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Modelling and Optimization of Hydroelectric Power Plants in Cameroon for the Development of the Green Energy Market in Neighboring Countries Using Homer Software

Bachirou Bogno[1,2*], Michel Aillerie[2], Kitmo[3], Dieudonné Kidmo Kaoga[3*]

[1]Faculté des Sciences, Université de Garoua, Garoua, Cameroon
[2]Laboratoire Matériaux Optiques, Photonique et Systèmes (LMOPS), Université de Lorraine, CentraleSupelec, Metz, France
[3] Department of Renewable Energy, National Advanced School of Engineering of Maroua, University of Maroua, Maroua, Cameroon
Email: *kidmokaoga@gmail.com, *boogno@gmail.com

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Abstract

Renewable energy is increasingly in demand for a variety of applications in both urban and rural areas. There are, however, a number of implementation constraints in some countries, even though sunshine, wind and water are abundant and available. As part of this research, we are carrying out a technical and economic study on the availability of renewable energy in Cameroon, with a view to combining several sources of solar, biomass, wind and hydroelectric power to meet energy demand both inside and outside the country, in countries such as Chad, Gabon and Nigeria. In this work, the implementation of the entire system in the HOMER software demonstrates the feasibility and possibility of implementing a multi-source power plant based on renewable energies. Calculation of the levelized cost of energy (LCOE) and the net present cost (NPC) shows that a capacity of 485 GW can meet the energy demand of the countries bordering Cameroon. Furthermore, the calculation of the performance ratio gives a PR = 46.52 and a Capacity factor of CF = 11.64. The system is profitable not only economically but also environmentally, as it reduces greenhouse gas emissions and energy losses.

Keywords

Wind Plant, PV Plant, Hydropower, Homer, Renewable Energy

1. Introduction

Nowadays, the progress of any country depends on its level of development in the energy sector [1]. Therefore, the use and production of energy are essential vectors in the development of industries and isolated areas of electrical distribution points. Since isolated areas are often affected by frequent power cuts, which constitutes a major obstacle to the economic growth of the country [2]. It is therefore necessary to provide good quality and uninterrupted energy for the economic development of the region and to provide a high quality of life to rural or urban populations [3]. The main reason for the energy deficit in rural areas is the lack of extension of the electricity network [4]. However, this challenge can be overcome by injecting renewable energy sources with one or more sources into conventional sources [5]. These systems aim to provide continuous, good quality and sustainable energy to isolated areas [6]. The major advantage of using these systems is that they use renewable energy sources, which shows satisfaction and independence from fossil fuels and also solves the problem of the fossil fuel crisis. Overall, the use of renewable energy reduces carbon emissions, which in turn reduces global warming. Some recent studies have shown that there is a reduction in CO2 emissions every year [7]. However, the increase in temperature caused by global warming leads to floods. Furthermore, population growth, in turn, increases the demand for electrical energy, which can only be met by conventional energy sources. Some studies show that the global demand for energy consumption will increase by 29% of the current energy demand [8]. However, if this increase in energy demand is to come from conventional and traditional sources [9], it will have a catastrophic effect on the world and on future generations. Many techniques are widely used in all areas to enhance systems performance [10]-[12]. Knowing these challenges, the current trend in electricity production in the world is towards renewable sources as they are easily renewable and non-polluting [13]. However, renewable sources such as wind and solar cannot be used alone to meet energy demand due to their dependence on climate and weather conditions, which are very unpredictable [14]. To avoid the above problem, renewable sources must be integrated with conventional sources and storage devices to provide reliable energy to consumers, although the use of conventional sources causes some problems. Cameroon is among the countries that have ratified the Kyoto Protocol on climate change. This means that it must comply with the regulations, that is, make the most of renewable resources. The country has increased its production capacity from renewable resources from 1.47% to 4% in almost five years [15]-[18]. Cameroon has significant potential in solar, wind and hydroelectric energy, making it a major player in green energy in the Central African sub-region. In order to harness this huge renewable energy potential, the Cameroonian government has launched various programs such as the Green Cities Program, the Central Public Sector Enterprises Program, the Sustainability Gap Financing Program and the Solar Park Program. Indeed, a solar power plant has been connected to the electricity grid in the Guider area. Therefore, it is clear from the previous section that the current and future trends in energy production are through renewable resources, especially hybrid multi-source systems, to meet future increases in load demand. Therefore, the integration of solar energy sources with conventional (thermal) sources and storage devices offers a viable option to electrify remote areas and boost the country's economic growth. Several researchers around the world have conducted extensive work on analyzing the performance of renewable energy sources such as solar PV, wind, or biomass and their injection into conventional sources to meet the load demand. In order to analyze the performance of the entire multi-source hybrid system, researchers have considered various parameters such as performance ratio (PR), capacity factor (CF), grid efficiency, final yield, etc [19].

In this regard, the performance of 2.07 kWp grid-connected multi-source hybrid systems in Iraq. Another researcher examined the performance of an 8 kWp grid-connected solar PV system on the roof in Morocco, using Homer software. In the sense, Ahmed *et al.* analyzed a set of 14 kWp grid-connected solar PV panels and wind farm in Algeria. Furthermore, Ali *et al.* [20] used three simulation tools, such as Homer, Retscreen Expert and PVsyst, to analyze the performance of a 7 MWp grid-connected solar PV system on the roof in Morocco.

The technical-economic study of the overall production system is done in Homer, and the configuration of the electricity production scheme is done using renewable energy sources and conventional sources. Various studies and analyses have been conducted on the different types of configuration schemes in order to see their feasibility. Thus, Aman *et al.* discussed the economic analysis of a hybrid model using two storage systems, namely a battery and a hydrogen fuel cell, to meet the nonlinear load demand of the remote hydrogen region of Italy. In the same vein, Weng *et al.* [21] analyzed hybrid systems consisting of solar wind, battery, to electrify urban and rural areas of Somalia. In [22], the authors designed a sustainable method involving renewable sources for pumping potable water in the coastal region of India. Their hybrid model thus designed could meet the load demand of a small-scale plant. In [23] and [24], the authors studied the feasibility of PV-Wind-Battery-Converter and PV-Wind-Hydro-Bio-generator, PV-diesel-Battery-Converter systems, respectively in rural areas of Morocco and Italy [25]. In [26] the authors analyzed the impact of the power grid on the size of the different components that are involved in the design of the hybrid system considered. Moreover, Ali *et al.* [27] analyzed the optimal cooling system for solar panels. In [28] the authors studied a neural network-based power control scheme for distributed grid-connected generation of multilevel inverters. Subsequently, Hung *et al.* [29] studied the optimal performance by doing the techno-economic study of grid-connected PV systems integrated into the building of a region of Egypt. In [30], the authors observed that the cost of energy (COE) obtained for the grid-connected solar PV system is lower than that of the grid-only system. In [31], the authors analyzed the performance of a hybrid system in terms of the highest renewable fraction (RF) and the lowest percentage of unmet annual load.

In this paper, a feasibility study was conducted using HOMER Pro software. This software is widely used by most researchers around the world [32]. HOMER Pro offers a more user-friendly interface compared to other simulation tools such as Retscreen Expert, PVsyst etc… Moreover, a study done in the literature shows that HOMER gives the best results in terms of PR and energy production for hybrid power plants. In addition, HOMER provides optimal solutions close to reality and does not take into account primary and secondary algorithms. Some studies show that HOMER takes less time than other software [33]. Considering the availability of energy resources in different CEMAC countries, the analysis of the results of countries such as GABON, Cameroon, Chad and Nigeria made it possible to define a hybrid model to meet the demand of the populations of these different regions of Africa as depicted in Figure 1. Based on the data and results obtained, it is clear that the integration of renewable energy systems with conventional systems better mitigates the demand for energy of a large capacity. Hence, there is a problem of intermittent power supply in rural areas or areas far from national or sub-regional power distribution lines. However, a number of factors must be taken into account to judge the feasibility of the proposed models, including the selection of energy sources based on the performance of the available resources. Therefore, attention must be paid to the impact of the penetration of renewable energies on the economy of the system considered.

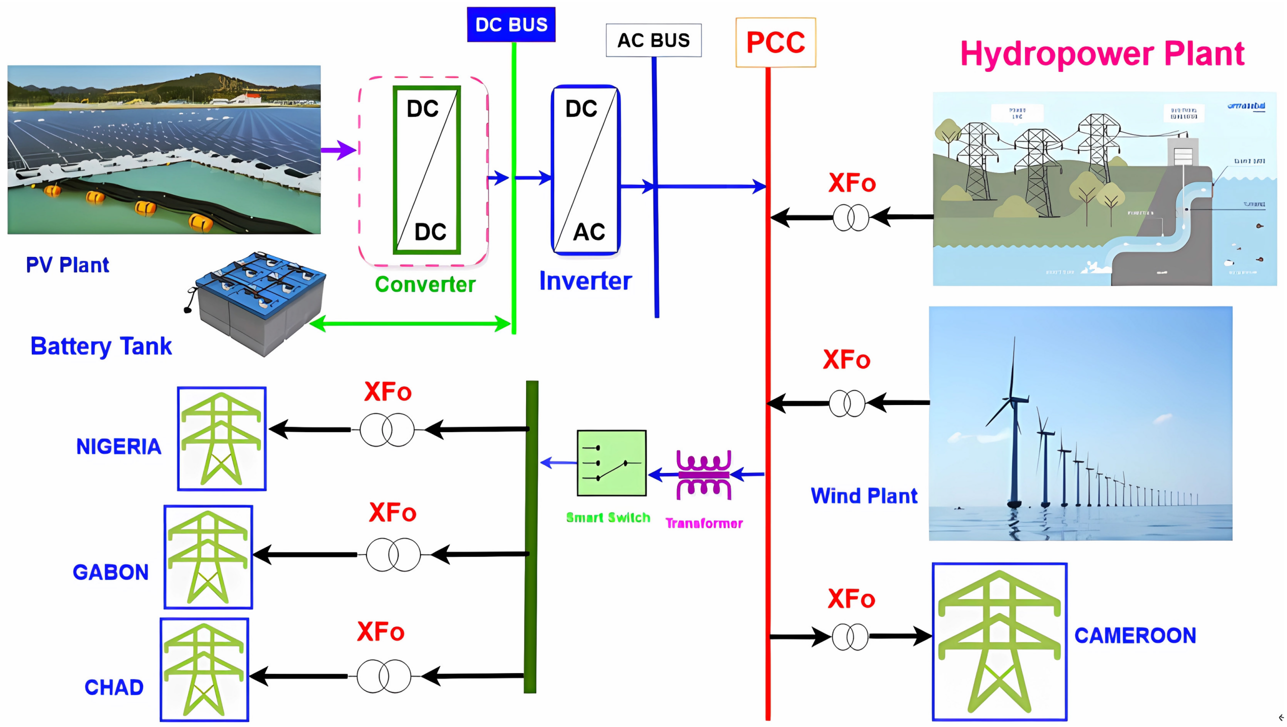

Figure 1. Configuration of the selected site.

2. Meteorological Condition and Load Estimation

The proposed study is retained in Cameroon in the locality of Lagdo. It is located in the northern part of Cameroon. Its geographical coordinates are 23.4013˚N and

88.5021˚E. This area is affected by excessive power cuts throughout the year and the extension of the electricity network is necessary not only for this locality of Cameroon but also for the countries of the sub-region. Due to the shortage of electricity, the economic growth of the region has been slowed down. However, the site benefits from a high level of solar radiation due to the passage of the Tropic of Cancer in this region and a wind speed sufficiently high for the operation of wind turbines. In addition, this area has significant water for the installation of an additional hydroelectric power plant compared to what has existed since 1982 [34], the date of its creation. This study aims to analyze the performance of solar PV, wind, hydro in this region and to integrate solar and wind energy with conventional sources to limit the damage caused to households due to energy deficit. Local weather and data such as ambient temperature and solar irradiance are essential factors to estimate the performance of solar PV and wind. The selected site weather and climate data are obtained from NASA Power Data Access Viewer [35]. The monthly average Global Horizontal Irradiance (GHI) for Lagdo locality is considered to be recorded at 4.82 kWh/m²/day, with maximum GHI observed in March (7251 kWh/m²/day) and minimum in April (3123 kWh/m²/day) as shown in **Figure 2**. Therefore, the monthly average Brightness Index (CI) for Lagdo is recorded at 0.53. Furthermore, the meteorological data indicates that the ambient temperature for this site locality is between (16.88˚C - 25.40˚C) with an average ambient temperature of 45.12˚C as shown in **Figure 3**. The load estimation for the site considered was obtained through a field survey of 500 households. The survey revealed that the majority of the essential electrical load requirements are for household appliances such as ceiling fans, water pump motor, lighting, television, etc. The daily demand of 800 households is estimated to be 78256.39 kWh with a peak load demand of 0.6 MW. The daily and monthly load profiles for the selected site are presented in **Figure 4** and **Figure 5**, respectively.

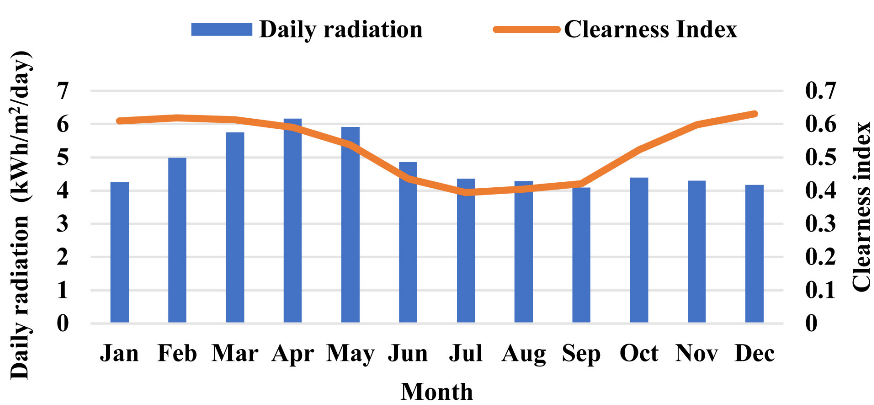

Figure 2. Solar and clearness index collected.

3. Configuration of the Proposed Hybrid System

This work presents a methodology that allows to understand the main articulations of the proposed method. It evaluates the data of the different sites of Nigeria,

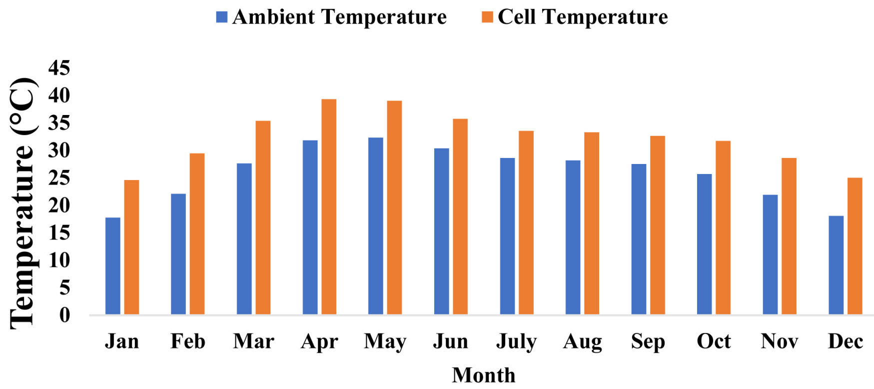

Figure 3. Temperature data collected.

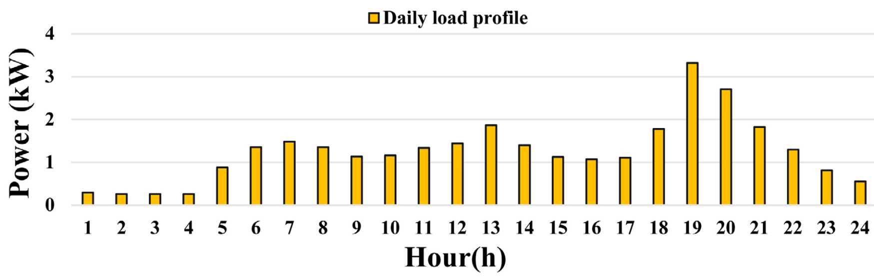

Figure 4. Load profile for the selected site.

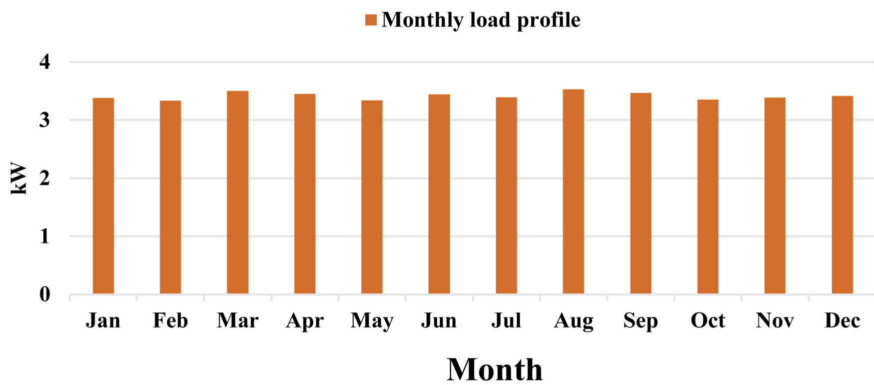

Figure 5. Monthly profile for the selected site.

Cameroon, Chad and Gabon and analyzes them in order to make an interpretation of the results at the end of the section. This system describes a functional diagram developed using the HOMER Pro software, as illustrated in Figure 6. Various data evaluations were carried out, including load and resource evaluations of the selected sites. The implementation of these HOMER parameters makes it possible to make simulations that provide values to be analysed using performance indicators. Regarding the solar system, the resource evaluation, solar irradiance and ambient temperature of the selected sites are taken into account knowing that these indicators have a direct impact on the type and size of photovoltaic solar energy production. The resource evaluation, the load demand estimated by the different countries led to an evaluation of the load at the connection points.

For the simulation, real-time cost information of the various components considered in the overall system design, as well as load details of the four selected sites, these values are provided as input parameters of HOMER Pro. The influence of temperature and sunshine on a solar field are also considered in this study, as is the wind speed at the various sites. After various techno-economic and comparative analyses are carried out, a conjecture is made. The time series data obtained from the simulation are analyzed to obtain different performance indices of the solar PV and wind system of the selected sites. Through an economic analysis carried out on the system, an optimal model based on the lowest net present cost (NPC) and COE has been proposed. Based on an environmental impact analysis of different configurations obtained from the simulation results, an ideal configuration based on the minimum amount of pollutants emitted has been proposed. This methodology of searching for an optimal solution for the selected areas has made it possible to propose a configuration, which is based on various technical-economic parameters such as COE, NPC, RF, PR and carbon emissions. Figure 6 represents this configuration in Homer Pro.

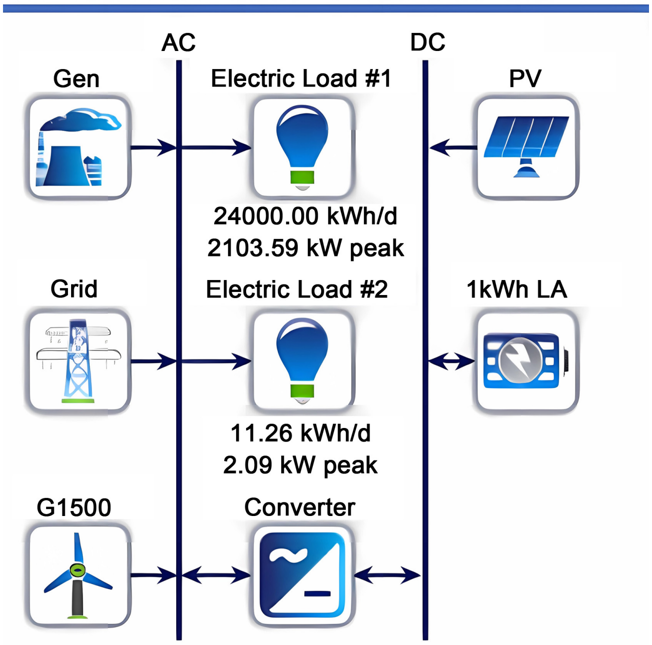

Figure 6. Configuration in Homer Pro.

4. Hybrid System Power Generation

The multi-source system consists of a solar PV system, a wind system, a hydroelectric power plant, a battery energy storage system and a smart inverter. A schematic representation of the system is shown in Figure 7. The operation of the solar PV system is described by the generation of a current by the solar radiation striking the solar PV panels with a specific inclination, which in turn converts these radiations into electrical energy. The direct current generated at the output of the chopper by the solar PV system is converted into alternating current by an inverter. The BESS system is included in the system to ensure a reliable and continuous and optimal energy flow.

4.1. Photovoltaic Power Generation

Among all renewable resources, solar energy and hydropower are the most used because of their ease of maintenance and implementation, hence they can be used to produce electricity in remote areas of Cameroon given the large and abundant deposits of sunshine in the northern regions of Cameroon. The energy produced by the solar photovoltaic system always depends directly on the amount of solar irradiation present at the location considered. Equation (1) represents the general expression for estimating the output power of a solar photovoltaic system regardless of the type of solar panels.

$$P_{pv} = Y_{pv} f_{pv} \left(\frac{G}{G_r} \right) \left[1 + \alpha_p \left(T_c - T_{cr} \right) \right] \tag{1}$$

The temperature of the cells is often higher than the ambient temperature during the day. This may be due to the abundance of solar radiation during the day. Unlike at night, the ambient temperature is the same as the cell temperature due to the absence of solar radiation. Considering the value of transmission and absorption of solar radiation, the analysis shows that it can be estimated as 0.88. Therefore, calculations can be performed to estimate the temperature of photovoltaic solar cells using the following Equations (2) and (3) [36].

$$\tau\alpha G = nG + U \left(T_c - T_a \right) \tag{2}$$

$$T_c = T_a + G \left(\frac{\tau\alpha}{U} \right) \left(1 - \frac{n}{\tau\alpha} \right) \tag{3}$$

Considering no load, the efficiency of the photovoltaic solar cell can be estimated to be zero at NOCT under standard conditions. Hence the value of $\tau\alpha / U$ can be determined using equation

$$\frac{\tau\alpha}{U} = \frac{T_{C,NOCT} - T_{a,NOCT}}{G_{NOCT}} \tag{4}$$

When considering $\tau\alpha / U$ as constant and by substituting the Equation (4) in the Equation (3), we can have the Equation (5)

$$T_c = T_a + G \left(\frac{T_{c,NOCT} - T_{a,?NOCT}}{G_{NOCT}} \right) \left(1 - \frac{n}{\tau\alpha} \right) \tag{5}$$

Canadian Solar's All-Blacks CSK-290 MS monocrystalline solar PV system has proven superior to other cell types due to its efficiency and durability. The work in [37] shows that it also produces more energy than other solar PV panels due to the presence of back-contact cells with a frame and black sheet. Given this proof of efficiency, the CSK-290MS is used in this paper for the analysis of simulation results. The input data of Homer Pro allows for a capital cost of the solar PV array of $8575, with an operating and maintenance cost of $452 per year.

4.2. Battery Energy Storage System

A storage system is used in this paper as described in the overall system configuration. This device is intended to ensure continuous and uninterrupted operation of energy at the connection point. The type of battery bank used in this system is lead-acid battery. The choice of this battery is based on its performance in addition to its low investment costs and ease of maintenance. The investment and replacement costs of these types of batteries are estimated at $510 and $410 respectively. The operating and maintenance cost is also estimated at $25 per year. The parameters of this battery allow for a maximum capacity of 48,000 Ah. These types of storage systems are used for solar fields on large areas.

4.3. Converter

The overall system integrates a DC to AC converter of the smart inverter type. A converter of this type is used to convert DC to AC and vice versa. For this installation, the investment and replacement costs of the inverter are estimated at $900 and $700 respectively. The costs allocated to operating and maintenance expenses are estimated at $20 per year. The converter life for this installation is estimated at 26 years. Furthermore, the converter efficiency estimated at 96.6% is a performance indicator for the feasibility study of the proposed system.

4.4. Wind Turbine Power Flow

The Wind Turbine produces a mechanical power output (P_{WT}) from the wind turbine depending on the intensity of the received wind speed. A part of the kinetic energy of the wind is transformed into electrical energy through the famous formula as follows:

$$P_{WT} = \frac{1}{2} C_p \rho v_{Turbine}^3 \tag{6}$$

where $v_{Turbine}^3$ is the wind speed, describes A the sweep area of the turbine blades and ρ is the density of the air present at the blades. Wind turbines operating between a maximum wind speed where the blades must be feathered or at a minimum wind speed used for their start-up, this condition is determined by engineering considerations and for the safety of the mechanical system, it is a minimum wind speed called the cut-in speed, which is ultimately determined by the friction in the mechanical system. The output power of the turbine is reached at a maximum, or nominal, value, which also corresponds to a nominal wind speed, in order to protect the turbine.

5. Hydropower Plant System

This excitation system block generates the excitation voltage that powers the synchronous generator. Controllers are utilised to govern both the generated excitation voltage and the mechanical power provided by the turbine. Its source is given as a direct current generator with a commutator. The equation is to set value for voltage output V_R used to control the excitor

$$\frac{V_R}{E_{FD}} = \frac{1}{K_E + sT_E} \tag{7}$$

The reason for considering these three as results to observe the

- Effects it has on the rotor part of generator machine of generating system.
- The voltage level on the whole generating side during operation.
- Excitation field voltage level determines for the output voltage from the generator part, controlled by the connected excitation system.
- Rotor speed will be kept in control by governing system, which regulates water flow into turbine. It helps to maintain the frequency rate of Mechanical part and Electrical part of the system.

By using these elements described above and consulting, in MATLAB Simulink, a simulation model of a hydro power plant of 45 MVA, 52.4 KV 50 Hz rating that will supply to load connected to it via a step-up transformer of rating 28.45 KV/280KV is created. The hydropower system employed here is used to represent islanded mode, solely delivering power to a load of 47 MW in all cases.

6. Evaluation of the System Performance

The objective of the proposed system configuration is to determine the performance of the installation while remaining within the standards and guidelines issued by the IEC 61724 standard. This is why the assumptions are issued as reference values in terms of the preservation of the environment and the study area and implementation of the proposed system. Several performance indices are chosen to evaluate the essential size of the capacity of the total energy production of the hybrid system. The parameters that allow to validate the proposed system in order to study the performances are the system efficiency, the final efficiency, the reference efficiency, the PR, the CF, the system loss and the system capture loss. These indicators are important when we want to evaluate the energy efficiency of such a system.

7. Inverter Output Power

The energy obtained from the solar PV is in the form of DC. The DC output of Solar PV is converted to AC energy by considering the efficiency of the converter. This is given by the following expressions in Equation (8).

$$E_{AC} = \mu E_{DC} \tag{8}$$

where μ is the converter efficiency and is assumed to be 95%.

8. Performance of the System

It depicts about the losses that take place in the system. These losses are inverter loss, heat loss, wiring loss, environmental loss etc. The PR of a solar PV system is defined as the ratio of the final yield to the reference yield. It is expressed in percentages. It shows how near the solar PV system is to achieve its optimal performance. Mathematically, it can be expressed in Equation (9).

$$\text{PR} = \frac{Y_{final}}{Y_{reference}} \tag{9}$$

9. Capacity Factor

The capacity factor may be defined as the ratio of actual AC energy output obtained from solar PV to the energy produced by the solar PV when operated at its rated capacity for 24 hours per day for the whole year. It is expressed in percentages. Mathematically, it can be expressed in Equation (10).

$$\text{CF} = \frac{E_{AC,yearly}}{Y_{PV\ rated} \times 24 \times 365} \tag{10}$$

10. Techno-Economic Analysis

Considering the solar, wind and hydro potentials of the different countries in the sub-region, an optimal configuration of the multi-source system design was determined. The economic feasibility and profitability of the project were determined using some performance indicators such as COE and NPC, which are determined using Homer Pro software. To talk about best performance in terms of system configuration, the COE and NPC obtained should be as low as possible as indicators of the best configuration. For this system implemented from real data, the NPC and COE for different system configurations are provided using Equations (11) and (12), respectively.

$$\text{NPC} = \frac{C_{yearly\ total}}{CRF\left(i, R_{project}\right)} \tag{11}$$

$$\text{COE} = \frac{C_{yearly\ total}}{E_{served}} \tag{12}$$

The present discounted cost of the installation depends on the overall annualized cost of the system. This value is obtained by using the initial capital investment, the cost of replacing, operating and maintaining the various components of the multi-source plant as well as the fuel prices over a period of 25 years [38]. In addition, the salvage value of the components also has an impact on the cost of the system considered since it is involved in the amortization of maintenance costs. It is also the remaining value associated with the components after the life of the project that is considered as the value of the depreciation cost. This salvage value is proportional to the remaining life in years of the components used in the installation. The present discounted cost also depends on the real discount rate and the life of the project. The present discounted cost and the COE are important indicators in the feasibility study of projects [39]. It is due to these essential parameters that the technical-economic study is possible. These are aspects to be taken into account in the study and economic analysis of systems in the Homer Pro software. The COE is the ratio between the total annual cost of the system and the total electrical load to be supplied. The loads that are generally considered are made up of the primary load and the deferrable load. In other words, the COE can be considered as the average cost of electrical energy produced per kWh.

The Fraction ratio obtained is determined using Cameroon data as a baseline. It is an important measure that defines the technical feasibility of the system. When the RF increases, the carbon or CO_2 emissions of the system also decrease. Equation (13) is used to determine the renewable fraction in %.

$$\text{RF} = \frac{P_R}{P_T} \tag{13}$$

11. Results and Discussion

In order to evaluate the performance of the system, which consists of solar photovoltaic, wind power, and hydraulic power plants that can be installed in Cameroon to supply the Central and West African sub-regions, certain parameters are chosen. Several parameters must be considered to determine the feasibility of the project. We have parameters such as network efficiency, final efficiency, reference efficiency, system loss, network capture loss, CF and PF. The energy yields of the multi-source system are determined using climate data from the HOMER Pro software. The energy efficiency of the conversion stage is estimated at 96.5%. At the chopper level, the average annual energy yield of the converter is 70% for photovoltaic energy, 78.8% for wind turbines and 80% for the hydraulic power plant. An average continuous conversion efficiency for Cameroon is 67.74 kWh, considering that the maximum energy efficiency is observed in March (62.81 kWh) and a minimum in April (40.55 kWh). It should be noted that the unfavourable weather is in July and August when the atmospheric CI is very low, this also results in a low energy efficiency. But thanks to the integration of the wind power plant, these values have been corrected. These results can be observed in **Figure 8**. Furthermore, in the Chad area, the maximum solar radiation and the CI are determined and obtained respectively in April and December. The data obtained by the Homer software show that the maximum photovoltaic solar energy production was obtained in March. However, during this time, rainwater is lacking, and the water level in the dams' water tanks can decrease. This is how the importance of involving the natural resources of other countries such as Gabon, Chad, Nigeria are important. This indicates that factors such as temperature play an important role in determining the production of photovoltaic solar energy, as does wind for wind energy and water for the energy that can be produced from the hydroelectric power plant. We then note that the average annual production of energy from the multi-source system is 152 GWh if we take into account the natural resources or potentials of the different countries. **Table 1** summarizes the indicators that allow the feasibility study of the multisource system. The values of CF and PR for the selected countries are reported in **Table 2**.

The profiles of available resources per country are depicted as shown in **Figure 7**. The provided energies based on selected areas and their potentials is given in

Table 1. Comparison of different scenarios.

Parameters	PV-Hydro-Wind-Battery-Converter	PV-Hydro-Wind-Battery
Initial cost ($)	2560.235	22458.845
Operating cost ($)	1254.235	816.87
NPC ($)	186544.325	2541.456
COE ($/kWh)	1.324	0.315

Table 2. Countries data comparison.

Sites	PR (%)	CF	Mean
Gabon	48.63	13.13	23.88
Cameroon	46.52	11.64	12.61
Chad	45.86	29.50	46.25
Nigeria	58.452	44.25	53.445

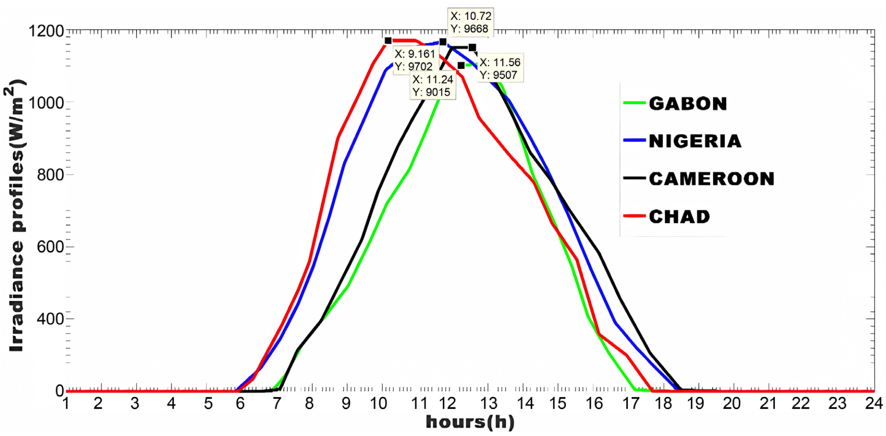

Figure 7. Countries PV resources.

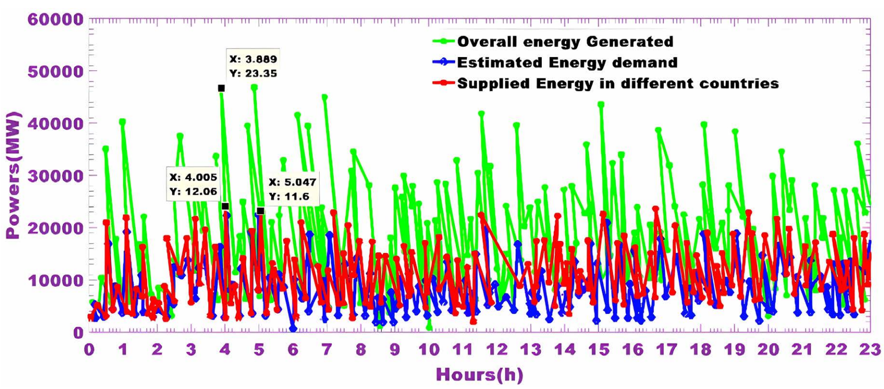

Figure 8. Load power profiles.

Figure 8. We have also the provided energies based on selected countries resources depicted in Figure 9.

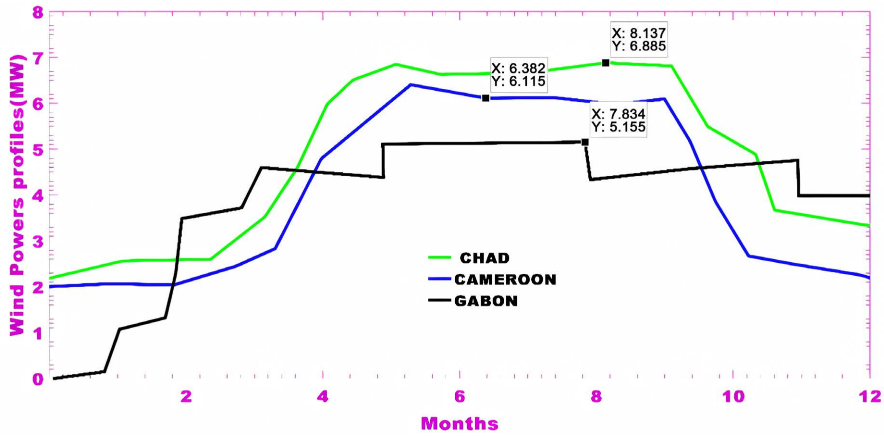

Figure 9. Wind power profiles for the selected site.

12. Conclusion

This article focuses exclusively on the technical and economic study of multi-source PV-wind-hydraulic systems to provide energy at reasonable prices to meet the energy demand in Cameroon as well as the needs of neighbouring countries such as Gabon, Chad and Nigeria. The exploitation of climate data from these countries made it possible to propose a model of a renewable energy system which is carried out by evaluating solar, wind and hydraulic energy resources in Cameroon. The analysis and interpretation of the results are done on the basis of the potentials of multi-source PV-wind-hydraulic systems. The performance indices make it possible to evaluate the proposed system. The results obtained are satisfactory and well within the range provided by the standard in force. Furthermore, it has been proven that the location is very suitable for the implementation of such a system. In addition, the study shows that the system architecture composed of 33.12 kW of hydro, 54.45 kW of wind, 80 kWh of battery and 54.55 kW of converter shows the optimal result for the location considered in terms of the lowest NPC and COE were determined, as for the RF and the lowest carbon emissions, a compromise was also found in the compatible range. The NPC and COE were estimated at 12536.458 and 0.457 dollars/kWh respectively. The study shows that the majority of the energy supplied comes from hydroelectric plants for the proposed configuration compared to the photovoltaic or wind system. This study also allows to conclude that the economic aspects of the system such as the COE or NPC are estimated at 81.5% for a configuration that is composed of solar, wind, and hydroelectric plant. For this type of configuration, carbon emissions represent only 1.68% of the base system. These results allow to conclude that the proposed system is more profitable, economical and obeys the constraints related to the environment and offers a very low price for the consumption of electricity. The study of the proposed system shows that the increase of the derating factor of the hybrid system can lower the COE and the NPC of the whole system. In addition, an increase in the ambient temperature and the diesel fuel rate increases the COE and the NPC in the case of the proposed system. Furthermore, the study shows that as the RF increases, the COE of the system decreases. These data allow to conclude that once the system has switched to a hybrid topology, the value of the COE decreases with an increase in the RF of the overall system. Therefore, it is concluded that the design of an electricity production model based on autonomous renewable energy offers a viable alternative for the electrification of remote areas in Cameroon and other neighbouring countries. These types of configurations not only produce green and sustainable energy, but also and most importantly, provide an affordable cost. In order to promote the feasibility of this system, the support of the government and policy makers is encouraged to be able to reduce the overall investment cost of the system by means of subsidies.

Conflicts of Interest

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

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