Journal of Energy and Power Engineering 10 (2016) 431-441
doi: 10.17265/1934-8975/2016.07.007

Comparative Study on Telecommunications Base Stations' Power Supply Systems on Remote Sites in the Northern Part of Cameroon

Bello-Pierre Ngoussandou[1], Oumarou Hamandjoda[2] and Haman Djalo[1]

1. Higher Institute of the Sahel, University of Maroua, P.O.Box 46 Maroua, Cameroon

2. National Advanced School of Engineering, University of Yaounde, P.O.Box 8390 Yaounde, Cameroon

Received: January 03, 2013 / Accepted: March 06, 2013 / Published: July 31, 2016.

Abstract: The TBS (telecommunications base stations) on remote sites in the northern part of Cameroon are mainly supplied by a system of two generating units. Only a few TBS located in the Waza and Benue National Parks are powered by a PV (photovoltaic) solar system to avoid any disturbance to wildlife. It is against this background that we decided to do a comparative study on these two systems. This study focuses on the reliability of electrical quantities, the environmental impact and the installation and operating costs of these two major systems namely the GU (generating unit) system comprising two generating units and the PV system. In conducting this study, we took a sample of TBS including those located in the Badjouma and Waza localities. After collecting data from mobile telephony operators, measurements of electrical quantities on the sites for twelve consecutive months and updating costs, their operation reveal indicators that are surprising, to say the least. Concerning the reliability index, the PV system is estimated at 99.9% as against 97.8% for the GU system. As for environmental impact, the mass of CO_2 released by the GU system reached 1,707.5 tons in 25 years for a single TBS while the PV system produced no emissions. In addition to its contribution to climate change, the GU system pollutes its immediate environment through the spillage of waste and production of deafening noise. On the other hand, economic analysis shows mixed results. The GU system has a lower installation cost of $6,640 as against $174,550 for the PV system, whose investment cost is its main handicap. Regarding operating costs, the GU system peaks at $923,940 in 25 years while the PV system requires only $487,550 for the same duration.

Key words: Reliability of power supplies, climate change, energy costs.

1. Introduction

The rapid expansion of telecommunications due to the advent of mobile telephony has led to the proliferation of TBS (telecommunications base stations) in both urban and rural areas. Unlike other electrical installations, TBS are peculiar because they function round the clock. They are very demanding in terms of stable and continuous power supply. As a result of the fact that they transmit huge amounts of communications at any time, TBS need to have continuous power supply from a source that is capable of avoiding any impact on the quality of transmission. Interruptions on the telephone network due to power outage causes financial and socio-moral prejudice to businesses and several other users.

Considering that TBS located on remote sites were previously supplied, for the most part by generating units, rarely by PV systems, we decided to conduct a "comparative study of TBS power supply systems on remote sites in the northern part of Cameroon" in order to determine the most appropriate option given the technical, economic and environmental conditions. Such a study has the merit of providing a decision-making tool for telecommunication operators. This comparative study consists in examining the

Corresponding author: Bello-Pierre Ngoussandou, Ph.D. student, research fields: energy storage, renewable energy.

provision of power supply through GU (generating units) and the photovoltaic (PV) system. In order to attain the overall objective, it was necessary to define the following specific objectives:

- Which of the power systems offers better reliability?
- Which of the systems has a more acceptable impact on climate change and on the immediate environment?
- Which of the systems has a lower overall cost in the medium term?

2. Generalities on Generating Units and PV Systems

Electrical energy can easily be used and transmitted, but it does not exist naturally. The generation of electrical energy still depends on another natural source of energy. It is the device that converts primary energy into electrical energy that is referred as the generator. There are several types of energy sources that can be classified into two broad families [1]: renewable and non-renewable sources of energy. Non-renewable energy sources can be classified into fossil (oil, coal and natural gas) and fissile (uranium, plutonium) sources.

Regarding renewable sources, we have geothermal, biomass, hydro, wind and solar (photovoltaic or thermal) energy sources.

2.1 Generating Unit

Fossil fuel refers to fuel produced from rocks derived from the fossilization of plant and living organisms. It comprises organic matter that has been buried in the soil or sediments that have settled at the bottom of lakes and oceans over time. This material is later transformed into fossil fuels. These are energy reserves in chemical form that nature has taken millions of years to produce. They represent considerable amounts of energy that humanity has passionately exploited over time to the extent that these resources risk being exhausted [1].

A generating unit generates electrical energy through combustion of fuel. This combustion involves the release of highly polluting carbon dioxide.

2.2 Photovoltaic Generating Unit

The sun is the source of most renewable energies. While its radiation is itself causable source of energy (photovoltaic and thermal), the same radiation controls or strongly influences winds, photosynthesis, the water cycle and tides. This implies that the sun is the primary source of all renewable energies [2].

Photovoltaic solar energy is derived directly from solar activity. The sun emits electromagnetic radiation in which we find notably cosmic, gamma, X-rays, visible light, infrared, microwaves and radio waves depending on the emission frequency. All these types of electromagnetic radiation emit energy. These rays can be used in two ways [3]:

(1) Solar thermal energy: this involves the transformation of these rays into heat;

(2) Photovoltaic solar energy is based on the photoelectric effect.

Solar panels comprise several basic V_{co} photovoltaic cells which can produce basic I_{co} current depending on the sun light conditions [4].

3. Equipment and Methods

3.1 TBS Power Budget

The method for determining the amount of electrical energy needed by the TBS to ensure a smooth functioning is based on the inventory of electrical receivers. In general, it requires making an inventory of all electrical components considering their electrical capacity and specifying the duration of their daily operating time. We can distinguish DC and AC receivers. The correction factors will be included in the calculation, which are dependent on the output of the various components of the power supply chain [5]. Total daily consumption of energy is calculated using the following formula:

$$E = E_1 + E_2 = \frac{1}{K_1}\sum_{i=1}^{n} P_i \cdot H_i + \frac{1}{K_2}\sum_{j=1}^{m} P_j \cdot H_j \quad (1)$$

In this formula, P_i is the capacity of the DC receiver in line i, H_i the daily operating time of the said receiver, P_j the capacity of the AC receiver in line j, K_1 and K_2 are the efficiencies of the generation chain of the DC and AC voltages, respectively.

We visited several TBS of the different operators located in the three regions covered by our work and found out that the power requirements were basically the same for stations located in rural or suburban areas. This explains why we took a sample of the TBS located in Badjouma, Benue Division, of the North Region and Waza, Logone and Chari Division, in the Far North Region. The choice of these TBS is based on the type of source used and accessibility to the site. While the Badjouma TBS is powered by a system using two generating units (Table 1), the Waza TBS is powered by a photovoltaic system. At the heart of the famous Waza National Park, the PV system was installed to avoid noise that could disturb the wildlife environment of the park. Badjouma is located 30 km from the town of Garoua on the national highway No. 1 towards Maroua. Similarly, Waza is located between Maroua and Kousseri on national highway No. 1, some 120 km from Maroua.

3.2 Badjouma Generating Units

The generating units used generally have the same basic characteristics. Although the trade marks may differ a little, the capacities, voltages and fuel consumptions are almost the same.

The characteristics of the generating units at the Badjouma station are in Table 2:

With an apparent power S = 16 KVA, we have an active energy of

$$P = S \cdot \cos\varphi \quad (2)$$

With $\cos\varphi$ the power factor whose critical value is about 0.8, we obtain:

P = 16,000 × 0.8 = 12.8 KW for a need of 3.6 KW. Only 28.4% of the energy generated is used.

This waste of energy is explained by the fact that generating units with low capacities are less stable, break down regularly and have very limited life spans [6]. In addition, their capacities in terms of litres are reduced. Their use requires more frequent interventions and manipulations, which further reduces their reliability and increases maintenance costs.

3.3 Waza PV System

The installed system is made up of photovoltaic panels, a charge controller, a battery, a DC/AC inverter, a junction box and all mounted on a frame built with angle bars.

3.3.1 Peak Charge of the PV Field

By using the relation in Eq. (1) with K_1 = 0.85 and K_2 = 0.8, we obtain:

$$E_1 = \frac{1}{K_1}\sum_{i=1}^{n} P_i \cdot H_i = \frac{80960}{0.85} = 95\ 247.1\ ;$$

$$E_2 = \frac{1}{K_2}\sum_{j=1}^{n} P_j \cdot H_j = \frac{200}{0.8} = 235.3;$$

$$E = E_1 + E_2 = 95\ 247.4\ Wh = 95.2\ KWh.$$

Table 1 Informations about the Badjouma TBS.

Equipment	Characteristics	Capacity (W)	Daily duration (H)	Daily energy output (Wh)
TBS	DC/48 V	900	24	21,600
Transmission	DC/48 V	1,600	24	38,400
Air conditioning	DC/48 V	800	24	19,200
Beacon system	DC/48 V	40	14	560
Lighting	DC/48 V	100	12	1,200
Total 1		3,440		80,960
Power outlet	AC/220 V	200	1	200
Total 2		200		200
Total		3,640		81,160

Table 2 The characteristics of the Badjouma generator.

Trademark	SDMO
Capacity	16 KVA
Voltage/frequency	220 V/50 Hz
Diesel consumption	2.7 litres/hour

The minimum value of radiation in the north of Cameroon stands at 5.75 KWh/(m^2·day^3). The modules are directed towards the South Hemisphere and its angle α is located in the interval [6.12°, 13.50°]. As regards Waza, α = 12°.

Thus, we determine the peak Charge as follows $P_c = {}^{E}/_{G} = 16.6\ KWp$.

3.3.2 Determination of the Capacity of Batteries

The average autonomy of the system in terms of days without sunshine is two days. In fact, the data that we obtained from meteorological department of the Ministry of Transport show clearly that there is hardly a day without sunshine in this part of the country.

Thus, the battery capacity can be calculated using the formula [7]:

$$C_{bat} = \frac{E \cdot N}{V_{bat} \cdot K_{bat} \cdot D_{max}} = \frac{95\ 247 \times 2}{48 \times 0.9 \times 0.7} = 6{,}315\ Ah \quad (3)$$

where,

V_{bat}—Storage battery voltage;

K_{bat}—Battery efficiency;

D_{max}—Maximum discharge.

The Waza site has 140 panels of 120 Wp each, which gives a total of 16.8 KWp and 14 × 4 gel storage batteries of 450 Ah/12 V, totalling 6,300 Ah/48 V.

3.3.3 Charge Controller and DC/AC Inverter

The STECA-brand controller with a capacity of 30 A can stop the charge or discharge of the battery when the critical values have been attained. The Charge value is digitally displayed and can, therefore, be checked any time. This device sends a signal to warn the user when the Charge is about to reach critical values.

The Steca Solarix inverter has the following specifications: input voltage: 48 V, output voltage: 220 VAC/60 Hz and power: 600 W.

3.4 Method of Analysing the Reliability of Systems

To conduct this analysis, we categorised the behaviours of TBS components during power failure. A failure is generally considered as the variation of the characteristic quantities of electricity, whether these failures cause outages or create small variations of the nominal values [8].

The method used to analyse the reliability of the power supply we considered is that of Sylvie LOGIACO [8] of the SCHNEIDER Institute. This MAFSE (method of analysing the reliability of electrical systems) is based on key components such as:

- Failure rate (permanent and temporary outages);
- Detection of failures in real time;
- Duration of repairs and return to service rate;
- Maintainability;
- Availability;
- Failure anticipation capacity;

Thus, reliability is calculated based on the quantities related to the different criteria listed above. These quantities are as follows:

- MDT (mean down time): Mean time during which power is unavailable. It includes the time of detection of the failure, time of mobilisation of the maintenance team, time of supply of faulty equipment and time of repair.
- MTBF (mean time between failure): Average time between two failures of a system that can be repaired.
- MTTF (mean time to failure): Average time of proper operation prior to failure.
- MTTR (mean time to repair): Average duration of repair.
- MUT (mean up time): Average time of proper operation between two failures of a system that can be repaired.

The MTTF is linked to other indexes by:

$$\text{MTBF} = \text{MUT}+\text{MDT} = \text{MTTF}+\text{MTTR} \quad (4)$$

The reliability index and failure rate are, consequently, defined as follows:

$$\lambda = 1 - \mu = 1 - \frac{\text{MDT}}{\text{MTBF}} = \frac{\text{MUT}}{\text{MTBF}} \quad (5)$$

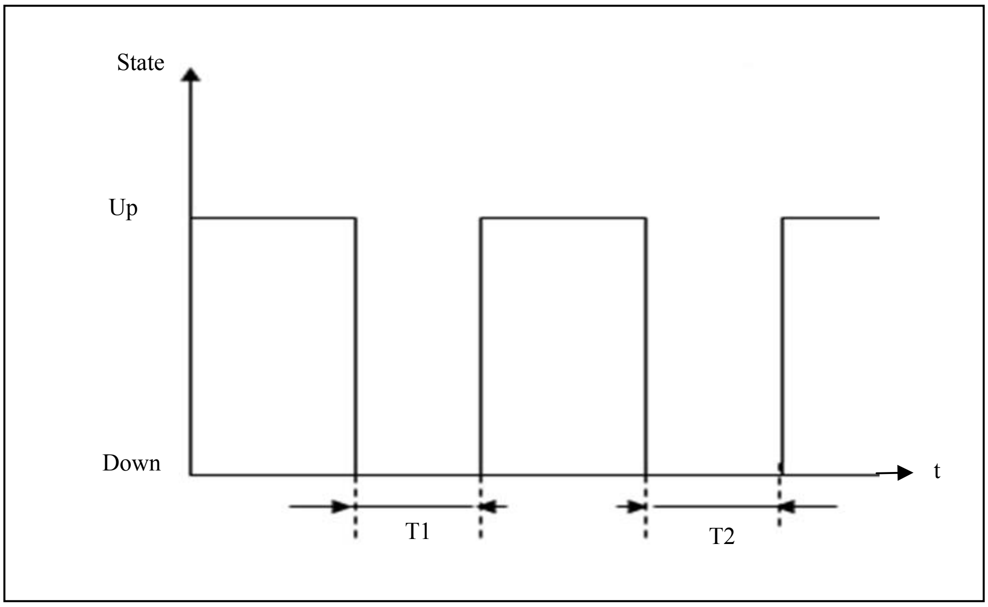


Fig. 1 Curve of the state of operation of a system.

$$\mu = \frac{\text{MDT}}{\text{MTBF}} \tag{6}$$

Method that consists in taking the indexes of electrical quantities per generating unit and comparing them with nominal values to bring out the undesired variations of these quantities.

4. Results and Discussions

4.1 Reliability Analysis

The TBS we studied require a continuous power voltage of 48 V. A variation above ± 2 V leads IPSO facto to disturbances affecting the quality of the signal received and emitted.

4.1.1 Reliability of the GU System

During the six months we spent observing the operation of two generating units currently used at the TBS in Badjouma, we recorded two power failures causing the system to stop completely. The first failure occurred on February 23, 2012 at 5: 30 pm. The generation unit was only returned to service on February 26, 2012 at 10: 45 am. During the duration of the failure, the second generating unit supplied power to the TBS between 7: 30 am and 9: 30 pm. The second failure occurred on June 22, 2012 at 6: 15 am and the system returned to service that same day at 7: 00 pm. The data on the failures recorded by the technical units since 1996 (16 years) confirm the frequency of these failures, which occur averagely 4 times in a year. These failures last on average for 48 hours (8 days out of 365).

The maintainability of the generating units is acceptable in the sense that the spare parts are available on the market and are generally available in the store.

Many of these failures are caused by wearing and increase in temperature.

The failure rate and, consequently, reliability index are determined as follows:

$$\mu = \frac{\text{MDT}}{\text{MTBF}} = \frac{8}{365} = 2.19\% \text{ ;}$$

$$\lambda = 1 - \mu = 97.81\%$$

In effect, this reliability index does not take into account failures that lead to the complete stoppage of the system. As for quantity variations that exceed acceptable margins, we considered 12 voltage values: V_{AC} at the output of the generating unit No. 2 and V_{DC} at the output of the AC/DC Inverter at 07/05/2012. The first value is obtained immediately after the generator is activated and the other values are obtained 1 hour after the activation. These values are presented in the Table 3.

Table 3 Variations of output voltages increasing by working time in Badjouma's generating unit.

Values No.	1	2	3	4	5	6	7	8	9	10	11	12
V_{AC} (V)	221	220	220	220	220	219	219	219	218	218	217	216
220 V – V_{AC}	-1	0	0	0	0	1	1	1	2	2	3	4
V_{DC} (V)	48	48	48	48	48	48	48	48	46	46	46	46
48 V – V_{DC}	0	0	0	0	0	0	0	0	2	2	2	2

Table 4 Variations of the output voltage for Solar system in Waza.

Values No.	1	2	3	4	5	6	7	8	9	10	11	12
V_{DC} (V)	47.8	47.8	47.8	47.7	47.8	47.6	47.7	47.7	47.8	47.8	47.7	47.8
48 V – V_{DC}	0.2	0.2	0.2	0.3	0.2	0.4	0.3	0.3	0.2	0.2	0.3	0.2

We observed here that the errors ΔV_{AC} = 220 V – V_{AC} and ΔV_{DC} = 48 V – V_{DC} increase with time. This means if the same generating unit operates for more than 12 hours non-stop, the V_{DC} voltage will be below 46 V, which will have an impact on the quality of the communications.

4.1.2 Reliability of the PV System

The PV system supplies a direct current voltage that does not require any conversion to supply power to the key components of the TBS. The DC/AC Inverter supplies power exclusively to the lamps that do not affect the quality of the communications. This is due to the fact that no part of the power supply system is in motion (rotation), as it is the case for many other systems; the wearing factor is negligible (wearing causes half of the failures of generating units) [8]. The Table 4 presents the values we recorded at the output of the storage batteries during 12 hours.

The error margin remains negligible over time. Power outages caused by the PV are generally due to maintenance. During the six months (March 2011 to August 2011) we spent in Waza, we did not record any failure; however, system stoppage was scheduled on June 16, 2011 for the overall maintenance of the PV system. This maintenance took 3 hours; however, the TBS power supply was suspended for only 15 minutes. A preventive stoppage was noted on August 23, 2011 between 1 am and 4 am at night. The month of August is generally very rainy and the clouds had covered the sky for two successive days. To avoid any sudden stoppage during the day, the technician decided to stop the system to save energy during the low periods.

We thus obtained the following: MDT = 3h 15min = 0.14 days out of 183.

Thus: μ = 0.14/183 = 0.00074, λ = 1 – μ = 0.9992 = 99.92%.

The PV system's reliability index is therefore higher than that of the GU system.

Moreover, the fact that the failure of the storage batteries causes power unavailability only at night is vital information for telecommunications operators. Monthly reports indicate that night communications (6 pm-7 am) represent only 22% of overall daily communications. Furthermore, the rainy season (with clouds) lasts only 3 months on average out of 12 months in a year [9].

The weakness of the PV system results from inadequate maintainability: battery replacement or repair generally takes more time than generating units [10]. PV spare parts are not readily available, and this slows down the replacement process.

4.2 Analysis of the Different Environmental Impacts

4.2.1 Impacts of the GU System

The problem of climate change has always been a major concern to the international community since the Earth Summit in Rio de Janeiro. Today, its impact is more visible and a cause for concern. The main causes of these malfunctions are people's lifestyles and green gas emission, the key component being the CO_2 which is released during the combustion of petroleum products [11].

Generating units used in the TBS in Badjouma consume 3 litres of fuel per hour. Whereas, each litre of diesel oil burnt releases a mass of 2.6 kg of CO_2 [11]. An evaluation of the contribution of only one TBS is done based on the following arithmetic model:

$$M(k) = k \cdot Q \cdot Mo \quad (7)$$

where,

$M(k)$—Mass of CO_2 for k days:

K—number of days of operation;

Q—quantity of diesel oil consumed per day;

Mo—Mass of CO2 released per litre of diesel oil.

$M(k) = 365 \times 3 \times 2.6 = 68.3$ t per year.

The immediate pollution of the TBS ecosystem caused by the generating unit is at several levels:

- Drainage is generally done in the open. Discharge of this liquid influences the chemical composition of the plants in the vicinity where some species grow under difficult conditions. The fauna living on this infected flora is indirectly affected by this pollution.
- The local populations have always complained of the unpleasant noise of the engines. This same noise that drove out many animal species (bees) that previous lived in the vicinity of the TBS.
- Oil refining to obtain several products is another source of atmospheric pollution.

Black gold, as oil is sometimes called, has the peculiarity of being unevenly distributed on earth. The high consuming countries are not oil producers. The discovery of a deposit of this mineral has always sparked off devastating conflicts.

Furthermore, there are lots of accidents and other risks involved in the processing or transportation of fuel over long distances.

4.2.2 PV System Impacts

Though PV modules are considered to have no effect on climate change, the module manufacturing industry pollutes. This pollution, which does not extend beyond the manufacturing level, is quite negligible for anyone to question the environmental friendliness of PV modules.

Since no waste is released into the environment, or noise emitted by the PV generator, it stands out as absolute clean energy. Worth pointing out, however, it is the fact that visual pollution is beginning to be introduced as justification to deplore the vast expanse of areas covered by PV panels. But as long as the application is on a small scale, as it is currently the case, the surface covered is less than the roofs of premises and thus does not call for concern. Furthermore, several technicians use modules as part of building roofs.

The delocalized nature of solar irradiation is a significant advantage of the PV technology. Once the system is installed, nothing else needs to be transported, thus limiting risks of accidents. Accidents cost much to companies as they need to incur expenses for the treatment of employees injured in accidents for a long time.

4.3 Economic Analysis

Economic analysis involves evaluating the various expenses incurred. It also includes installation costs, operating costs and possibly losses due to the breakdown of power sources as showed in Tables 5-10.

The GU system consumes 26,280 litres of diesel per year and the cost of one litre is about \$1.3, thus an annual cost of \$34,164.

Table 5 Assessment of GU system installation cost.

Description	Unit price ($)	Quantity	Total price ($)
Engines	1,600	2	3,200
Battery	240	1	240
AC/DC inverter	1,200	1	1,200
Transport	600	1	600
Labour	1,000	1	1,000
Other accessories	400	1	400
Total			6,640

Table 6 Assessment of GU system operating costs.

No.	Description	Price ($)	Frequency
1	Replacement of engines	3,200	7 years
2	Gas-oil	34,164	1 year
3	Replacement of battery	240	5 years
4	Replacement of inverter	1,200	10 years
5	Maintenance	1,000	1 year
6	Transport	1,000	1 year

Table 7 Assessment of cumulative expenses of the GU system in 25 years.

Year	Gasoil+Trans +Maint	Battery	Engine	Inverter	Operation	Cumulative expenses
1	36,164	0	0	0	36,164	42,804
2	36,164	0	0	0	36,164	78,968
3	36,164	0	0	0	36,164	115,132
4	36,164	0	0	0	36,164	151,296
5	36,164	240	0	0	36,404	187,700
6	36,164	0	0	0	36,164	223,864
7	36,164	0	3,200	0	39,364	263,228
8	36,164	0	0		36,164	299,392
9	36,164	0	0		36,164	335,556
10	36,164	240	0	1,200	37,604	373,160
11	36,164	0	0	0	36,164	409,324
12	36,164	0	0	0	36,164	445,488
13	36,164	0	0	0	36,164	481,652
14	36,164	0	0	0	36,164	517,816
15	36,164	240	3,200	0	39,604	557,420
16	36,164	0	0	0	36,164	593,584
17	36,164	0	0	0	36,164	629,748
18	36,164	0	0	0	36,164	665,912
19	36,164	0	0	0	36,164	702,076
20	36,164	240	0	1,200	37,604	739,680
21	36,164	0	0	0	36,164	775,844
22	36,164	0	0	0	36,164	812,008
23	36,164	0	3,200	0	39,364	851,372
24	36,164	0	0	0	36,164	887,536
25	36,164	240	0	0	36,404	923,940

Table 8 Assessment of PV system installation cost.

Description	Quantity	Unit price ($)	Total price ($)
PV modules	140	480	67,200
Batteries	56	1,800	100,800
Inverter	1	300	300
Charge controller	1	300	300
Cables	1	1,000	1,000
Metal frame	1	1,800	1,800
Transport	1	900	900
Labour	1	1,400	1,400
Other accessories	1	1,000	1,000
Total cost		174,700	

Table 9 Assessment of PV system operating cost.

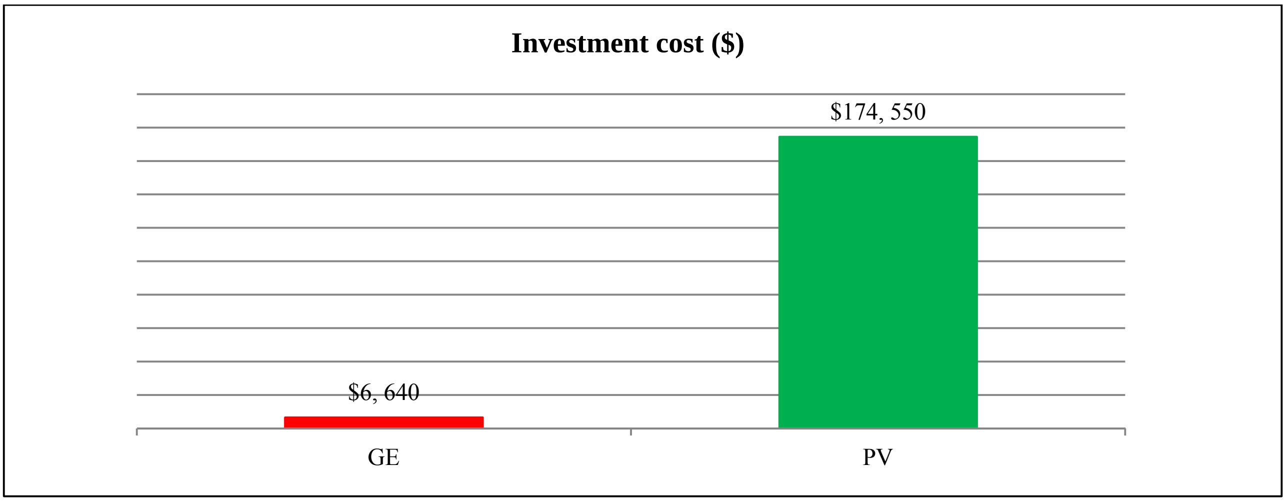
Description	Expenses ($)	Frequencies
Preventive Maintenance	400	1 year
Replacement of Batteries	100,800	8 years
Replacement of Inverter	150	12 years
Replacement of Charge Controller	300	15 years

Table 10 Assessment of PV system cumulated costs in 25 years.

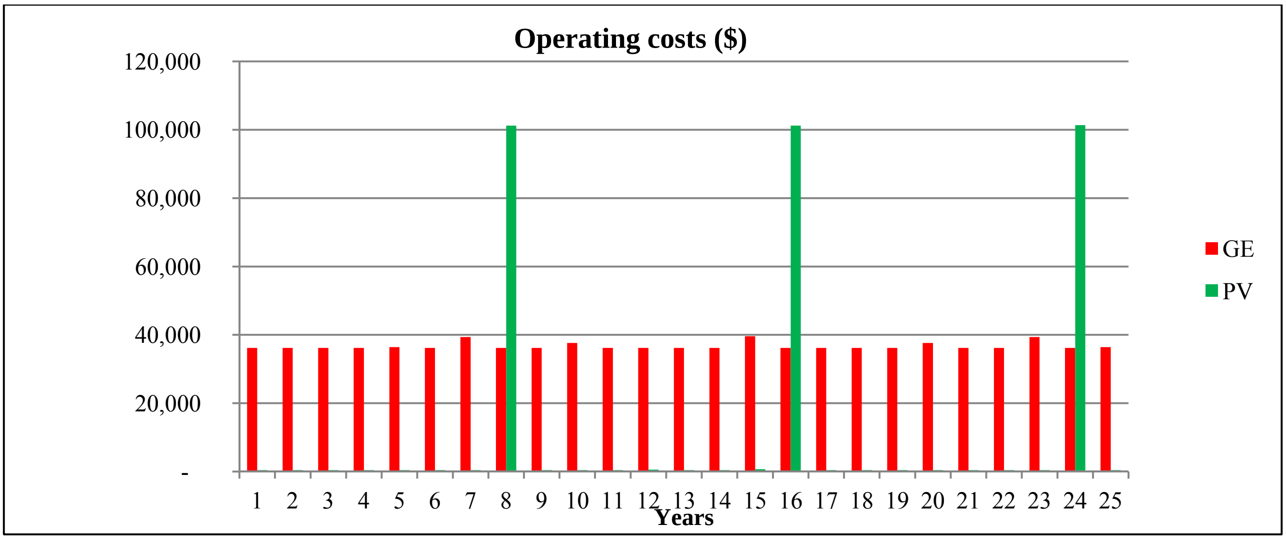
Year	Maintenance	Batteries	Inverter	Controller	Operation	Cumulated Costs
1	400	0	0	0	400	174,950
2	400	0	0	0	400	175,350
3	400	0	0	0	400	175,750
4	400	0	0	0	400	176,150
5	400	0	0	0	400	176,550
6	400	0	0	0	400	176,950
7	400	0	0	0	400	177,350
8	400	100,800	0	0	101,200	278,550
9	400	0	0	0	400	278,950
10	400	0	0	0	400	279,350
11	400	0	0	0	400	279,750
12	400	0	150	0	550	280,300
13	400	0	0	0	400	280,700
14	400	0	0	0	400	281,100
15	400	0	0	300	700	281,800
16	400	100,800	0	0	101,200	383,000
17	400	0	0	0	400	383,400
18	400	0	0	0	400	383,800
19	400	0	0	0	400	384,200
20	400	0	0	0	400	384,600
21	400	0	0	0	400	385,000
22	400	0	0	0	400	385,400
23	400	0	0	0	400	385,800
24	400	100,800	150	0	101,350	487,150
25	400	0	0	0	400	487,550

Table 11 General comparison of GU and PV systems.

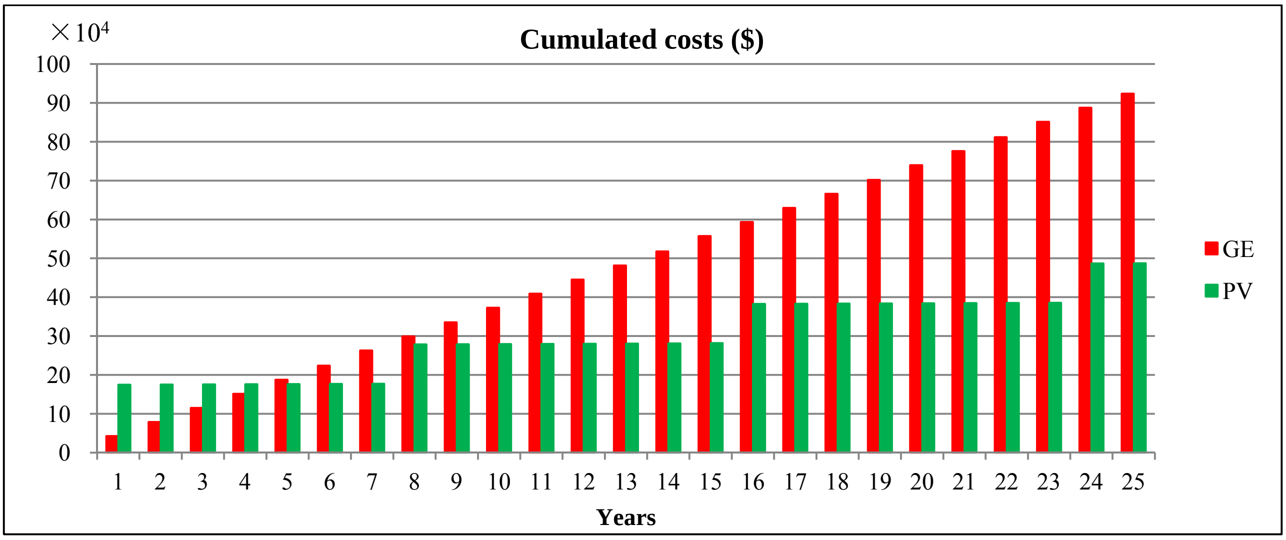
Systems	Investment	Costs after 25 years	Reliability	CO_2 after 25 years
GU	$6,640	$923,940	97.81%	1,707.5 tons
PV	$174,550	$487,550	99.92%	–



(a) Histograms of installation costs



(b) Histograms of operating costs



(c) Histograms of cumulated costs in 25 years

Fig. 2 Operating costs.

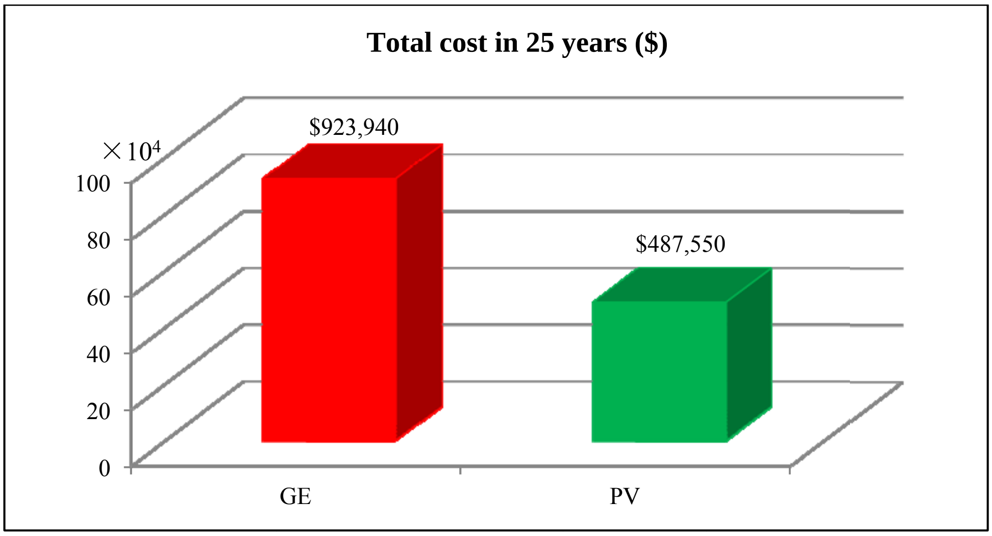


Fig. 3 Histogram of total cost in 25 years.

In this case, only preventive maintenance and transportation make up annual expenditure. It is at the end of a given period (years) that the histogram of operating costs can witness peaks.

The GU system operating cost is higher; more than three times that of the PV.

5. Conclusions

The comparative analysis of the GU and PV systems which powers the TBS on remote sites in the northern part of Cameroon in terms of reliability, costs and various impacts made it possible to obtain the results contained in the summary Table 11.

It can be seen from the table that the only advantage of the GU system is the low cost of installation. Its overall cost in 25 years is far higher than that of the PV system. It can be recommended in a situation where the capital to be invested is low. This system is highly pollutant and less reliable than the PV system whose reliability is not far from the ideal value.

References

[1] Flèche, B., and Delagnes, D. 2007. Electric energy production: *photovoltaic solar energy, June*. Lecture or eBook. Accessed July 14, 2016. www.livrespourtous.com.

[2] Renewable Energy World. 1998. Accessed July 14, 2016. http://www.renewableenergyworld.com/index/tech.html.

[3] Ayangma. 2008. "Evaluation of Solar Energy Potential of Cameroon: Case of Northern-Cameroon." *African Journal of Science and Technology* 9: 32-40.

[4] Brigand, S. 2000. *Principles of Photovoltaic Solar Energy*. Paris: DUNOD.

[5] Boitier, V., and Alonso, C. 2005. "Dimensioning of a Photovoltaic Installation for Domestic Use." Presented at the Symposium on Systems and Information Technologies Teaching, Nancy, France.

[6] Rodot, M., and Benallou, A. 1987. "Solar Electricity for Rural Development." Edition Quadrichromie.

[7] Achaïbou, N. 1999. "Introduction to the Study of the Storage System for Photovoltaic Energy." *Revue des Energies Renouvelables*.

[8] Logiaco, S. 1999. "Study of Electric Installations Reliability." *Cahier Technique No.184*.

[9] Kamta, M., and Bergossi, O. "Factors Affecting the Valorisation of Photovoltaic Water Pumping Projects for Irrigation in the Adamawa Province." *International Scientific Journal for Alternative Energy and Ecology* 6.

[10] Monchy, F. 2000. *Maintenance: Methods and Organization*. Paris: DUNOD.

[11] Lefevbre, J. 1978. *Chemistry of Hydrocarbons*. Paris: Eyrolles.