International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 10 Issue 4, Jul-Aug 2026 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Sizing and Cost of a Photovoltaic Power Plant for the City of Kenge

Mayamba Kiese Kiapumbu Emmanuel[1]*, Cimbela Kabongo Joseph[2], Bondo Muteba Patrice[3], Ngoie Caleb Caleb[4]

[1]Physics and Technology Section, Higher Pedagogical Institute of Kenge, Democratic Republic of Congo
[2,3]Department of Physics and Applied Sciences, National Pedagogical University, Democratic Republic of Congo
[4]Research Centre on Mathematics Education, Democratic Republic of Congo
*Corresponding Author: Mayamba Kiese Kiapumbu Emmanuel

ABSTRACT

This study focuses on the sizing and cost evaluation of a photovoltaic power plant intended to supply the city of Kenge with electricity. The study employs both qualitative and quantitative approaches, including a field survey to identify the population's actual energy needs, the types of equipment used, and existing energy sources.

From a technical standpoint, the photovoltaic system was sized by determining the optimal number of solar panels, batteries, and inverters needed to meet the energy demand. Monocrystalline 500 Wp panels were chosen, resulting in a total of 8,494 installed panels, combined with a storage system of 7,836 lithium batteries to provide three days of autonomy.

This study also includes cable sizing, equipment compatibility verification (power, voltage, current) and optimization of panel orientation and tilt to maximize energy production.

Finally, an economic analysis estimated the overall cost of the project at approximately US$8,089,576, including equipment, installation, maintenance, and contingency costs. This study demonstrates that, despite a high initial investment, the implementation of a photovoltaic power plant represents a sustainable and appropriate solution for improving access to electricity in the city of Kenge.

KEYWORDS: *Evaluation, Energy needs, Sizing, Photovoltaics, Power plant.*

How to cite this paper: Mayamba Kiese Kiapumbu Emmanuel | Cimbela Kabongo Joseph | Bondo Muteba Patrice | Ngoie Caleb Caleb "Sizing and Cost of a Photovoltaic Power Plant for the City of Kenge" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-10 | Issue-4, August 2026, pp.337-351, URL: www.ijtsrd.com/papers/ijtsrd142022.pdf

IJTSRD142022

1. INTRODUCTION

The city of Kenge, located in the Democratic Republic of Congo, faces a significant energy deficit, characterized by limited access to electricity, dependence on traditional sources (generators, biomass) and often unstable service quality.

Despite the presence of operators like SNEL, the energy supply remains insufficient to cover the growing needs linked to urbanization, population growth and the development of economic activities.

Furthermore, Kenge benefits from high solar potential, with average irradiance favorable to the exploitation of photovoltaic energy. This context creates a strategic opportunity for:

- reduce dependence on fossil fuels,
- improve access to electricity,
- to support socio-economic development,
- to promote clean and sustainable energy.

Thus, the sizing of a photovoltaic power plant constitutes an appropriate response to local energy challenges, provided that it is based on a rigorous assessment of real needs and technical conditions.

Despite its significant solar potential, the city of Kenge suffers from several constraints:

- Insufficient electricity production in the face of growing demand;
- Inequalities in access to energy between households and economic sectors;
- Lack of reliable energy planning based on real data;
- High cost of alternative solutions such as generators;

- Lack of modern infrastructure to harness renewable energy.

Therefore, the central question is:

- How can a photovoltaic power plant be optimally sized to meet the actual energy needs of the city of Kenge while minimizing investment and operating costs?

This issue can be broken down into sub-questions:

- What is the city's actual energy consumption?
- What power output is needed to meet this demand?
- What is the overall cost of the system?

The study is based on the following assumptions:
Homogeneity of consumption classes

Households, offices and other structures in the same category have similar energy profiles.

Stability of consumption habits:
The duration of use of electrical appliances remains constant over a given period.

Availability of solar radiation:
The solar irradiation at Kenge is sufficient and stable to guarantee good photovoltaic performance.

Overall system efficiency
A coefficient of performance ($K \approx 0.65$) is used to account for losses (batteries, inverters, cables, etc.).

Reliability of survey data:
The data collected in the field accurately reflects the local energy reality.

The main objective is to:
Determine the optimal power and cost of a photovoltaic power plant capable of meeting the energy needs of the city of Kenge.

To achieve this objective, this study aims to:

- Assess the energy needs of households, offices and economic sectors;
- Calculate the total daily consumption of the city;
- Determine the total power required;
- Size the photovoltaic system (modules, batteries, inverters);
- Estimate the overall cost of the project (investment and maintenance);
- Analyze the technical and economic feasibility;
- To propose a sustainable solution adapted to the local context.

To carry out this research, we used the following methods: descriptive, analytical, and comparative. These methods were complemented by documentary research, interviews, questionnaires, observation, and sample size analysis.

2. Theoretical approach to photovoltaic solar energy

The term photovoltaic is composed of the Greek word *photos,* meaning light, and *volta,* the name of the Italian physicist Alessandro Volta, who invented the electrochemical cell in 1800. The photovoltaic effect was discovered by the French physicist Alexandre Edmond Becquerel in 1896. He observed that certain materials could generate a weak electric current when exposed to light. (Labouret, A. and Villot, M., 2003).

The photovoltaic effect is the direct conversion of the light energy of sunlight (photons) into electricity. Wave theory cannot explain the experimental results concerning the existence of the photon. Einstein explained them by stating the following postulates:

- Light is made up of massless and chargeless particles called photons.
- Photons of sufficient energy are capable of releasing electrons from a metal.

An electromagnetic wave of frequency ν is associated with a photon whose energy is:

$$E = h.\ \nu \quad \text{with:} \qquad (1.\ 1)$$

E: energy of the photon in Joules (J);

ν : wave frequency in hertz (Hz);

h: Planck constant: $h = 6.62\ .\ 10^{-34}$ Js

To achieve the photovoltaic effect, photovoltaic modules composed of cells are used. These photovoltaic cells are made of semiconductors based on silicon (Si), germanium (Ge), selenium (Se), etc. Silicon is currently the most widely used material for manufacturing photovoltaic cells because it is very abundant in nature. (Labouret, A. and Villot, M., 2003).

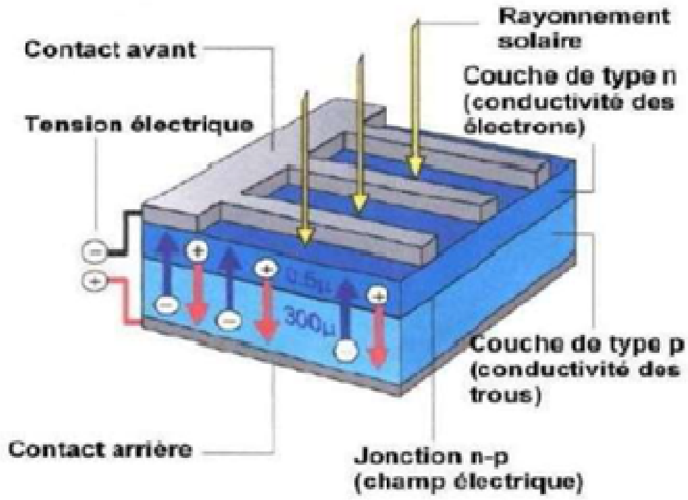


Figure 1: The photovoltaic effect.
Source: Jean C., 2023.

The advantages and disadvantages of photovoltaic solar energy

1. **Advantages of photovoltaic solar energy**

- A source of renewable energy; it uses an inexhaustible resource, the sun.
- Reduces electricity bills; generates free electricity after installation.
- Low environmental impact; does not produce greenhouse gases or pollution during use.
- Adaptable installation: can be installed on roofs, facades, or even as a standalone system for specific applications.

2. **Disadvantages of photovoltaic solar energy**

- Solar panels are extremely expensive due to the high level of technology they require.
- The current efficiency of photovoltaic cells remains quite low (around 10% for the general public) and therefore delivers only low power.

2.1. The photovoltaic system

A. Composition of the photovoltaic system

Our thesis concerns the autonomous photovoltaic system. The purpose of a photovoltaic (PV) system is to use the direct conversion of solar energy by the photovoltaic effect to meet the electrical energy needs of the application.

Overall, a stand-alone photovoltaic installation includes the following elements: the panels (p. v), the batteries, the regulators, the converters, and the load.

B. Photovoltaic cell

A photovoltaic cell is an electronic component that, when exposed to light, produces electricity. The photovoltaic cell is the basic element of solar panels. It is a silicon-based semiconductor device that delivers a voltage of approximately 0.5 to 0.6 V (Tighilt, F., 2009).

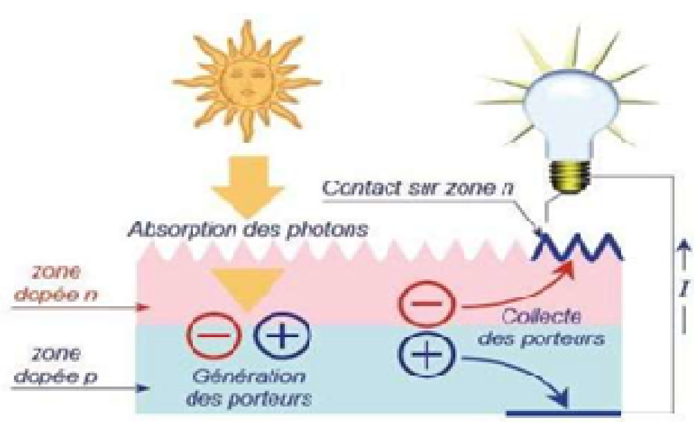


Figure 2: Structure of a photovoltaic cell
Source: Mukoko J., 2020.

a) Operating principle

A photovoltaic cell is made from two layers of silicon (semiconductor material):

- A layer doped with boron which has fewer electrons than silicon, this area is therefore positively doped (P-zone).
- A layer doped with phosphorus, which has more electrons than silicon, therefore this region is negatively doped (N-zone). This creates a PN junction with a potential barrier (Tighilt, F., 2009).

b) Types of photovoltaic cells

Silicon is currently the most widely used material for manufacturing PV cells because it is very abundant in nature, second only to oxygen. It does not exist in its pure form; sand and quartz contain it. Currently, there are three main types of silicon PV cells (Vechiu, I., 2005).

- **Monocrystalline silicon cell:** During cooling, the molten silicon solidifies into a single, large crystal. This crystal is then sliced into thin wafers, which become the cells. These cells are generally a uniform blue. The monocrystalline silicon cell is historically the most widely used and commercially available, and offers the best performance.

Benefits :

- Very good yield of 14 to 20%;
- a small surface area (7 m² are needed to obtain 1 kWp;
- long lifespan (30 years).

Disadvantages: High cost; low yield under low light conditions.

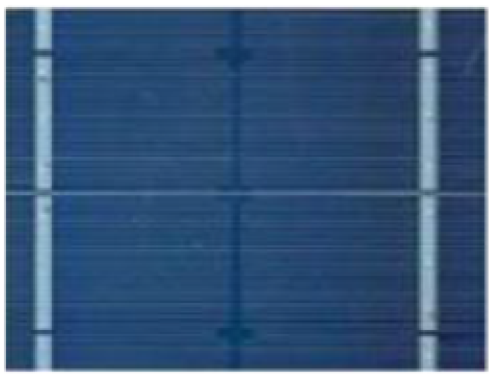


Figure 3: Single crystal cell

Source: Zairi, S., and Boubiada, S., 2009.

- **Polycrystalline silicon cell:** During the cooling of silicon in an ingot mold, several crystals form. Patterns created by different crystals can be distinguished. Polycrystalline silicon cells are less expensive than monocrystalline silicon cells, but their efficiency is lower and their manufacturing processes are less stringent.
- **Advantages:** Good yield (11 to 15%); easy to manufacture; cheaper manufacturing cost than monocrystalline panels.
- **Disadvantages:** Low yield under low light or diffuse sunlight.

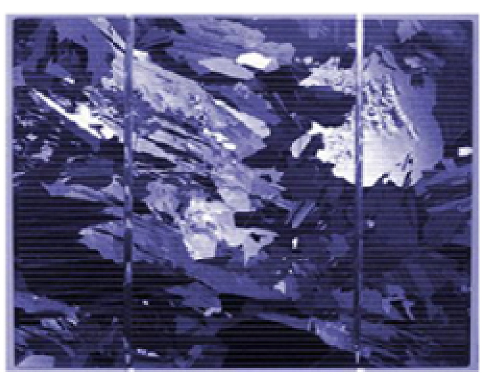
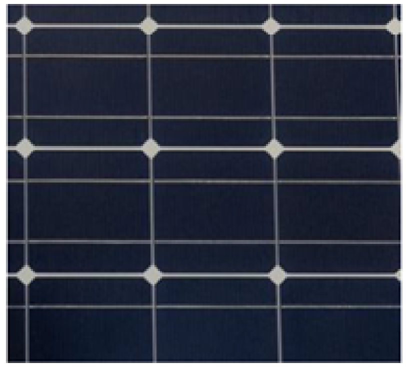


Figure 4: Polycrystalline silicon cell

Source: Zairi, S., and Boubiada, S., 2020

- **Amorphous silicon cell:** During its transformation, silicon produces a gas that is sprayed onto a sheet of glass. The cell is very dark gray. This is the cell used in calculators and so-called solar watches.
- **Advantages:** Cell that works with low or diffuse illumination; slightly cheaper than other cells; integration on flexible or rigid supports.
- **Disadvantages:** Low efficiency in full sun of 5% to 7%; high cost due to the superposition of two cells.



amorphous silicon cell
Source: Zairi, S., and Boubiada, S., 2020

Regarding the research methods and techniques used, we employed both qualitative and quantitative approaches.

3. Investigation approach

3.1. Survey Questionnaire

We divided the survey questionnaire into five sections:

- Investigator identification: this involves describing the investigator's environment, their municipality, their neighborhood, their age and their sex.
- Types of energy used: the energy sources used in the city of Kenge are listed: coal, petroleum, palm oil, batteries, solar energy, electricity, etc…
- Types of receivers used: The population of the city of Kenge uses the following receivers: radio, lamp, telephone, television, fan, freezer, iron, air conditioner, computer, etc.
- Usage time: The usage time of the receivers differs from one receiver to another. The 24-hour period is taken as the unit of time.
- Preferred Power Plant Types: The population of Kenge has generally always wanted electricity from the micro-power plant at the Bukanga -Lonzo Agro-Industrial Park . However, due to a lack of funding, the project initiated by the Kwango Provincial Government was never implemented. As an alternative to this electricity source, the population is opting for the installation of a photovoltaic power plant in Kenge. Besides photovoltaic plants, wind power plants are another option.

3.2. Survey Procedures

We used investigative techniques by proceeding as follows:

- Selection of investigators: Most of the investigators chosen were students. They were interested in the work as it was a research topic, despite the voluntary nature of the assignment. We used a total of 25 investigators, with 5 investigators per commune. The communes in the city of Kenge are not very large, unlike those in major cities such as Kinshasa or Lubumbashi.
- Selection of surveyed plots: To obtain reliable and realistic data, the surveyors selected one out of every three plots on each side of the avenue. If a plot was empty, they moved directly to the next one.
- Selection of respondents: Surveys were conducted in households, administrative offices, and industrial and semi-industrial sectors.
- Training seminar: Due to a lack of financial resources, we did not organize a formal training seminar. However, we held a preparatory meeting during which we provided some guidelines and direction to the interviewers regarding how to complete a survey questionnaire, appropriate conduct during the survey, and how to ask questions in a simple manner, adapted to the language used by the respondent.

4. Sizing of photovoltaic panels

This step involves determining the number of PV modules or solar panels needed to cover the site's energy needs.

4.1. Panel selection

Before any sizing is carried out, it is important to choose photovoltaic panels that provide the minimum technical characteristics. Photovoltaic panel manufacturers provide the panel characteristics ($I_{cc}, I_{max}, U_{co}, U_{max}$) under standard operating conditions (Conrad, Y., 2011).

We chose 500Wp peak power solar panels, model CE-M500w, monocrystalline type

Table 1: Panel Characteristics

N ^{0}	Elements	Symbol	Values
01	Maximum power	P_{max}	500W
02	Voltage at maximum power point	U_{max}	40.65 V
03	Current at maximum power point	I_{max}	12.3 A
04	Open circuit voltage	U_{co}	50.34 V
05	Short-circuit current	I_{cc}	13.01 A
06	Maximum system voltage	U	1000/1500 VDC
07	Dimensions	L x W x H	1908x1134x30 mm
08	Weight	P	22.5 kg
09	Module efficiency (STC)		≥ 23%
10	Guarantee		25 ns

4.2. Calculating the number of panels

Total number of panels. The number of photovoltaic panels is calculated based on the characteristics of the chosen panel and the peak power of the generator (Conrad, Y., 2011). The total number of photovoltaic panels is determined using the formula:

$$N_{pt} = \frac{P_c}{P_p} \quad (1.2)$$

With

N_{pt} Total number of panels

P_c Peak power of the photovoltaic field

P_p Peak power output of the selected panel

Digital application

P_c= 4,247,087 Wp, P_p = 500 Wp

$$N_{pt} = \frac{P_c}{P_p} = \frac{4.247.087}{500} = 8494{,}17 = 8494\ panneaux$$

Number of panels in series

$$N_{ps} = \frac{U_s}{U_p} \quad (1.3)$$

N_{ps} Number of panels in series

U_s Inverter input voltage (System voltage)

U_p Panel voltage (maximum voltage in V)

4.3. Digital application

U_s= 600V; U_p= 40.65V

$$N_{ps} = \frac{U_s}{U_p} = \frac{600}{40{,}65} = 14{,}76 = 15\ panneaux\ en\ serie$$

Number of panels in parallel

$$N_{pp} = \frac{Npt}{Nps} \qquad (1.4)$$

N_{pp}Number of panels in parallel

N_{ps}Number of panels in series

N_{pt}Total number of panels

4.4. Digital application

$N_{pp} - \frac{N_{pt}}{N_{ps}} - \frac{8494}{15} - 566$ parallel panels

4.5. Calculation of the surface area and total weight of the panels

Knowing the total number of panels to be installed should lead to estimating the total surface area and total weight of the panels.

➢ **Total surface area of the panels**

$$S = S_p x N_{pt} \qquad (1.5)$$

STotal surface area of the panels in m²

S_pUnit surface area of a panel

N_{pt}Total number of panels

➢ **Total weight of the panels**

$$P - P_P x N_{pt} \qquad (1.6)$$

PTotal weight of panels in kg

P_PUnit weight of a panel

4.6. Digital application

$N_{pt} - 8494\, panneaux, P_P = 22.5\ kg\ ; \ell = 1908mm\ ; \ell = 1134mm$

$S_p = Lxl = 1908\ x\ \ 1134 = 2.163.672mm^2 = 2{,}16m^2$

$S = S_p x N_{pt} = 2{,}16\ x\ 8494 = 18.347m^2 = 1{,}83ha$

$P = P_P x N_{pt} = 22.5\ x\ 8494 = 191.115\ kg$

In conclusion: The photovoltaic power plant to be installed in the city of Kenge must consist of 8494 500W solar panels mounted as follows:

➢ Number of panels in series: 15 panels

➢ Number of panels in parallel: 566 panels

4.7. Choosing the tilt and orientation of photovoltaic panels

The ideal orientation of a photovoltaic module follows a rule towards the equator: southward orientation in the Northern Hemisphere and northward orientation in the Southern Hemisphere. Since the city of Kenge is in the Southern Hemisphere, the panels will be oriented northward. The latitude of Kenge is 4 ° 48'29" (< 10 °). Referring to Table 1.1, we will use a module tilt of 10 °.

5. Battery sizing

To ensure continuous power supply during less sunny days, a storage system, generally consisting of batteries, is used. The required capacity depends on the battery voltage, the battery's depth of discharge, the energy demand of the load, and the number of days of autonomy that the initially charged batteries can provide without the modules operating (Yamume, K., 2004).

5.1. Battery selection

The choice of batteries should be based on the products available on the market and the battery voltage (Cabal, S., 2011). In this study, we chose lithium batteries, which offer the following advantages:

➢ Long lifespan;

- High energy;
- Easy installation;
- Waterproof battery
- Requires no maintenance;
- Yield greater than 90% (±95%)
- Model: Lux – Y – 48100 Hc G01
- Type: LFP (Life P04): Lithium Iron phosphate

Table 2: Battery Specifications

N ^{0}	Elements	Values
01	Energy	5.12 kWh
02	Nominal capacity	100Ah
03	Nominal voltage	51.2 V
04	Discharge depth (D)	≥ 95%
05	Lifetime	30 years
06	Autonomy (N)	3 days
07	Dimensions	482.6 x 565 x 150 mm
08	Weight	10.3 kg

5.2. Calculating battery storage capacity

This is the amount of energy a battery can store. It is calculated by:

$$C_{bt} = \frac{E_c.N}{D.U_b} \quad (1.7)$$

With

C_{bt} Total battery capacity in ampere-hours (Ah)

E_cEnergy consumed per day in watt-hours per day (Wh/day) or in kWh/day

NThe number of days of autonomy refers to the period during which the batteries must supply power to the load (N = 3 days). This number varies depending on the application and geographical location (Zairi, S. and Boubadia, S., 2020).

DMaximum battery discharge or depth of discharge (0.95% for lithium batteries). This is the amount of energy that has been discharged from the battery. A battery should not be discharged below a certain threshold, otherwise it risks being damaged (Toumi, N. and Kouda, I. 2021).

U_b Battery voltage in V

5.3. Digital application

$E_c = 12.698.790\frac{Wh}{j}$; $N - 3jours$; $D - 0,95$;U_b $- 51,2\ V$

$$C_{bt} = \frac{E_c.N}{D.U_b} = \frac{12.698.790 \ x\ 3}{0,95\ x\ 51,2} = \frac{38.096.370}{48,64} = 783231\ Ah$$

5.4. Calculating the number of batteries

- **Total number of batteries**

$$N_{bt} = \frac{C_{bt}}{C_b} \quad (1.8)$$

With

N_{bt}Total number of batteries;

C_{bt}Total battery capacity in Ah;

C_bBattery capacity in Ah

5.5. Digital application

$C_{bt} = 783231Ah$,$C_b = 100Ah$

$$N_{bt} = \frac{C_{bt}}{C_b} = \frac{783231}{100} = 7832\ batteries$$

➢ **Number of batteries in series**

$$N_{bs} = \frac{U_s}{U_b} \qquad (1.9)$$

N_{bs}: Total number of batteries in series;
U_b: Battery voltage in V;
U_s: Photovoltaic field voltage V ;

Digital application
$U_s = 600\ v ; U_b = 51.2V$

$N_{bs} - \frac{U_s}{U_b} - \frac{600}{51,2} - 11,71 - 12\ batteries\ en\ serie$

➢ **Number of batteries in parallel**

$$N_{bp} - \frac{N_{bt}}{N_{bs}} \qquad (1.10)$$

N_{bp}Number of batteries in parallel;
N_{bs}: Number of batteries in series;
N_{bt}Total number of batteries;

Digital application

$N_{bt} = 7832\ batteries, N_{bs} = 12\ batteries$

$N_{bp} = \frac{N_{bt}}{N_{bs}} = \frac{7832}{12} = 653\ batteries\ en\ Parallele$

The total number of batteries required to ensure proper coupling is therefore

$$N_{bt} - N_{bs} x N_{bp} - 12\ x\ 653 - 7836$$

Conclusion : we have 7836 solar batteries, lithium type LiFePO4 (lithium iron phosphate, model Lux-y-48100HCG01, with a capacity of 100Ah and a voltage of 51.2V each. They will be connected, 12 in series and 653 in parallel.

5.6. Inverter sizing

➢ **Inverter selection**

Regarding the choice of inverter and regulator, based on our research we chose a hybrid inverter that acts as both regulator and inverter.

This is the hybrid inverter

Model: T-REX-50 KHP 3 G01

Type: HYBRID SOLAR INVENTOR

Table 3.12 presents the technical specifications of the hybrid inverter.

Table 3: Hybrid Inverter Characteristics

N 0	Elements	Values
01	Maximum DC input power	65 kW
02	Maximum DC input voltage	1000 V
03	Minimum DC input voltage	150 V
04	Nominal DC input voltage	600 V
05	MPPT input voltage range	200V-850V
06	Input current	66 A
07	Maximum AC output power	55 kW
08	Rated AC output power	50 kW
09	Rated AC output current	72.5 A
10	Maximum AC output current	79.7 A
11	Nominal output voltage	220/380, 230/400

12	Nominal output frequency	50/60 Hz
13	Dimensions	940 x 595 x 340 mm
14	Weight	
15	Lifetime	10 years

The sizing of an inverter is based on three criteria:
- Potential compatibility;
- Voltage compatibility;
- Current compatibility.

a) Power compatibility

The inverter power must be greater than the total peak power (Pc) of the AC receivers (Tighilt, F., 2009)

$$Pond \geq 1.25 \times Pc \qquad (1.11)$$

Note: For good safety, the inverter must have power and current values multiplied by a safety factor of 1.25 (Canrad, Y., 2011)

Pond ≥ 1.25 x 4.247. 087 = 5,308,859W = 5308.859 kW

6. Calculating the number of inverters

$$N_o = \frac{Pond}{P} \qquad (1.12)$$

$$N_o = \frac{Pond}{P} = \frac{5308{,}859kw}{50} = 106\ onduleurs$$

6.1. Calculating the number of panels for each inverter

$$N_p = \frac{N_{pt}}{N_o} \qquad (1.13)$$

$$N_p = \frac{N_{pt}}{N_o} = \frac{8494}{106} = 80\ panneaux$$

6.2. Power compatibility check

We have 80 panels of 5000 Wp each: 80 x 500 = 40,000 Wp

40,000 Wp < 50,000 Wp

Therefore, the inverter is compatible in terms of power.

a) Voltage compatibility

The DC voltage of the panel output must be within the range of the inverter's input voltage, or sometimes there are inverters that have a fixed input voltage, so the inverter's input voltage must be equal to the panel output voltage or the system voltage.

6.3. Calculation of the maximum and minimum number of PV panels in series for each inverter compatible with the inverter's MPPT voltage range

The inverter's technical specifications indicate the following:

The maximum permissible input voltage of the inverter: Umax = 600V

The input voltage range of the inverter: [Umppt, min- Umppt max] = [200V – 850V].

6.4. Maximum number of panels in series for each inverter

$$N_{ps}max = E - \left[\frac{U_{mppt,max}}{U_{mpp}\ x\ 1{,}15}\right] \qquad (1.14)$$

$$N_{ps}max = E - \left[\frac{U_{mppt,max}}{U_{mpp}\ x\ 1{,}15}\right] = E - \left[\frac{850}{40{,}65\ x\ 1{,}15}\right] = 18{,}18 = 18\ panneaux$$

6.5. Minimum number of panels in series for each inverter

$$N_{ps}min = E + \left[\frac{U_{mppt,min}}{U_{mpp}\ x\ 0{,}85}\right] \qquad (1.15)$$

$$N_{ps}min = E + \left[\frac{U_{mppt,min}}{U_{mpp}\ x\ 0{,}85}\right] = E + \left[\frac{200}{40{,}65\ x\ 0{,}85}\right] = 5{,}78 = 6\ panneaux$$

With
$E + [X]$: *La partie entiere supérieure du nombre X*
$E - [X]$: *La partie entiere inférieure du nombre X*
$U_{mppt,max}$: *Tension maximale admissible par l'onduleur*
$U_{mppt,min}$ Minimum voltage allowed by the inverter
U_{mpp} : *Tension de puissance maximale du panneau*

1.15: Increase coefficient used to calculate the voltage Mpp at -20 ^{0} c

0.85 : Reduction coefficient used to calculate the voltage Mpp at 70 $^\circ$C

6.6. Voltage compatibility check

An inverter is characterized by a maximum permissible input voltage. If the voltage delivered by the modules exceeds this maximum input voltage, the inverter may be damaged. Therefore, for the T-REX-50 KHP 3G01 hybrid inverter, the voltage delivered by the modules must not exceed Umax = 600 V.

According to the calculation, the number of modules in series should be between 6 and 18

$$U_{max} = N_{ps} \times U_{co} \times 1.15 \qquad (1.16)$$

With
U_{max} : voltage at the maximum power point
N_{ps}number of panels in series
U_{co} : open-circuit voltage.

$$N_{ps}, \max = 18\ panneaux : U_{max} = 18\ x\ 50{,}34\ x\ 1{,}15 = 1042\ V$$

$$1042\ V > 600\ V$$

The inverter is not compatible in terms of voltage

$$\text{avec } N_{ps}, \min = 6\ paneaux\ , U_{max} = 6\ x\ 50{,}34\ x\ 1{,}15 = 347,35\ V$$

$$347,35\ V < 600\ V$$

Therefore, a configuration with 6 panels in series is compatible, with the maximum permissible voltage at the inverter input.

6.7. Checking the inverter 's MPP range

The range of the MppT voltage at the inverter input is between two voltage values.

$$[U_{mppt}, \min - U_{mppt}\ , max] = [200\ V - 850\ V\ ]$$

$$[200\ V \quad 850V]/6 = [33{,}33\ V \quad 141{,}66\ V\ ]$$

The voltage range is compatible, since$U_{mpp} = 40{,}65\ V$

6.8. Current compatibility

A conductor is characterized by a maximum permissible input current. The current delivered by the PV array must not exceed the value of the maximum permissible current.I_{max} by the inverter. During sizing, the current delivered by the PV string is equal to the short-circuit current of the PV modules, denoted *Icc.*

The inverter's technical data sheet gives the maximum permissible input current for the inverter: Imax = 66A.

Maximum number of photovoltaic strings in parallel for each inverter

$$N_c - E - [\frac{I_{max}}{I_{cc}\ x\ 1{,}25}] \qquad (1.17)$$

$N_c - E - [\frac{66}{13{,}01\ \ x\ 1{,}25}]$

$N_c = 4{,}05 = 4\ chaines$

1.25: safety factor imposed by the UTEC15-712 standard

Current compatibility check

$$I_{max} = N_c x I_{cc} x 1{,}25 \quad (1.18)$$

$$I_{max} = 4\ x\ 13{,}01\ x\ 1{,}25 = 65{,}05\ V$$

$$65{,}05\ V\ < 66\ V$$

Therefore, the inverter is compatible in terms of current

7. Cable sizing

7.1. Cable Selection

The highest current levels occur in the DC section of the installation. Therefore, it is in this section that the problem of Joule losses and voltage drops in the cables arises. The cable cross-section that results in the least possible voltage drop is determined. (Tighilt, F., 2009)

We use the following voltage drop law:

$$\Delta U = R.I \qquad (1.19)$$

Every electrical cable has a resistance given by the formula:

$$R = \rho \frac{L}{S} \qquad (1.20)$$

RElectrical resistance of cables (Ω)

ρresistivity (Ωm). This depends on the material .

L: cable length (m)

S: cable sector ($^{m^2)}$

ΔUVoltage drop (V)

ICurrent flowing through the cables

From (3.21) and (3.22)

We find:

$$S - \frac{\rho\ x\ I\ x\ L}{\Delta U} \qquad (1.21)$$

This formula is multiplied by 2 because the current makes a round trip between the panels and the battery or inverter (Tighilt, F., 2009)

Either :

$$S = \frac{\rho\ x\ I\ x\ 2L}{\Delta U} \qquad (1.22)$$

To size the cables, we chose copper conductors based on resistivity $\rho = 1{,}7.10^{-8}\Omega m$and voltage drop.$\nabla U = 3\%$

7.2. Calculation of sections

In general, the existing connections between the various components in a battery-based system can be summarized as follows:

- Panel-junction box connection: cable length 7 m
- Connection box to inverter: cable length 10 m
- Inverter-battery connection: 4 m cable length

a) Cable cross-section between the panel and the junction box

Calculating the output current of a panel at its rated power

$$I = \frac{P_{max}}{U_{max}} = \frac{500}{40{,}65} = 12{,}3A$$

L = 7m; I = 12.3A; $\rho = 1{,}7.10^{-8}\Omega m$; $\Delta U = 3\%$= 40.65 x 0.03 = 1.22 V

$$S_1 = \frac{\rho \ x \ I \ x \ 2L}{\Delta U} = \frac{1{,}7.10^{-8} \ x \ 12{,}3 \ x \ 2 \ x \ 7}{1{,}22} = 239{,}95.10^{-2} = 2{,}40mm^2$$

b 2. Cable cross-section between the junction box and the inverter

Calculation of the current flowing between the connection box and the inverter.

Peak power of the photovoltaic field

$$P_c = N_{pt} x P_p = 8494 \ x \ 500 = 4.247.000 \ Wc$$

$$U_s = 600 \ V$$

$$I = \frac{P_c}{U_s} = \frac{4.247.000}{600} = 7078 \ A$$

Since we have 106 inverters in our system, we are looking for the current flowing through a single inverter:

$$I = \frac{7078}{106} = 66{,}77 \ A$$

$$S_2 = \frac{\rho \ x \ I \ x \ 2L}{\Delta U} = \frac{1{,}7.10^{-8} \ x \ 66{,}77 \ x \ 2 \ x \ 10}{1{,}22} = 18{,}60mm^2$$

b) Cable cross-section between the inverter and the battery

Calculation of the current flowing between the inverter and the battery.

Inverter power: $Pond = 50 \ kW = 50.000 \ W$

$$I = \frac{Pond}{U_s} = \frac{50.000}{600} = 83{,}33 \ A$$

$$S_3 = \frac{\rho \ x \ I \ x \ 2L}{\Delta U} = \frac{1{,}7.10^{-8} \ x \ 83{,}33 \ x \ 2 \ x \ 4}{1{,}22} = 9{,}29 \ mm^2$$

After calculating the cable cross-sections, the commercial cross-section must be chosen which is greater than the calculated cross-section (Vechiu, I., 2005).

Standardized cross-sections in mm^2

1.5-2.5-4-6-10-16-25-35-50-70-95-120-150

The table below shows the copper cable cross-sections we will need to use.

Table 4: Cable cross-section

N^0	Section	Calculated section	Standard section
01	Between the panel and the junction box	$S1 = 2.40 \ mm^2$	$S1 = 2.5 \ mm^2$
02	Between the junction box and the inverter	$S_2 = 18.60 \ mm^2$	$S_2 = 25 \ mm^2$
03	Between the inverter and the battery	$S3 = 9.29 \ mm^2$	$S_3 = 10 \ mm^2$

8. Project cost

After a technical study, it is important for any project to estimate the necessary expenses for its completion. For our study, the project cost includes the following expenses:

- Purchase cost of the components of the PV system: PV panels, batteries, inverters, cables and accessories;
- Maintenance and operating costs equal to 5% of the initial investment;
- Labor costs equal to 10% of the initial investment;
- Cost of technical study and unforeseen expenses

Table 5: Project cost

N^0	Designation	Model	Number	Unit price ($)	Total price ($)
01	Panels	CE-M500W	8494	120	1,019,280
02	Batteries	Lux-Y-48100 HCGo1	7836	680	5,328,480

03	Hybrid inverter	T-REX-50 KHP 3Go1	106	3900	413,400
04	Cables				
	Cables	mm^2 copper	8490 × 7m = 59,458 m	1	59458
	Single-core cables	mm^2 copper	2106 ×x ×10m = 2120m	5	10,600
	Single-core cables	mm^2 copper	2 ×106 ×4m=848m	2	1.696
05	Accessories (fuse, surge protector, circuit breaker, etc.)				1500
06	Operation and maintenance				351.721
07	Workforce				703.441
08	Technical study				120,000
09	Unforeseen circumstances				80,000
	Total project cost				8,089,576

The cost of a photovoltaic system increases according to energy demand; indeed, the higher the consumption, the greater the number of panels to be used, as well as the storage capacity.

High-power PV systems require a large number of components (panels, batteries, charge controllers, inverters, cables, and other equipment) for their operation. The high cost of these components explains why installing a photovoltaic power plant is very expensive.

Conclusion

This study on the sizing and cost of a photovoltaic power plant for the city of Kenge concludes that solar energy is a suitable, sustainable, and relevant solution to meet the growing energy needs of this region. Analysis of the survey data revealed a high demand for electricity and a significant dependence on traditional energy sources, which are often expensive and polluting.

The technical design study allowed for the precise definition of the system's essential components, including 8,494 photovoltaic panels, 7,836 lithium batteries, and 106 inverters, thus guaranteeing sufficient energy production and several days of energy autonomy. The study also considered technical constraints such as equipment compatibility, energy losses, and installation optimization, thereby ensuring the reliability of the proposed system.

From an economic standpoint, although the overall cost of the project is estimated at over 8 million US dollars, this investment is justified by the long-term benefits, including reduced operating costs, improved living conditions for the population, and environmental protection.

In conclusion, the construction of a photovoltaic power plant in Kenge represents a strategic solution to address the energy deficit, foster socio-economic development, and promote the use of renewable energy. However, its implementation requires substantial financial support, rigorous planning, and a commitment from public authorities and technical partners to ensure the project's success and sustainability.

Bibliographical references

[1] National Agency for Electrification and Energy Services in Rural and Peri-urban Areas (ANSER, 2024).

[2] Anne-Marie, D. and Thomas, Z. (1984), Physics Classes of first year S and E, Hatier, Paris.

[3] Atlas of the Ministry of Energy and Hydraulic Resources, (2021), Kinshasa DRC.

[4] World Bank, (2024), Annual Report.

[5] Cabal, C. (2008), Energy optimization of the adaptation stage for photovoltaic conversion, Doctoral thesis, University of Toulouse, 2008

[6] Conrad, Y. (2011), Study and Design of a Mini Photovoltaic Power Plant to Supply Part of the Electrical Installation of the Presidency of the Republic of Benin, Master's Thesis, International Institute for Water and Environmental Engineering, Benin

[7] Jean, C. (2003), Photovoltaic solar energy, Lycée des métiers, Louvre, Paris.

[8] Labouret, A. and Villoz, M. (2009), Photovoltaic solar energy, Dunod Edition, Paris.

[9] Luc, C. and Eric, L. (2008): Photovoltaic electricity, Dunod Edition, Paris.

[10] Kenge City Hall, (2024), 2024 Annual Report.

[11] Toumi, N. and Kouda, I. 2021. The Electrification of a city by the photovoltaic solar system, Master's thesis Mohamed Khider University of Biskra, Algeria.

[12] Mukoko, J. (2020), Feasibility study of a hybrid renewable energy power plant “solar photovoltaic - Biomass” for the production of electricity and heat in N'Kamba. DEA thesis, National Pedagogical University, DRC.

[13] National Electricity Company (SNEL). (2024), DRC.

[14] Tighilt, F. (2009), Sizing and installation of a photovoltaic system, final year project, Mouloud Mammeri University, Algeria

[15] Vechiu, I. (2005), Modeling and analysis of the integration of renewable energies in an autonomous network, doctoral thesis, University of Le Havre

[16] Yamume, K. (2004), Preliminary design for the installation of a photovoltaic power plant for the permanent power supply of the Luano control tower, TFC, University of Lubumbashi, Faculty of Engineering, DRC

[17] Zairi, S. and Boubiada, S. (2020), Study and dimensioning of a photovoltaic power plant, Master's thesis, Mohamed Khider University of Biskra, Algeria

[18] https://eduscol.education.fr photovoltaic system, 2020, Accessed on 26/09/2024

[19] https://www.researchgate.net Study and sizing of a solar installation on a site, 2021, Accessed on 24/09/2024

[20] https://document.environnement.brussels Photovoltaics, 2019, Accessed 29/10/2024

[21] https://projects.worldbank.org/en/projects/2017/11/29, Solar, accessed on 02/11/2024

[22] http://www.nrel.gov, Design of photovoltaic, solar thermal, and wind power projects, 2020, Accessed 15/11/2024