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Design of a "Mini Smart Grid" for the electrification of Koumnéré locality: Power supply via a hybrid PV/Diesel power plant with battery storage

Dioari Ulrich Combari [1, 2, *], Arnaud Ouermi [1, 2], Wend Yam Mickaïla Tertus Dermé [1], Mamoudou Saria [1, 2] and Issa Zerbo [2]

[1] *Multidisciplinary Research Laboratory in Engineering Sciences (LMRSI), Polytechnic School of Ouagadougou (EPO), Ouagadougou, Burkina Faso.*
[2] *Laboratory of Renewable Thermal Energies (L.E.T.RE), Doctoral School of Sciences and Technologies, Joseph KI-ZERBO University, Ouagadougou, Burkina Faso.*

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Abstract

This work concerns the design of a small hybrid photovoltaic/diesel generator power plant with battery energy storage. This system will supply electricity to the Koumnéré area, located in the South-Central region of Burkina Faso. Photovoltaic energy is obtained from a free primary energy source: solar energy. However, it is an intermittent energy source that depends on the time of day and is generally subject to weather conditions. Electricity production from diesel generators is stable, but the fuel it requires has a high cost. Furthermore, its operation is accompanied by greenhouse gas emissions. In addition, its efficiency remains average, estimated at around 45%. Therefore, we opted for a hybrid system, which offers several advantages.

The energy needs assessment for the Koumnéré area was based on statistical data from the fifth General Population and Housing Census (GPHC) of Burkina Faso, conducted during 2019-2020 and provided by the National Institute of Statistics and Demography (NISD). A grid connection rate of 65% was also taken into account. This resulted in a daily energy requirement of 600.64 kWh/day. This allowed for the definition of a peak power of 158.47 kWp for solar PV system and 125 kVA for the diesel generator. The combination of these two sources, along with battery storage, resulted in a Mini-Power Plant characterized by competitive cost, a low environmental footprint, and a reliable and continuous energy supply.

Keywords: PV/Diesel Power Plant; Energy Storage; Sizing; Rural Electrification; Koumnéré Locality

1. Introduction

The socio-economic development of rural areas is closely linked to access to a reliable and sustainable energy source. Unfortunately, many remote localities remain disconnected from the national electricity grid, which significantly limits their opportunities for growth and development. In this context, rural electrification becomes essential to improving the quality of life for residents and fostering economic progress. The main objective of this study is to design a sustainable electrification system for the locality of Koumnéré using a "Mini Smart Grid". This aims to provide a reliable, relatively clean, and affordable energy source for the area's inhabitants, while promoting optimal energy demand management. This implies:

- Analysis of the energy needs of the Koumnéré locality in terms of power, duration, and stability, taking into account various uses such as lighting, household appliances, and economic activities;

* Corresponding author: Dioari Ulrich Combari

- Design and sizing of a "Mini Smart Grid" system, effectively integrating photovoltaic solar components, energy storage devices, energy management systems and distribution systems.

This power system is a hybrid system designated as scenario 1 in our previous study where the energy management and distribution system was defined [1], Photovoltaic solar power production alone is intermittent, and that of a diesel generator is obtained with greenhouse gas emissions. In addition, the electrical efficiency of a diesel generator is quite low; it is generally between 30 and 45% [2], [3], [4].

A hybrid power generation system is defined as a system combining at least two energy sources of different types, often (but not necessarily) including an energy storage system, either connected to the public grid or operating off-grid [5]. Hybrid systems can incorporate various energy sources such as wind, solar PV, micro-hydropower, diesel generators, the electrical grid, and different storage systems such as flywheels, supercapacitors and batteries. To ensure reliable production and address the intermittency of solar energy, it is necessary to combine this energy source with a controllable system. The integration of solar energy into diesel systems thus presents itself as a suitable technological solution for the efficient and low-cost production of electricity. Furthermore, this technology is particularly well-suited for rural areas [6].

2. Materials and Methods

Initially, an assessment of the locality's energy needs is conducted. The population's electricity needs primarily concern households, social needs (street lighting, schools), the needs of economic infrastructure, and self-consumption. These needs may arise from the likely use of a number of electrical appliances, namely:

- Lighting (public and domestic);
- Audiovisual (Radio, Television, Set-top box/Satellite dish, Computer);
- Telecommunications (landline and mobile telephony);
- Comfort (Fans, Air conditioners);
- Household appliances (Irons, Refrigerators/Freezers);
- Industrial (powerful electrical machines, electric mills, welding equipment, cold storage rooms, industrial refrigerators, etc.).

Considering the aforementioned appliances and using a number of static data points, such as the types of electrical appliances used in the south-central region and the number of appliances per household, we were able to inventory the electrical energy needs of the population of Koumnéré under three main headings.

2.1. Household Needs

To assess the needs of households in Koumnéré, we largely used figures from the fifth (5th) General Population and Housing Census (GPHC) of Burkina Faso, which took place from November 16 to December 15, 2019, with an extension in some localities until January 2020. This document shows us that the population of Koumnéré in 2019 was 701 inhabitants distributed among 101 households [7], [8].

The results of Volume 2 of the 5th General Population and Housing Census (GPHC), which provides household and population characteristics, supplied by the National Institute of Statistics and Demography (NISD), also give us the proportion of ordinary households owning at least one capital item, broken down by region (the central-southern region in our case). Assuming a connection rate of 65%, we assessed the power and energy needs of households in Koumnéré using Tables 1 and 2.

Table 1 Assessment of household electricity needs in Koumnéré

HOUSEHOLD POWER NEEDS							
Devices	Number (n)	Proportion of households (Prop) (%)	Estimated number of households able to own the device (Estim)	Unit power (W)		Power × Number (W)	
				Normal use	Standby use	Normal use power (PN)	Standby power (PSTBY)
Home lighting (T8 LED Tube)	3	65	65.65	18	0	3,545.1	0
Radios	1	60.6	61.206	5	0	306.03	0
Cell phones	1	24.7	24.947	5	0	124.735	0
	2	33.1	33.431	5	0	334.31	0
	3	14.9	15.049	5	0	225.735	0
	4	06.7	6.767	5	0	135.34	0
	5	03.8	3.838	5	0	95.95	0
	6	03.3	3.333	5	0	99.99	0
Land phones	1	01.2	1.212	5	0	6.06	0
Computers	1	02.4	2.424	80	5	193.92	12.12
Television devices	1	16.2	16.362	100	5	1,636.2	81.81
Decoders/Satellite dishes	1	07.9	7.979	18	8.5	143.622	67.8215
Fans	1	16.2	16.362	50	0	818.1	0
Air conditioners	1	02.4	2.424	500	0	1212	0
Refrigerators/ Freezers	1	02.5	2.525	150	0	378.75	0
Irons	1	02.4	2.424	800	0	1,939.2	0
Total	-	-	-	-	-	11,195.042	161.752

The power ratings previously determined will be used to calculate the energy needs of households in Koumnéré by multiplying the total power of each appliance by its daily operating time.

Table 2 Assessment of daily household electricity needs in Koumnéré

DAILY ENERGY NEEDS OF HOUSEHOLDS					
Devices	Power × Number (W)		Operating time (h)		Daily Energy consumption Ed (Wh)
	Normal use power (PN)	Standby power (PSTBY)	Normal use time (TN)	Standby time (TS)	
Home lighting (T8 LED Tube)	3,545.1	0	5	19	17,725.5
Radios	306.03	0	8	16	2,448.24

Cell phones	124.735	0	3	21	374.205
	334.31	0	3	21	1,002.93
	225.735	0	3	21	677.205
	135.34	0	3	21	406.02
	95.95	0	3	21	287.85
	99.99	0	3	21	299.97
Land phones	6.06	0	24	0	145.44
Computers	193.92	12.12	3	21	618.12
Television devices	1,636.2	81.81	5.5	18.5	9,449.055
Decoders/Satellite dishes	143.622	67.8215	4	20	845.774
Fans	818.1	0	5	19	4,090.5
Air conditioners	1,212	0	4	20	4,848
Refrigerators/ Freezers	378.75	0	24	0	9,090
Iron	1,939.2	0	0.15	23.85	290.88
Total	11,195.042	161.752	-	-	52,599.689

Equations 1 and 2 will be used for the calculations.

$$Estim = \frac{101 \times \Pr op}{100} \quad (1)$$

$$Ed = \left(P_N \times T_N\right) + \left(P_{STBY} \times T_S\right) \quad (2)$$

Estim is the estimated number of households able to own a given appliance, while *Prop* is the proportion that this number represents. *Ed* represents the daily energy requirement; P_N and T_N represent the power and operating time in normal operation, respectively; P_{STBY} and T_S represent the standby power consumed and standby time, respectively.

2.2. Social Needs

In this case, these needs primarily concern public lighting and the school's electrical supply. Regarding public lighting, we selected 40-watt light fixtures (LED STREET LIGHT type) using the DIALux software, with an average daily operating time of 11 hours. The school has two buildings, each with six classrooms. We estimated four lamps, two fans, one computer, and one printer/copier per classroom. In addition, there is an administrative office equipped with two lamps, one fan, and one computer. All social needs were assessed and recorded in Table 3.

Table 3 Assessment of power and electrical energy needs for social activities in Koumnéré

Electrical power and energy requirements (social activities)								
Devices	Number (n)	Unit power (W)		Power × Number (W)		Operating time (h)		Daily energy Ed (Wh)
		Normal	Standby	Normal	Standby	Normal	Standby	
Public lighting								
Typical light fixture LED STREET LIGHT	40	40	0	1,600	0	11	13	17,600
School								
T8 LED tube	50	18	0	900	0	7	17	6,300
Fans	26	50	0	1,300	0	4	20	5,200
Computers + flat screen	1	80	5	80	5	5	19	495
Printer-Copier	1	800	10	800	10	3	21	2,610
Total	-	-	-	2,980	15	-	-	32,205

2.3. Economic needs and self-consumption

Economic needs primarily concern the needs of small and medium-sized industrial activities in the locality. These activities are generally centralized in the market. Table 4 illustrates the steps involved in assessing the power and electricity needs for economic activities in the Koumnéré locality and for self-consumption.

Table 4 Assessment of electricity power needs for economic activities in Koumnéré and self-consumption

Electrical power and energy requirements (economic activities and self-consumption)								
Devices	Number (n)	Unit power (W)		Power × Number (W)		Operating time (h)		Daily energy E_d (Wh)
		Normal use	Standby	Normal use power (P_N)	Standby power (P_{STBY})	Normal use time (T_N)	Standby time (T_S)	
Economic activities								
Electric motor for mill	4	12,000	0	48,000	0	8	16	384,000
Welding workshop	1	4000	0	4,000	0	8	16	32,000
Industrial freezers (500L)	2	530	0	1,060	0	24	0	25,440
T8 LED tube	25	18	0	450	0	10	14	4,500
Self-consumption								
T8 LED tube	15	18	0	270	0	10	14	2,700
LED STREET LIGHT	20	40	0	800	0	24	0	19,200
Drill pump	1	2,000	0	2,000	0	6	18	12,000
Auxiliaries and Miscellaneous	-	-	-	1,500	-	24	0	36,000
Total	-	-	-	58,080	0	-	-	515,840

By synthesizing the results obtained in Table 4, we determine the total power and electrical energy requirements of the Koumnéré locality. The final results are summarized in Table 5.

Table 5 Summary of Koumnéré's power and electrical energy requirements

	Normal use power (W)	Standby power (W)	Daily energy (Wh)
Household needs	11,195.042	161.752	52,599.689
Social needs	2,980	15	32,205
Economic activities needs and self-consumption	58,080	0	515,840
Koumnéré area total needs	72,431.794		600,644.689

From this analysis of Koumnéré's electricity needs, it becomes clear that implementing a mini smart grid powered by a hybrid PV/Diesel power plant and incorporating a storage system constitutes a strategic response to the energy challenges of this locality. The data collected underscores the need for an innovative approach to ensure a stable and adaptive electricity distribution. This analysis will lay the foundations for a resilient energy system, thus offering a promising prospect for energy independence and the sustainable development of Koumnéré.

2.4. Sizing of the Mini Smart Grid components

Here, we will address the sizing of the hybrid solar photovoltaic/generator power plant and the storage system. This part of our study aims to detail the technical aspects of implementing the system, while integrating an economic and environmental analysis to guarantee a holistic and sustainable approach.

For the Koumnéré mini smart grid, we proposed an architecture that takes into account all the necessary components for the system's implementation, namely: the diesel generator, the PV generator with storage, the technical room, the system management unit, and several other secondary components [9].

Figures 1 and 2 show, respectively, the proposed structure and location of the power plant at the Koumnéré site.

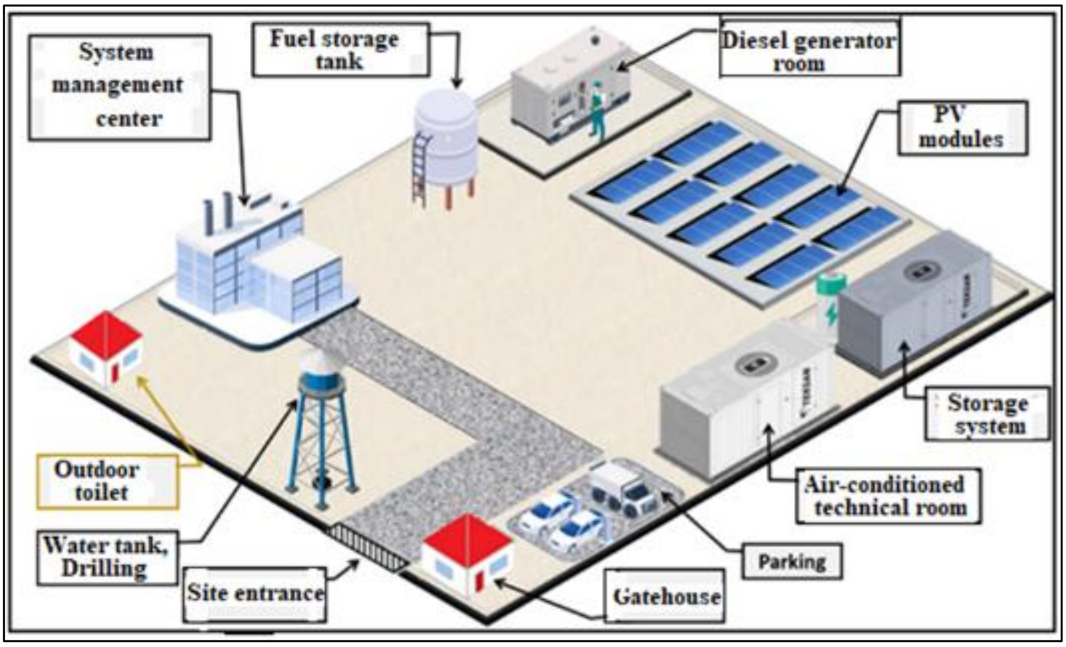

Figure 1 Interior architecture of the mini smart grid

Figure 2 Location of the power plant on the Koumnéré site (Google Earth software)

The daily energy consumption (Ed) of Koumnéré was determined earlier and is Ed = 600,644.689 Watt-hours/day (Wh/day). The choice of system voltage depends on this daily energy consumption. Table 6 gives an idea of the applicable voltage depending on the energy ranges.

Table 6 Choosing the system voltage based on daily needs

Daily Energy *Ed* (kWh)	***Ed* <1**	**1< *Ed* <4**	***Ed* >4**
System voltage *U* (V)	12	24	48

The power balance gives an estimate greater than 4 kWh; therefore, the system voltage we will use is 48 V.

Sizing the PV array essentially involves determining parameters such as the peak power, the total number of PV modules to be installed, the average PV module operating temperature, the average PV module efficiency, the minimum number of PV modules connected in series, the maximum number of PV modules connected in series, and the number of parallel branches, among others.

2.4.1. Sizing of the PV generator

Equations (3) to (9) are used to calculate, respectively, the peak power, the average operating temperature of PV modules, the average efficiency of a PV module, the minimum number of PV modules connected in series, the maximum number of PV modules connected in series, the number of parallel branches, and the total number of PV modules to install.

Peak power (P_P):

$$P_P = \frac{Ed}{C_P \times E_{in}} \quad (3)$$

Average operating temperature of PV modules (T_{avg}):

$$T_{avg} = T_{amb} + \frac{E_{in} \cdot (NOCT - 20)}{7.1 \times 800} \quad (4)$$

Average efficiency of a PV module (η_{avg}):

$$\eta_{avg} = \eta_{STC}\left[1 - \frac{\gamma\left(T_{avg} - 25\right)}{100}\right] \quad (5)$$

Minimum number of PV modules connected in series (N_{S_min}):

$$N_{S\_\min} = \frac{V_{\min}}{V_{mpp} \times 0.85} \quad (6)$$

Maximum number of PV modules connected in series (N_{S_max}):

$$N_{S\_\max} = \frac{V_{\max}}{V_{OC} \times 1.15} \quad (7)$$

Number of parallel branches (N_{pb}):

$$N_{Pb} = INT\left(SF \cdot \frac{Ed}{E_{in} \times \eta_{avg} \times \eta_{conv} \times A_{\text{mod}} \times N_{S\_\max}}\right) \quad (8)$$

Total number of PV modules (N_{mod}):

$$N_{\text{mod}} = N_{Pb} \cdot N_S \quad (9)$$

With

- *Ed:* Daily energy consumption (Wh/day);
- C_p: Coefficient that accounts for losses, C_p = 0.50 to 0.70;
- Ein: Solar irradiance of the location (kWh/m^2/day);
- T_{amb}: Ambient temperature of the location (°C);
- *NOCT*: Nominal operating temperature of the PV modules (°C);
- η_{STC}: Efficiency of the PV modules under STC (Standard Test Conditions);
- γ: Variation in PV module efficiency (%/°C);
- V_{min}: Minimum controller voltage;
- V_{max}: Maximum controller voltage;
- V_{mpp}: PV module voltage at Maximum Power Point;
- V_{OC}: Open-circuit voltage;
- 0.85: Reduction coefficient used to calculate the MPP voltage at 70 °C;
- 1.15: Reduction coefficient used to calculate the MPP voltage at 20 °C;
- *INT*: Integer part of the expression in parentheses;
- *SF*: Safety factor;
- η_{conv}: DC/AC converter efficiency;
- A_{mod}: PV module surface area (m^2);
- N_{Pb}: Number of parallel branches;
- N_S: Number of PV modules connected in series.

The PV module selected for this study is of the SE4-72H-P polycrystalline series from SunEvo Solar Co. Ltd. It was chosen because it is better suited to high-temperature areas, for its high efficiency (around 19.30%), and its remarkable characteristics summarized in Table 7.

Table 7 Characteristics of the PV modules used [10]

Model	**Polycristalline**
Efficiency	19.30%
Maximum power point, P_{mpp}	420 Wp
Maximum power point voltage V_{mpp}	39.55 V
Maximum power point current I_{mpp}	10.62 A
Open circuit voltage V_{oc}	48.25 V
Short-circuit current I_{sc}	11.17 A
Modules nominal operating temperature	45±2 °C
Temperature coefficient	-0.36 %/°C
Solar modules surface area	2.1735 m^2
Weight	23.3 kg

Regarding the tilt angle "i", it varies according to latitude. Table 8 allows to determine the value to use during sizing.

Table 8 Degree of tilt of the PV module as a function of latitude

Latitude *L*	**Inclinaison *i***
$L < 10°$	$i = 10°$
$10° < L < 30°$	$i = L$
$30° < L < 40°$	$i = L + 10°$
$L > 40°$	$i = L + 15°$

We note that the latitude of Koumnéré is L = 11°, which falls between 10° and 30°. Therefore, the tilt (i) and the latitude have the same value: i = 11°. Using PVGIS software, we obtained the solar irradiance data for the Koumnéré site, which are summarized in Table 9.

Table 9 Solar irradiance data for Koumnéré site

Month	**GHI: Global Horizontal Irradiance (kWh/m²/d)**	**G_{opt}: Global irradiance on an optimally inclined plane (kWh/m²/d)**	**G (11): Global irradiance on an angular plane (11°) (kWh/m²/d)**	**T : Temperature (°C)**
January	6.147	7.136	6.855	27
February	6.803	7.49	7.312	28.2
March	6.938	7.145	7.123	32.5
April	6.72	6.517	6.626	33.5
May	6.65	6.135	6.341	32.6
June	5.937	5.384	5.598	29.8
July	5.899	5.407	5.602	26.3
August	4.913	4.71	4.803	25.2
September	5.445	5.455	5.485	25.6

October	6.118	6.565	6.46	26.7
November	6.219	6.877	6.859	27
December	5.964	7.062	6.745	26.5
Year	**6.146**	**6.324**	**6.317**	**28.4**

With an 11° tilt angle, the average annual solar irradiance is 6.317 kWh/m^2/day. The results of the PV array sizing calculations, using equations (3) to (9) and the data from Tables 7 and 9, are summarized in Table 10.

Table 10 Results of the PV array sizing calculations

Characteristic parameters	Results	Variables and coefficients
Peak power	Pp = 158,473.0856 Wp	A loss coefficient of 0.67 was considered
Average operating temperature of PV modules (T_{avg})	Tavg = 55.903 °C	-
Average efficiency of a PV Module	η_{avg} = 17.15%	-
Minimum number of PV modules in series	N_{S_min} = 15	An inverter with an input voltage varying between 440 and 800V and an efficiency of 0.9 was chosen
Maximum number of PV modules in series	N_{S_max} = 16	-
Number of parallel branches	N_{Pb} = 21	-
Total number of PV modules	N_{mod} = 336	-

2.5. Battery bank sizing

Equations (10) to (13) are used for sizing the battery bank. They allow the calculation of the total required capacity of the battery, the number of batteries connected in series, the Number of parallel branches of batteries, and the total number of batteries, respectively.

Total required capacity of the battery bank (C_{req}):

$$C_{req}\left[Ah\right]=\frac{Ed\times DoA}{V_{syst}\times DoD\times\eta_{bat}} \quad (10)$$

Number of batteries connected in series (N_{Sbat}):

$$N_{Sbat}=\frac{V_{syst}}{V_{bat}} \quad (11)$$

Number of parallel branches of batteries (N_{Pbat}):

$$N_{Pbat}=\frac{C_{req}}{C_{bat}} \quad (12)$$

Total number of batteries (N_{Tbat}):

$$N_{Tbat}=N_{Pbat}\cdot N_{Sbat} \quad (13)$$

With:

- Ed: Daily energy consumption (Wh/day);

- *DoA*: Days of autonomy or number of days of storage;
- η_{bat}: Battery efficiency (75% – 90%);
- *DoD*: Depth of Discharge;
- V_{syst}: Batteries bank voltage;
- N_{Sbat}: Number of batteries connected in series;
- N_{Pbat}: Number of batteries parallel branches;
- V_{bat}: Nominal voltage of a battery;
- C_{bat}: Nominal capacity of a battery.

Batteries whose characteristics are listed in Table 11 will be selected for the battery bank.

Table 11 Characteristics of the chosen batteries [11]

Discharge current (A)	20
Nominal capacity (Ah)	4,700
Nominal voltage (V)	2
Depth of Discharge (%)	80
Weight (kg)	229.6
Dimensions (Length × Width × Height) (mm)	215 × 580 × 815

The results of the battery bank sizing calculations are summarized in Table 12.

Table 12 Battery bank sizing results

Characteristic parameters	Results	Data
Total required capacity of the battery bank (C_{req})	C_{req} = 17,379.765 Ah	*DoA* = 1 day; η_{bat}= 90%; V_{syst}= 48 V
Number of batteries connected in series (N_{Sbat})	N_{Sbat}= 24 batteries	-
Number of parallel branches (N_{Pbat})	N_{Pbat} = 4 branches	-
Total number of batteries (N_{Tbat})	N_{Tbat} = 96 batteries	-

2.6. Inverter sizing

Equations 14 and 15 are used to size the inverters.

Inverter nominal power (P_N):

$$P_N \geq \frac{P}{k} \quad \textbf{(14)}$$

Number of inverters required (N_{conv}):

$$N_{conv} = \frac{P}{\eta_{conv} \times P_{conv} \times \cos(\varphi)} \quad \textbf{(15)}$$

With:

- *P*: Peak power of all loads [W];
- *k:* Inverter load rate;
- P_{conv}: Rated power of a inverter [W];
- η_{conv}: Inverter efficiency;
- *cos(ϕ):* Overall power factor of loads.

The maximum voltage that a PV string can provide is crucial information for choosing the inverter. This maximum voltage is calculated using equation (16):

$$V_{\max} = N_{S\_\max} \times V_{OC} \times 1.15 \qquad \textbf{(16)}$$

The total power requirement for the Koumnéré locality (peak power of all loads) corresponds to a peak demand of P = 72,431.79 W. The integration of a coefficient k prevents the inverters from being loaded beyond k = 80% of their power rating to ensure their longevity.

The results of the inverter sizing calculations are summarized in Table 13.

Table 13 Results of inverter sizing

Characteristic parameters	Results	Coefficients
Converter power	$P_N \geq 90{,}539.74$ W	A safety factor of 0.80 was considered
Number of converter	N_{conv}= 1	η_{conv} = 0.987, $cos(\phi)$ = 0.80
Maximum PV field voltage (V)	*850*	

The data in Table 13 allowed us to choose the converter whose characteristics are given in Table 14.

Table 14 General characteristics of the chosen inverter [12]

Characteristic parameters	**Maximum efficiency (%)**	**98.7**
	Dimensions (mm)	995.5 × 693.5 × 368
	Weight (kg)	90
DC Input (PV field)	MPP minimum voltage (V)	500
	MPP maximum voltage (V)	850
	Absolute maximum PV voltage (V)	1,100
AC Output (Network)	Type	Three phases
	Frequency (Hz)	50/60
	Network voltage (V)	230
	Nominal AC power (W)	100,000
	Nominal AC current (A)	160

2.7. Diesel generator sizing

The choice of diesel generator must be made in compliance with the following conditions:

- The rated power of the diesel generator must be greater than the average power consumption of the site, in order to avoid overloading the unit and causing irreversible damage;
- Avoid choosing a very high-power output as this results in high fuel consumption relative to the needs;
- The rated power of the diesel generator must also be greater than the peak power and the inrush power of certain appliances;
- It is also recommended not to load the diesel generator beyond k = 80% of its power to guarantee its lifespan.

The total load power is P = 72.43 kW. Therefore, we will consider a power factor $cos(\phi)$ = 0.8.

Equations (17) and (18) allow us to perform the calculations of the characteristic parameters of the diesel generator.

Apparent power required by the load (S):

$$S = \frac{P}{\cos(\varphi)} \tag{17}$$

Apparent power of the diesel generator (S_{DG}):

$$S_{DG} \geq \frac{S}{k} \tag{18}$$

The results of the diesel generator sizing calculations are summarized in Table 15.

Table 15 Results of the diesel generator sizing

Characteristic parameters	Résultats	Coefficients
Apparent power of all loads	$S = 90.54\ kVA$	An overall power factor of 0.80 was used
Apparent power of diesel generator	$S_{DG} \geq 113.18\ kVA$	A safety factor of 0.80 was considered
Nominal power of diesel generator	$S_{DGN} = 113.18\ kVA$	An overall power factor of 0.80 was considered

The data in Table 15 allowed us to choose a 125 kVA diesel generator.

3. Results And Discussion

Following the analysis of statistical data from the fifth General Population and Housing Census (GPHC) conducted during 2019-2020, a daily requirement of 600,644.69 Wh/day was determined to meet the needs of the Koumnéré locality. To supply this electrical power, a Mini Smart Grid comprising a solar PV generator, a diesel generator, and a battery storage system was constructed. The PV generator consists of a field of 336 polycrystalline PV modules. It will be composed of 21 parallel branches, each with 16 PV modules connected in series. This PV generator will provide a peak power of 158,473 Wp. To compensate for the intermittent nature of the solar photovoltaic production, a 125 kVA diesel generator was also selected. A battery bank will store some of the photovoltaic energy during daylight hours and the excess output of the diesel generator when it is running. This bank, with a total capacity of 17,379.77 Ah, consists of 96 2V batteries. To meet the voltage requirement, it is configured as four parallel branches of 24 batteries connected in series. To handle alternating loads and for future grid injection, a 125 kVA inverter has been selected. This combination of several small-scale energy production sources with intelligent management planning constitutes a Mini Smart Grid [13], [14], [15]. However, other challenges remain to be addressed to enable it to fully fulfill its role of guaranteeing the population of Koumnéré a stable and sustainable supply of electricity while ensuring environmental protection. A smart control algorithm for this mini-power plant, defining optimal combination scenarios that take into account operational constraints, must be considered [16].

4. Conclusion

The objective of this study was to design a mini hybrid PV/Diesel power plant to supply electricity to the rural area of Koumnéré, a locality located in the Centre-South region of Burkina Faso. This area, not yet connected to the National Interconnected Grid (NIG), lacks sufficient electricity for the development of its various socio-economic activities. A daily requirement of 600,644.69 Wh/day was identified to meet household consumption (8.76%), social needs such as powering a school and providing street lighting (5.36%), and the needs generated by economic activities (85.88%). PVGIS software was used to generate the site's elevation data, while DIAlux software was used to design the lighting systems. A 158.47 kWp solar PV array was determined. A 125 kVA generator was selected based on the design calculations. To compensate for the intermittent production of the PV generator and to store the power produced by the diesel generator but not consumed instantaneously, a battery with a capacity of 17,379.77 Ah was determined. Since the loads must be supplied with alternating current, a 125 kVA converter was sized and selected. Given that this network has more than two energy sources, an Energy Management System (EMS) will be necessary to optimize energy distribution between these different sources.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Statement of Ethical Approval

The authors declare that this research did not involve any experimentation on humans or animals and was conducted in accordance with the ethics of scientific research.

Statement of informed consent

The authors assert that there has never been any experimentation on a human being or an animal. Consequently, they did not need any informed consent.

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