioritization of the Factors of the PV/Diesel System Subject to Comparison

This part gives a weighting based on the failure modes of each of the study factors submitted for comparison. The result of the weighting is given in the following Table 4. Figure 3 below, gives a histogram overview of the results in Table 4.

Table 4 summarizes the criticality weighting of failure modes. It gives the result of summing the failure modes included in each factor. Then it also gives the rank of factors according to the highest criticality. Following the results from the table, an interpretation of the ranking is made below.

<u>1st place:</u> the first place is occupied by the factor, quality of the energy of the system. This proves that this factor is the most critical or the most important to take into account in the PV/diesel system, according to the comparison study conducted on said factors.

<u>2nd place:</u> the second place is taken by the monitoring of the data, this factor which is non-structural for the system thus reveals its importance for a better management of the energy of the system.

<u>3rd place:</u> autonomy occupies the third place of the factors in comparison [12]. It is a structural factor placed in this position, it is not to be neglected in the system, but is less sensitive compared to the other two that precedes it in the ranking.

<u>4th place:</u> the stability of the PV/diesel system occupies the last place in the ranking. It is a structural factor placed in last place, it is not also to be neglected in the system, but is only less sensitive compared to the other factors taken into account in the study.

Table 4. Prioritization of factors by their criticality.

Factor	Criticality according to failure modes by factor	Criticality weighting	Rank
System autonomy	8 9	17	**3 em**
System Power Quality	24 12	36	**1er**
System stability	6 9	15	**4 em**
System data monitoring	18 9	27	**2 em**

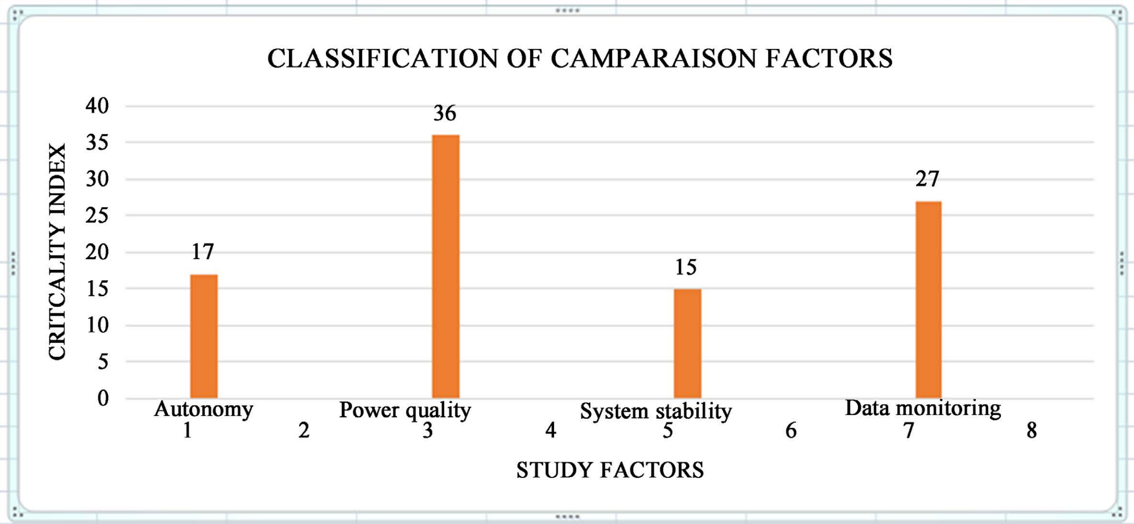

Figure 3. Ranking of factors taken into account in the comparison study.

4. Optimization through Data Monitoring

4.1. Description of the Monitoring of the Data Studied

This study is based on data monitoring applied to a hybrid PV/diesel system. In simple terms, if there is a need to power a predefined load, we first use photovoltaic production sized to the size of the load requirement. Then, in the event of non-productive periods of photovoltaic plates, it is at this moment that a series of diesel generators are operated, the total power of which covers the value of the need. The groups thus take over to feed the load requested. The main role of monitoring is; the control of the device of the system and trigger each device according to the request. It can be deduced that monitoring plays the essential role of coordination or management or dispatching of energy in the given system. The specific objectives (or working procedure) sought by data monitoring are, among others,

- Record in real time the values involved (the power of the load need, the power of the PV, and the power from the generators),
  - ➢ This function allows a synchronized 24-hour monitoring of the installation in order to detect malfunctions.
- Collect the power of the load requirement before the respective inputs, the power available at the PV terminals and that to be requested from the diesel unit,
  - ➢ This function assigned to our monitoring model avoids overproduction, it is an option to optimize production while having in memory the requested value in order to solicit the use of production sources according to this value.
- Check with the power of the photovoltaic if the need can be fully covered or not,
  - ➢ This function allows the photovoltaic source to be used as the primary source of energy in the system.
- Activate the successive start-up of generator sets to the competition of the value in lack with photovoltaic production,
  - ➢ This function also makes it possible to optimize production. Indeed, it uses only generator sets of small capacities that will have this opportunity to operate at their optimal loads.

The working procedure (still referred to as specific objectives) of the monitoring is translated in **Figure 4** below.

The flowchart describes the successive steps for executing the monitoring command. This control is integrated into the inverter which is the menu of a system for remote recording and control of the start/turn off function of generator sets [13]. The inverter solicits the value of the need first, then it recovers the value of the photovoltaic and submits to it a condition (photovoltaic value equivalent or not to the value of the need) if the condition is a “yes”, then, the generator is kept at rest. In case the condition is a “no”, the generators start automatically one after the other, to cover the shortfall found in the production of photovoltaics. At the end, we report the total production of the system which is

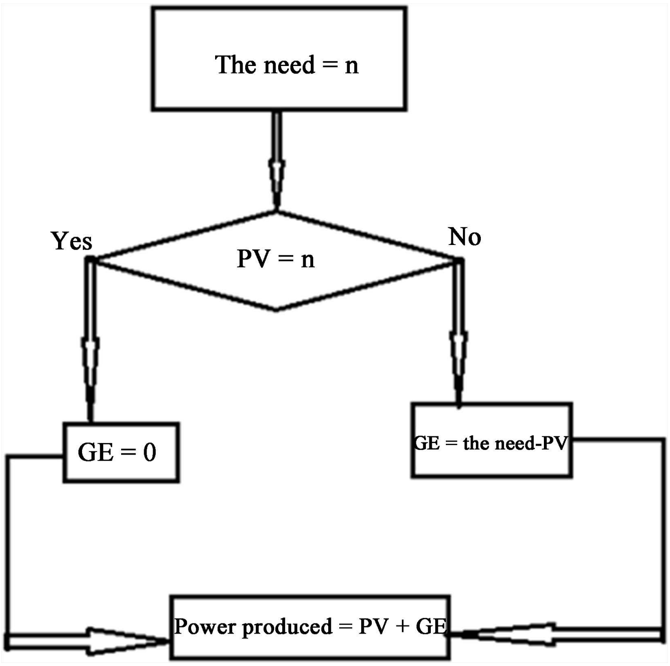

Figure 4. Data monitoring control flowchart.

reduced to the sum of the powers (photovoltaic and generators in series) debited.

The automatic system for starting the sources is thus recommended in our installation model. It is carried by the inverter which integrates the artificial intelligence function related to algorithmic programming clearly describing the instructions of the proposed model.

4.2. Presentation of Results

In order to verify the evolution of a number of parameters, I developed an algorithmic program that translates the idea described in the flowchart of **Figure 4**. An example of a system in which, the value of the load requirement does not vary and coupled with a decrease in PV production is taken for simulation.

The algorithmic program was developed [14] under the Matlab language according to the structure of the flowchart.

There is a constant value set at 100 W as the power of the load requirement at the level of **Figure 5**. So, we are in the presence of a need that does not vary regardless of the weather.

The power delivered by the photovoltaic plates and shown in **Figure 6** shows a decrease in PV production over time. This could say that the PV encounters an unfavorable situation (nightfall, fog...) on the sunshine of the installation site.

At the level of **Figure 7**, we deduce a growth in the power provided by the generators according to time.

I see in **Figure 8**, opposite variations of the two curves. The power produced by the photovoltaic plates decreases successively while that provided by the relay generators grows at the same rate as the decrease in the power produced by the PV. **Table 5** below, represents an example of data for the test simulation.

Table 5. Test values for constant need and decreasing PV.

P. of need	100	100	100	100	100	100	100	100	100	100	100
P. of PV	100	90	80	70	60	50	40	30	20	10	0
P. of groups	0	10	20	30	40	50	60	70	80	90	100

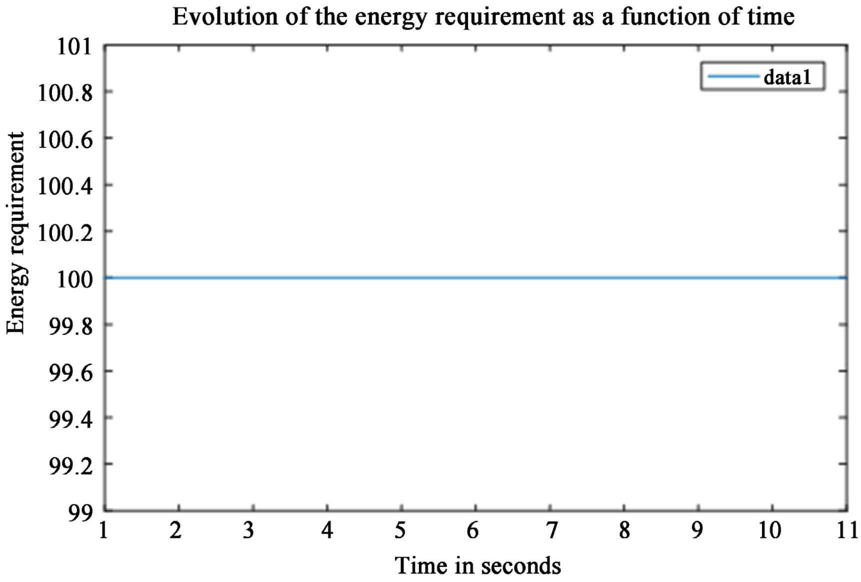

Figure 5. Evolution of the value of the need according to time.

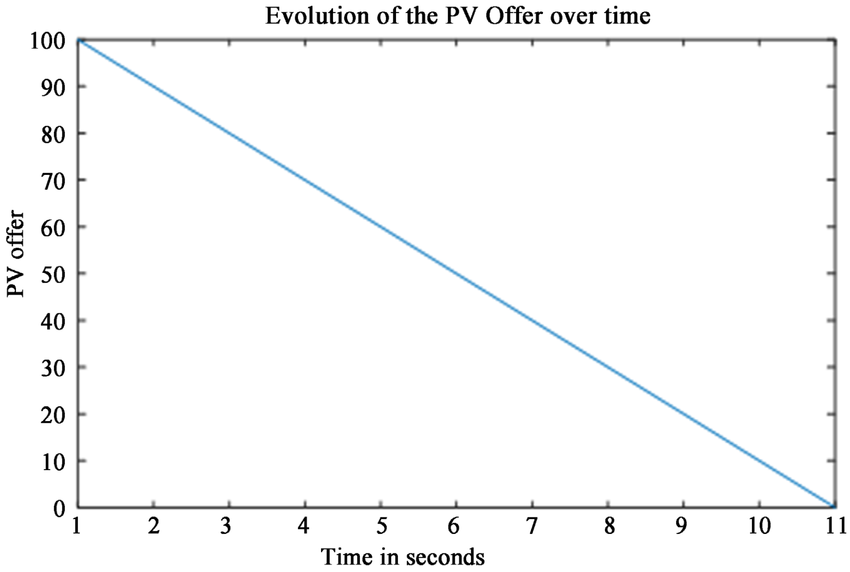

Figure 6. Evolution of the value of photovoltaic power according to time.

5. Conclusions

The study on the optimization of PV/diesel production through data monitoring also made it possible to compare some of the key factors of the PV/diesel system. Autonomous microgrids with a combination of PV/diesel for energy production are systems that must also meet the quality criteria recommended for national

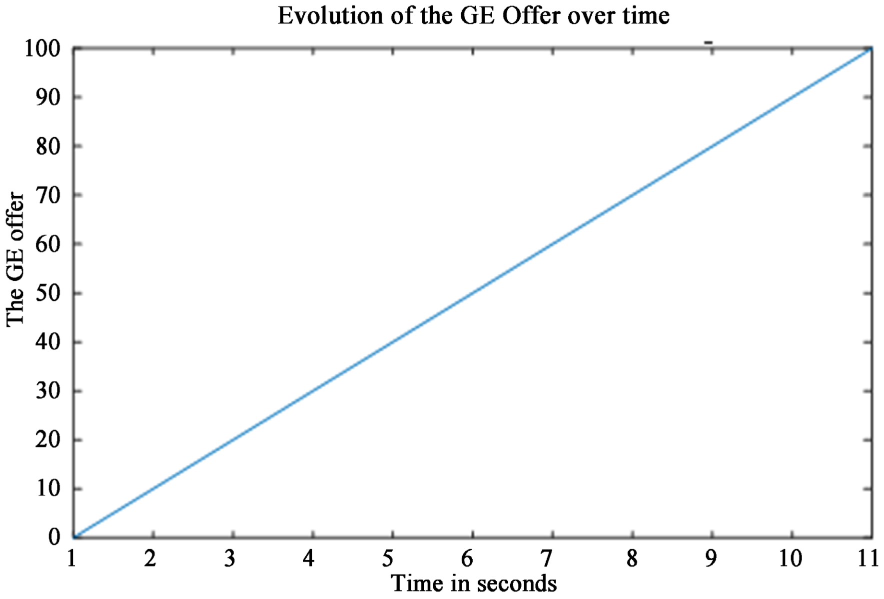

Figure 7. Evolution of the value of the power produced by the relay generator sets according to time.

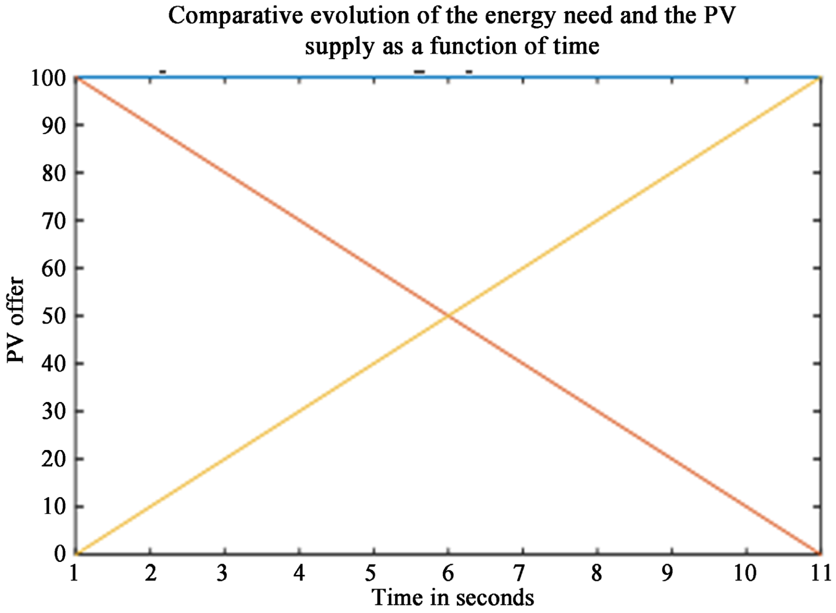

Figure 8. Evolution of the values of the powers of the generator set and photovoltaic plates according to the time.

energy networks. It is in this sense that this study was conducted, taking into account the sensitive factors for the proper start-up of autonomous PV/diesel microgrids. A brief description of the data monitoring was carried out, then it was taken into account as a factor for a comparison with others, considered sensitive in the production of PV/diesel. Following a literature search for the choice of factors, which are a synthesis of such sensitive defects, a comparison was made in the study. Energy quality factors and system stability are identified as structural factors of the system. The factor, autonomy of the system, is also considered as a structural element, however, it could be taken as a non-structural element in the same way as the data monitoring factor. From its factors, it emerged to us that that of data monitoring, is a very crucial element for a good management of the product from the autonomous micro-grid PV/diesel. In addition, the latter, which is optional, is not accessible to any producer of PV/diesel energy systems because of the expensive costs he incurs.

A test of development of optimization methodology made it possible to lay the foundations for a possible implementation of a software solution related to this optimization method.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Rezgui, W. (2015) Système intégré pour la supervision et le diagnostic des défauts dans les systèmes de production d'énergies: les installations photovoltaïque. Doctoral thesis, Université de Batna 2, Batna.

[2] Wikipédia (2019) onduleur hybride. le 15-06-21 /La dernière modification de cette page a été faite le 14 juillet 2019 à 01: 25.

[3] Nguewo Yamegueu, D. (2012) expérimentation et optimisation d'un prototype de centrale hybride solaire PV/diesel sans batteries de stockage: validation du concept "flexyenergy". Doctoral thesis, Université de Perpignan, Perpignan.

[4] Stoyanov, L. (2011) Etude de différentes structures de systèmes hybrides à sources d'énergie renouvelables.

[5] Wikipédia (mise à jour le 25/08/2020) monitoring des données. © 2021 Photovoltaïque. Energie de juin 21: dernière.

[6] Korsaga, E., Koalaga, Z., Bonkougou, D., *et al.* (2018) Comparaison et détermination des dispositifs de stockage appropriés pour un système photovoltaïque autonome en zone sahélienne.

[7] Iberraken, F. and Maouche, C. (2012) Analyse des Modes de Défaillance des Systèmes Photovoltaïques installés dans le sud Algérien. Mémoire de master.

[8] Houari, A. (2012) Contribution à l'étude de micro-réseaux autonomes alimentés par des sources photovoltaïques.

[9] Kundur, P. (2012) Power System Dynamics and Stability.

[10] Bun, L. (2011) Détection et Localisation de Défauts pour un Système PV. thèse doctorat, Université de Grenoble, Grenoble.

[11] Chen, H., Cong, T.N., Yang, W., Tan, C., Li, Y. and Ding Y. (2009) Progress in Electrical Energy Storage System: A Critical Review. *Progress in Natural Science*, **19**, 291-312. https://doi.org/10.1016/j.pnsc.2008.07.014

[12] Lucien, B.Y., Byiringiro, J.B., Abraham, B.W., Aristide, G.B. and Célestin, K. (2021) Evaluation of the Criteria in the Choice of Energy Storage or Non-Storage in Photovoltaic Systems in the Sahelian Zone. *Energy and Power Engineering*, **13**, 236-242. https://doi.org/10.4236/epe.2021.136016

[13] Obaraa, S. and Miyazakib, W. (2020) Numerical Modeling to Determine the Limits on Photovoltaic Capacity When Operating in a Microgrid with Solid-Oxide Fuel

Cell Triple Combined-Cycle Plants. *International Journal of Electrical Power & Energy Systems*, **124**, Article ID: 106325. https://doi.org/10.1016/j.ijepes.2020.106325

[14] Lucien, B.Y. (2021) optimisation via le monitoring des données d'un micro-réseau autonome alimenté par la combinaison photovoltaïque-diesel sans stockage d'énergie de production. thèse doctorat, UNILIS/DPHU, Ouagadougou.