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Modeling and Simulation of a Solar Multifunctional Platform

Deli GORON*
Department of Renewable Energy,
National Advanced School of Engineering,
University of Maroua, Cameroon
P.O. Box: 46, Maroua, Cameroon

Talla Konchou Franck Armel
Department of Energetic, Environment and Thermal, IUT-FV Bandjoun, UR-ISIE, University of Dschang, P.O. Box 134, Bandjoun, Cameroon

Donatien Njomo
Environmental Energy Technologies Laboratory (EETL), Faculty of Sciences, University of Yaoundé 1, P.O. Box 812, Yaoundé, Cameroon

Abstract:- In rural area, many people still lack access to energy necessary for their sustainable livelihoods, development and self-reliance. They legitimately aspire to an energetic security just as a food security. It is well known that the diesel multifunctional platforms (MFP) make an effective contribution to the fight against poverty through the energetic services rendered. However, they contribute to the global warming that's why one to exploring new sources of cleaner energy, free for all. Solar photovoltaic generator is chosen for this substitution. A simulation of different operating modes of the solar MFP is carried out in normal period of sunshine, in autonomy mode operating and in maximum load opérating. A dynamic simulation of the solar MFP is also detailed over the course of a year depending on variations in weather conditions and energy demand.With the help of a power losses diagram, we describe the operating principle and the management of the solar MFP in different operating mode which revel that:p the system performance index is 0.673 with a solar fraction of 97.1%. If the initial investment cost of a solar MFP is more than 3 times that of the diesel MFP, then just the maintenance and the mending cost of a diesel MFP can cover the cost of investing in 3 solar MFP or in 10 diesel MFP in a period of 20 years. Furthermore, a solar MFP will avoid about 7.07 eqt.CO2 of greenhouse gases per year.

Keywords:- *Solar Multifunctional Platform - Energy Poverty - Greenhouse Gases – Management Of Solar Multifunctional Platform.*

I. INTRODUCTION

Energy is the most important factor for economic development and prosperity of any country. It is directly related to the global key challenges that the world faces poverty alleviation, global environmental change and food security [1]. In sub-Saharan Africa, more than 90% of the rural population still has no access to electricity [2], to modern energetic services for heating and lighting, to the supply of potable water, to refrigeration, to agricultural transformation necessary for its human and economic development. Recognizing the importance of energy for sustainable development, the United Nations General Assembly has designated, by its resolution 65/151, the year 2012 as the International Year of Sustainable Energy for All [3].

Energy poverty complicates the daily task of the African rural woman who does not have enough time to devote for her blooming. Lack of time is therefore an important cause but unrecognized of poverty which particularly affects women and children. It is in this context that the United Nations development Programme (UNDP), in its fight against poverty objectives, has dissimilated in certain African countries, especially in West Africa and a little in East Africa some diesel multifunctional appliances commonly called multifunctional platforms.

Indeed, a multifunctional platform is a mechanical and electrical energy source supplied by an 8 to 12 CV diesel engine mounted on a frame onto which various equipment can be connected such as; mills or grinders, battery chargers, electric water pumps, nut or vegetable presses, weld machines, carpentry tools, electric sub network path for lighting [4].

There are several types of platforms: standard diesel MFP constituted of a 10 to 12 CV diesel engine with diesel fuel consumption; biodiesel MFP where the oil extracted from jatropha's grains is used as fuel in standard diesel engine; hybrid MFP using fossil and solar energy as source; MFP connected to an electric sub network; MFP connected to a potable water supply System [5], [6].

In the philosophy of this concept, a platform offers energetic services for productive, social, individual and collective uses. Energy services therefore helps to save both human energy and time, and raise the possibility of income generation, poverty reduction and human development [7].

Weingart Jerome M. showed that MFP helps in increase of the economy and productivity in rural areas of Africa and the Philippines by providing to the populations, energy services needed for development [8]. He also describes how to manufacture Jatropha oil, bioenergy fuel for MFP and alternative potential to diesel [9], made a comparative analysis of solar installations and diesel MFP in rural zones of Ghana and Burkina Faso. He highlights the importance of energy services rendered and the choice difficulty between the two systems. Nygaard Ivan studied the concept of MFP in West Africa [10]. He went through the history of MFP and gives their importance towards human development of rural populations in a context of decentralization and popularization of energy. Sovacool et al. introduced the rural energy situation in Mali and described the history of the MFP project. Then, they discussed the benefits of the project achieved, as well as five sets of challenges the MFP faces: a growing number of nonfunctional platforms, lack of policy coordination, poverty, dependence on imported technology and fuel and patriarchy [11].

However, even if these diesel multifunctional platforms are an effective solutions to the fight against poverty, they nevertheless certain limits: the diesel engine is a source of pollution that generates two types of emissions: greenhouse gas (GHG) emissions and harmful gases which have respectively a negative impact on the environment and on human health [12] [5]; the supply of diesel fuel in rural areas which are sometimes far away from traffic roads are difficult; noise and regular engine defaults are often registered; finally, according to experts in geopolitics of energy, the exhaust of petroleum reserves will be in about 40 years. Thus, in an effort not to only contribute to environmental protection and human health but also to improve the functioning of multifunctional platforms, we have proposed to replace the thermal engine with a solar photovoltaic generator. This work is in line with the objective of reducing greenhouse gas at a level to limit global warming to below 2°C formalized by the United Nations Framework Convention on Climate Change (UNFCCC) since the Cancun 2010 summit in Paris and then to continue the action to limit the temperature increase at 1.5°C [13]. For this feasibility study, the participative planning unit (PPU) of Mordok consisting of ten (10) villages and 4,000 inhabitants with the focal village is Mordok was chosen as pilot town. Situated in the Far North region of Cameroon, Mayo-Kani division, Moutourwa subdivision, the geographical coordinates of Mordok are latitude 10° 12' 13.7" North and longitude 14° 04' 44.8" East.

The solar generator will supply a maximum power of 10 hp compared to the diesel engine of the same power and will guarantee the same or more services.

This article is divided into four sections. The second section describe the adopted method which successively consist of: an evaluation of the greenhouse gases avoided from a solar MFP; a precise evaluation of foreseen energetic demand and a master of the load profile; a solar MFP modeling. Section 3 analyzes and gives different results from models developed in section 2. This section also describes the behavior of a solar MFP in its various operating scenarios and makes a comparative analysis between a solar and diesel MFP. Finally, Section 4 is reserved for the conclusion.

II. METHOD

2.1. History

After the undertaken efforts to adapt the traditional cereal mill to the energetic need of the rural population, many modifications were done giving rise to the concept of multifunctional platform. During the 1990 to 2010 period, the platform concept was dominated by the standard MFP constituted of a diesel engine supplying many modules like the cereal mill, the peeler, the water pump, the welding post and lighting, etc. From the year 2010, the MFP concept was oriented on the development of alternative sustainable technologies and to ameliorate the technical performance. This is how the mixed MFP constituted of two energy sources (fossil and solar) took over. Here, the solar generator supplies the energy for water pumping and for the lighting. This type of MFP was for the first time experimented in 2011 in Burkina Faso [6].

In the trial to exploit solar radiations, the abundant and available energy source that abound Africa. Mauritania has gain interest in the solar MFP concept in the second program phase. Here, each platform's module is constituted of a solar kit. That is, to every MFP module, corresponds a mini PV system for its functioning. We will talk of grinder kit, freezer kit, battery charger kit for example, each constituted of a PV module, regulators and batteries. This type of platform which is an association of kits do not enter in the light of multifunctional platforms which we have defined.

A solar multifunctional platform is therefore constituted of solar exchange that can supply many modules simultaneously (see Fig. 1). Up to today, the literature on MFP and our field trip that we have undertaken do describe this type of platform.

The solar MFP is hence a new concept which aims to ameliorate the needed functioning MFP by using clean energy sources with respect of the environment.

2.2. Characteristics of a solar MFP

Through its solar generator, a MFP is aimed at (Fig. 1):

- Providing a vital minimum to the rural population which include potable water, health, watering.
- Stimulating the economic development with its multifunctionalities. This development will pass through the creation of employment, the modernization of artisanal activities in the village, the motorization of grinders and peelers, irrigation.
- Improvement the living standard of the populations with lighting and the use of communication and telecommunication means [14].

A solar MFP therefore makes it possible to offer energy services for productive, social, individual and collective uses while respecting the environment. In fact, solar PV is a source of renewable and clean energy. As such, the solar MFP is respectful of our human environment in that it saves us bad performances compared to a standard MFP. It does not emit harmful pollutants and greenhouse gases for our environment. Indeed, it is thanks to the light of the sun transformed into electricity by means of the photovoltaic cells that the modules of the platform are constantly supplied without interruption.

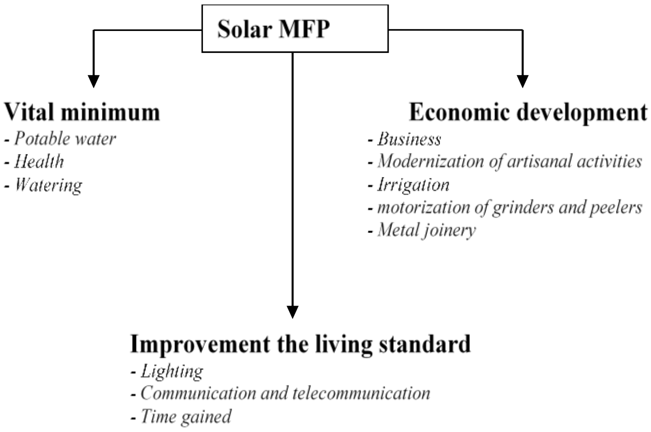

Fig. 1: Multiservice of a solar MFP

2.3. Energy situation in rural sub-Saharan Africa: case of Mordok

The main sources of energy used in Mordok are those found in rural areas of sub-Saharan Africa.

- Biomass: nearly Nearly 730 million people in sub-Saharan Africa rely on the traditional use of solid biomass for cooking typically with in efficient stoves in poorly ventilated space [2] [15]. In Mordok, 100% of the population uses it for cooking, heating water with wood and charcoal fuels provided by the natural forest. Agricultural residues such as peanut shells, cotton stalks, millet and maize stalks and rice husks are also used as fuel. According to a study carried out in the far-north region of Cameroon in 1997, each inhabitant consumes not less than 1.65 kg of firewood per day in the [16] [17].This brings to a daily consumption of 3300 t of firewood for the 2,000,000 inhabitants living in rural area in the Far-North region. For the poorest people in the world, especially those who live in the poorest countries, the most inelastic segment of demand for energy is that for cooking and heating to ensure basic survival.

This "household energy" is often poorly understood by development planners at large and within the energy sector it is often not considered in policies that historically have been focused on electricity supply rather than other house hold fuels [15], [18].

- Solar energy is used in its raw and traditional state to dry the skins of animals and clothing; keep the meat and dry the crops. In the northern part, particularly in the far north of Cameroon, solar radiation averages 6.214 kWh.m-2 [19]. The solar potential in the study area can therefore be estimated at 11.4 GWh per year.

- Petroleum products (Kerosene, gasoline and diesel) that we encounter are from the Cameroonian society of petroleum deposits (CSPD) and Nigeria with contraband gasoline still called 'Zoua Zoua,' which is the main illegal product exported to the countries of the franc zone [20].

2.4. Assessment of GES emissions from a standard MFP

The exhaust gases are the main source of pollution. They are due to the combustion reaction of fuel (gas oil) with air whose non complete combustion equation [21], [5] can also be written as:

$$C_xH_y + \upsilon_{air}(O_2 + 3{,}77N_2) \rightarrow \upsilon_{CO_2}CO_2 + \upsilon_{CO}CO + \upsilon_{CH_4}CH_4 + \upsilon_{H_2O}H_2O + \upsilon_{NO_2}NO_2 + \upsilon_{O_2}O_2 \quad (1)$$

With υi the stoichiometric coefficient of the compound i.

The amount of GHG emitted is given by the following equation 2:

$$GHG\left(tCO_2Eq\right) = \begin{bmatrix} Activity \\ quantity \end{bmatrix} \times \begin{bmatrix} Emission\ factor \\ (tCO_2Eq / quantity) \end{bmatrix} \quad (2)$$

2.5. Energy demand

Energy demand is basically for lighting, cooking and the powering of household appliances such as televisions, audio systems and electric motors for grinding food. However, most farming operations, especially irrigation and rural drinking water pumping machines, also need electricity for their operation [15] [17] [22].

The multifunctional platforms must adapt to the energy needs of people. This flexibility character is based on the evaluation and estimation of the villagers' needs. These energy needs can be divided into two (02) categories according to whether they are mechanical or electrical in nature: the electrical needs mostly for lighting of homes, health centers, educational and community centers, charging batteries, pumping water and welding; mechanical loads consist of a sheller, a grain mill, nuts or vegetables pressers. Fig. 2 shows some energy services rendered by a solar MFP.

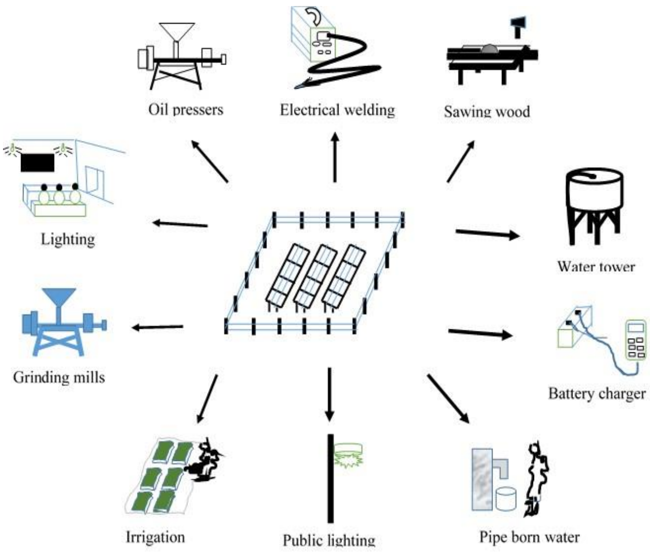

Fig. 2: Data sheet of a multiplatform.

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2.6. Consumption profile management

By assumption, the energy supply will consist of a generator which can deliver a useful electrical power of 10 Hp or 7.36 kW for the operation of the various equipment. It is therefore necessary to define an energy demand profile so as to avoid overload problems in the mini-network. Thus, a more rational management of consumption is necessary.

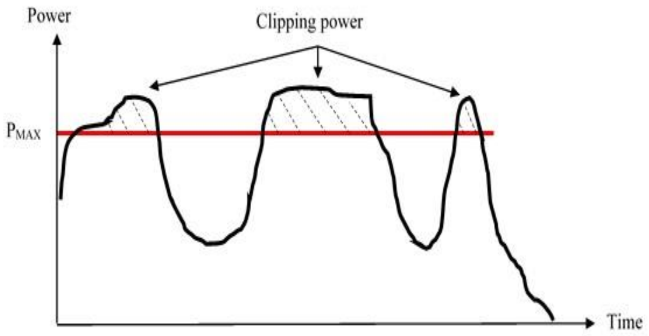

Fig. 3: clipping action on load profile

Clipping consumption consists of limiting the power of use at a given moment of the day to a maximum value. It is an action that limits the power demands on the network [23] [24]. Fig. 3 illustrates the clipping action on a load profile.

For the shape modification of the load profile, the energy consumed by the load remains constant, but the consumption profile is modified. This change is made by:
- A time lag (Fig. 4-a) which consists of moving a load over time. This offset is to prevent overloads in a time of day when several devices are turned on;
- An amplitude modulation (Fig. 4-b) which consists in modulating the shape of the load profile. Indeed, the principle is to consume in a short time with significant power or consume longer with less power [24].

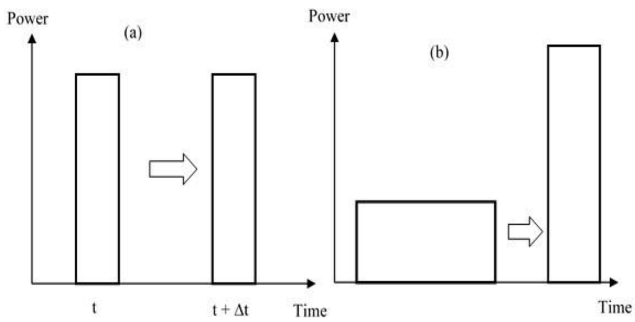

Fig. 4: time lag (a) and amplitude modulation (b)

The shedding of consumption load consists in no longer supplying energy to the user. This phenomenon occurs when the energy supply is not able to meet the energy needs of the use [24].

2.7. Evaluation of the solar field

The database used consists of three full years of measurements recorded in Kolara (latitude 10.263620 ° North and longitude 14.644086 ° East), from 2011 to 2013. The data were collected using a standalone Vantage Pro weather station [13].

Based on the daily changes of the overall solar radiation on the horizontal plane, the database can be divided into three categories: Adverse month, average months and the most favorable months (Table 1).

Table 1: Different types of monthly irradiation

Type of Period	Month	Daily Mean Irradiation (Wh/m2)
Unfavorable	July, August	5200
Mean	June, September, December, January	5750
Favorable	February, March, April, May, October, November	6400

2.8. Solar MFP modeling

A solar MFP has the general configuration of a photovoltaic system and includes a photovoltaic field, a solar thermal controller, a storage system, an inverter and the load (Fig. 5).
To determine the output power of a PV field, several models have been developed, including the Borowy and Salameh model or the Lu Lin model developed in 2004 [25], [26], [27].

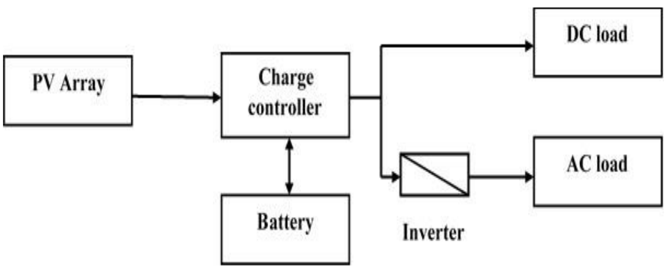

Fig. 5: Components of a solar photovoltaic system.

In this work, we will use the five-parameter numerical model where the power produced by the PV field is given by equation (3),

$$P = N_{\text{mod}} V \left[I_{ph} - I_0 \left[\exp\left(\frac{(V + IR_s)}{Avt} \right) - 1 \right] - \frac{V + IR_s}{R_{sh}} \right]$$
(3)

This power is influenced by irradiance, temperature and wind speed. At its point of maximum power, it is defined at each instant by the relation (4):

$$\begin{aligned} P_{mp}(t) &= N_{\text{mod}} I_{mp} V_{mp} \\ &= N_{\text{mod}} I_{mp,ref} \frac{G(t)}{G_{ref}} \left[V_{mp,ref} + \beta_{Voc} \left(T(t)_c - T_{c,ref} \right) \right] \\ &= N_{\text{mod}} I_{mp,ref} \frac{G(t)}{G_{ref}} \left\{ V_{mp,ref} + \beta_{Voc} \left[T_a(t) + \alpha(1 + \beta T_a(t))(1 - \gamma W)(1 - 1,053\eta) G(t) - T_{c,ref} \right] \right\} \end{aligned}$$
(4)

With N_{mod} total number of PV modules in the field.
- There are several types of regulator including serial regulator, shunt regulators, Pulse Width Modulation (PWM)

regulators, and Maximum Power Point Tracker (MPPT) regulators [28], [29]. It is this last type of regulator we will use. It allows to control the static converter, connecting the load and the photovoltaic panel, so as to permanently provide maximum power to the load [30].

- The inverter is modeled by its power efficiency. It characterizes the efficiency at maximum load (maximum efficiency) and at partial load (European efficiency). The maximum efficiency of the inverters is not very significant for the design of a photovoltaic system as the inverter works most often at partial load and rarely at full load [31].

$$\eta_{euro} = 0.03\eta_{5\%} + 0.06\eta_{10\%} + 0.13\eta_{20\%} + 0.10\eta_{30\%} + 0.48\eta_{50\%} + 0.20\eta_{100\%} \quad (5)$$

nx% is the inverter efficiency for x% of the nominal power of the load.

- The model of the storage system used is the one which enables to calculate the energy storage capacity as a function of the power generated by the PV array and load. Given that the power generated and consumed data are taken at the hour scale, we shall assimilate these data to energy capacities expressed in Wh. The model in question allows to determine the state of charge of the battery at a given time t by considering not only its state of charge at the time t-1 but also the energy generated by the PV array and that consumed by the load.

When the power generated by the PV array is greater than that consumed by the load, the battery charges. This operating state is described by the battery's energy capacity modelled by the equation (6) [32]:

$$E_b(t) = E_b(t-1).(1-\sigma) + \left[\eta_{reg}.E_{pv}(t) - E_L(t)/\eta_{ond}\right].\eta_{bat} \quad (6)$$

Where $E_b(t)$ is the energy stored in the battery at the time t, (Wh); $E_b(t-1)$ is the energy stored in the battery at the time t-1, (Wh); $E_{pv}(t)$ is the energy generated by the PV array at the time t, (Wh); $E_L(t)$ is the energy consumed by the load at the time t, (Wh) and σ is the self-discharged rate; η_{ond}, ηbatt and η_{reg} respectively represent efficiencies of the inverter, the battery and the controller.

When the load's energy consumption is greater than the energy generated by the PV array, the battery discharges. The energy available in the battery at a given time t is then given by equation (7):

$$E_b(t) = E_b(t-1)(1-\sigma) - \left[E_L(t)/\eta_{ond} - \eta_{reg}.E_{pv}(t)\right] \quad (7)$$

The energy stored in the battery is then constraint to obey expression (8) below:

$$E_{b,\min} \le E_b(t) \le E_{b,\max} \quad (8)$$

Where Eb,max is the authorised maximum energy stored. This energy equal is to the nominal energy storage capacity Eb,n of the battery bank.

Eb,min is the authorised minimum energy stored

The state of charge SOC is given by equation (9):

$$SOC(t) = \frac{E_b(t)}{E_{b,n}} \quad (9)$$

The wiring system influences the performances of a photovoltaic system. We shall reduce the voltage drop in wires using equation (10) [25], [28], [29], [31].

$$V(t) = \frac{2\times\varphi_c\times L\times I(t)}{S} = 2\times R\times L\times I(t) \quad (10)$$

Where φc is the resistivity in the copper electrical wire (Ω.m); R the resistance per unit length (Ω.m-1); L the total length to and fro; I the current (A); S the wire cross section area (mm).

2.9. Sizing

Based on energy demand and solar radiation measured at the study site, sizing the PV system is made using PVSyst 6.23 which is a simulation software and sizing of solar photovoltaic autonomous and connected the network.

2.10. Simulation Principle

The sizing characteristics and results necessary for the simulation are given in table 2 below:

Table 2: Technical slip of the platform's sizing

operating voltage of the System	120
Peak power of the PV field (kWp)	21,60
Number of PV modules	90(5X18)
Storage Park capacity (Ah)	1747
Maximum yield of regulator	97%
Nominal power (kVA)	12
Daily load (Wh)	119058
Atonomous day	2

From the model proposed above, the operating principle and the behaviour of the solar multifunctional platform are described by the simulation synoptic diagram of Fig. 6.

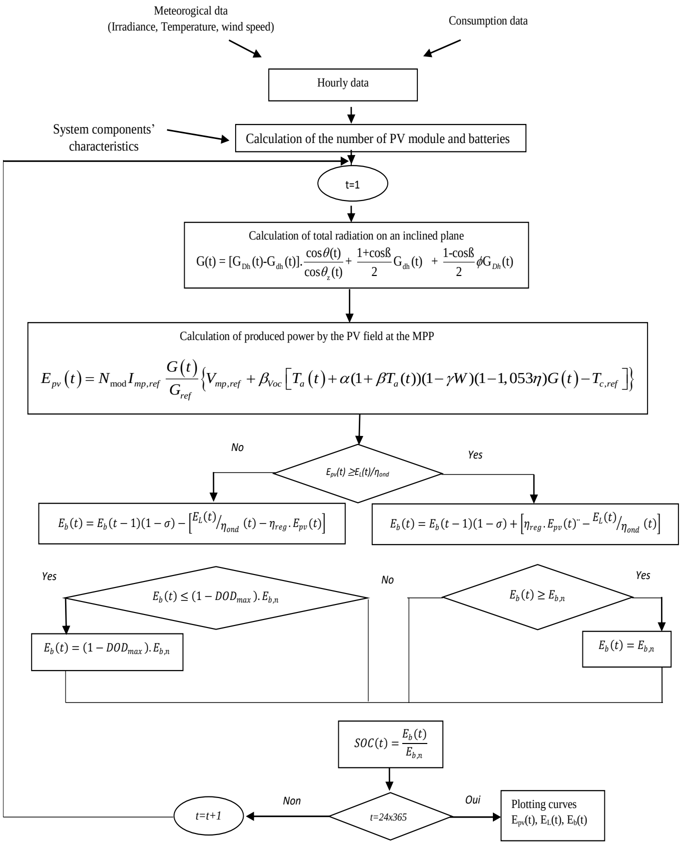

Fig. 6: Block diagram of the control platform

III. RESULTS AND DISCUSSIONS

3.1. The Load

Fig. 7 shows the load curve of the studied site. The main peak on this curve lies between 10 am and 4 pm. Indeed, it's a deliberate choice to run a maximum number of loads during this sunny period. These devices operate over the sunny period in view of the high energy produced by the PV field. We also notice 2 sub peaks just after sunset (6pm and 7pm) and just before sunrise (4 am and 5 am). These sub peaks are mainly due to the high energy needed by the water pumping system at that time of the day.

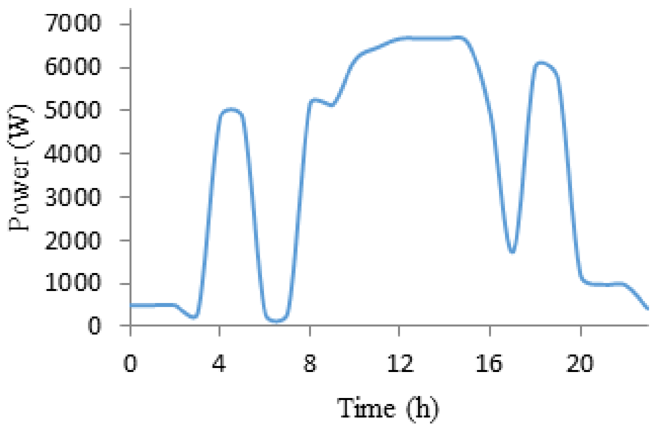

Fig. 7: load curve of the platform

3.2. Unregulated operating

Fig. 8 shows the simultaneous evolution in real time of the power generated by the PV array, the load power and the behaviour of the storage system.

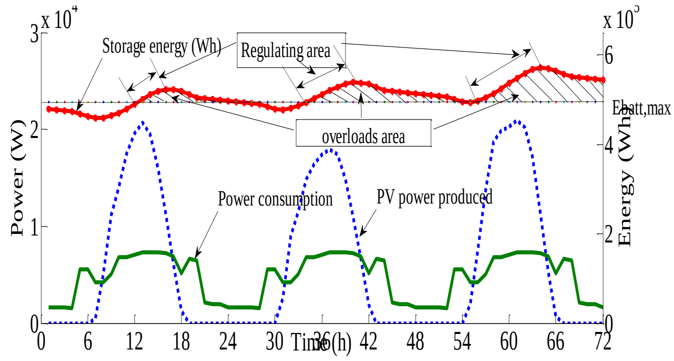

Fig. 8: Operation without control of the PV system.

We notice that at certain moments of the day, the state of charge of batteries is above its maximum level (shaded areas). This phenomenon is due to the fact that, although the load is satisfied and the batteries fully charged, the PV generator still generate current: thus there is overload of the batteries. This situation could destroy the batteries because there is gasification.

3.3. Regulated operating

To solve the problem of overloading of batteries mentioned above, the system needs to be regulate by acting on the parts of the curve of increasing energy stored and which are above the maximum level of the battery bank (see Fig. 8).

Indeed, the state of charge of batteries at the time t being a function of its previous time t-1, we take the value of the stored energy at every time of this zone to be regulated equal to the maximum energy of the battery bank. In this case, there is the link breakage of the PV array-storage. Fig. 9 is a revised and regulated layout of the previous operating mode partitioned into 3 zone types (numbered 1, 2 and 3) characterising the change of the system's operating state.

-The storage system is in discharging mode when the power of the load is greater than the generated power. In this case, the batteries discharge. This is described by parts numbered 1 of Fig. 9.

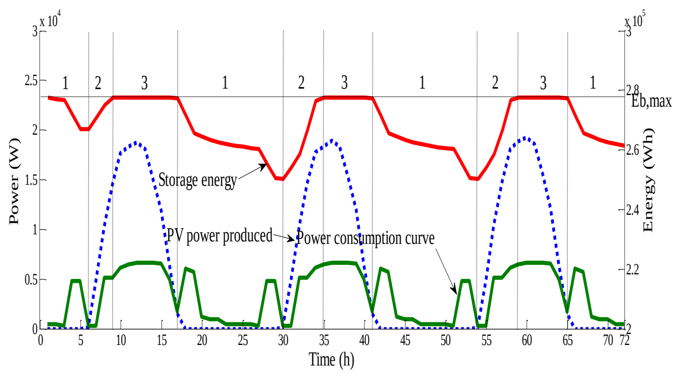

Fig. 9: in regulated mode System Operation

-The charging mode only comes in when the generated power is greater than the power of the load. In this case, the batteries are charging as shown by the parts numbered 2 of Fig. 9.
-The full charged mode is achieved when the batteries are full and all the generated power is directly used or consumed. It is the operating over the sunshine. This operating mode is described by the part numbered 3 of Fig. 9.

3.4. Autonomy mode operation

In this operating mode, the PV array does not generate any current for a given period. During this time, the batteries must satisfy the loads. This operating mode is described by Fig. 10 in its second part indexed A.

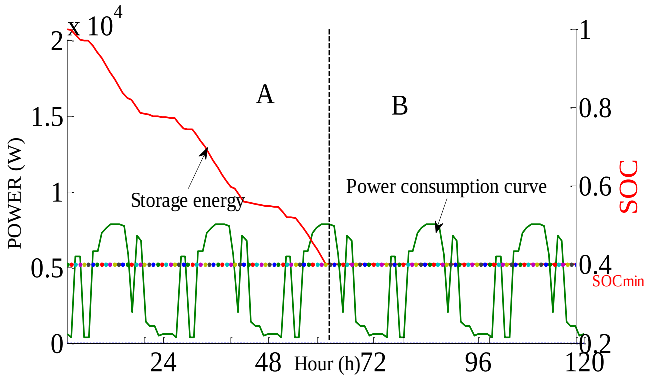

Fig. 10: Demonstration of the autonomy of the PV system

We notice that the storage system can satisfy the energy needs for 2 days as indicated during the pre-sizing of the system.

In its third day, the system stops operating. This is explained by the fact that, not only the energy in the storage system can no more satisfy the load but also for protection reasons of the batteries, it is necessary to break the link to prevent more energy from being extracted and to go below the minimum required level. This phenomenon is described by the part indexed B of Fig. 10.

3.5. Maximum load operating mode

We talk of maximum load operating mode when throughout the day, the power of the load is equal to the useful and maximum power of the system (here 7.36 kW). Fig. 11 is an illustration of this operating mode.

We notice that the system can operate for 4 days (indexed part A): consumption is not mastered and PV system, in bad shape, covers this period thanks to the autonomy reserve. The storage system can no more reach its full charged. On the fifth day, the batteries are completely discharged and can only charge at 10% of the daily energy capacity. We then understand that the system can no more satisfy the load (indexed part B of Fig. 11).

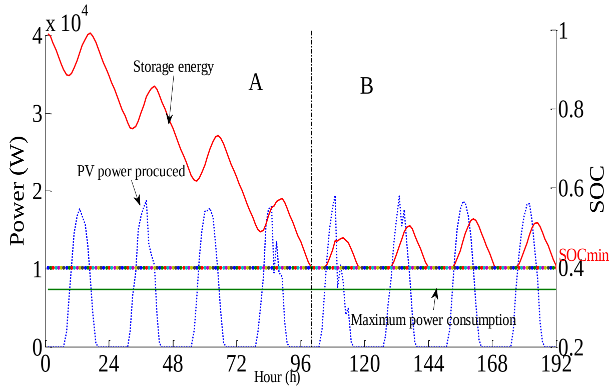

Fig. 11: Maximum load operation of the PV system

3.6. Behaviour of the solar MFP in the raining season

During the raining season (Fig. 12), the climatic conditions are unfavourable to electricity generation from PV panels due to the solar intermittency caused by the cloudy sky. This is why based on the energy supplied to the user, the energy need is only satisfied at 90% during the month of August, 92.5% for July and 95% for June. The batteries are therefore highly solicited with a depth of discharge reaching 55% for the month of August. To solve this problem of unsatisfied energy need, it is necessary to oversize the PV system (PV generator and batteries) or put off some appliances. The second solution seems to be more plausible and so we shall revise the operating time of the water pumping system given that we can get water from rain during this period.

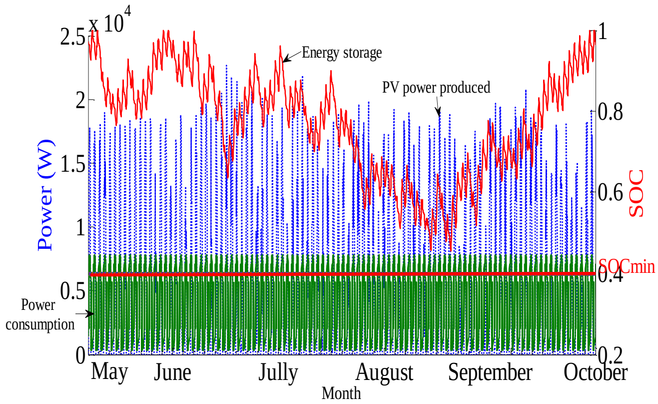

Fig. 12: Behaviour of the solar MFP in the raining season

3.7. Behaviour of the solar MFP during the dry season

During the dry season (Fig. 13), the climatic conditions are favourable to electricity generation. The energy needs of the user are completely satisfied and the batteries rarely discharge below 10% of their nominal capacity. When the batteries are fully charged, the system loses about 11% of the installed peak power as shown by the following Fig. 14

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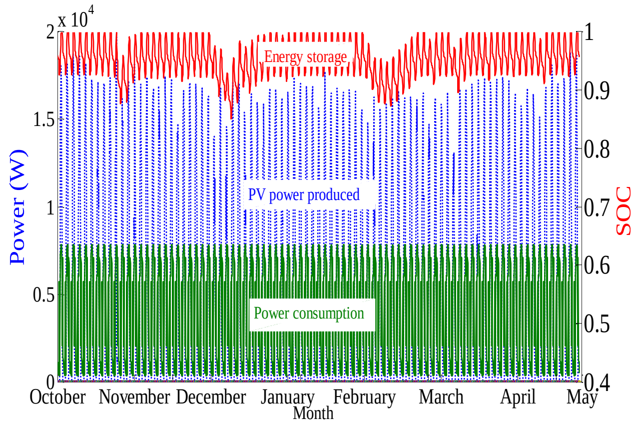

Fig. 13: Behaviour of the solar MFP during the dry season

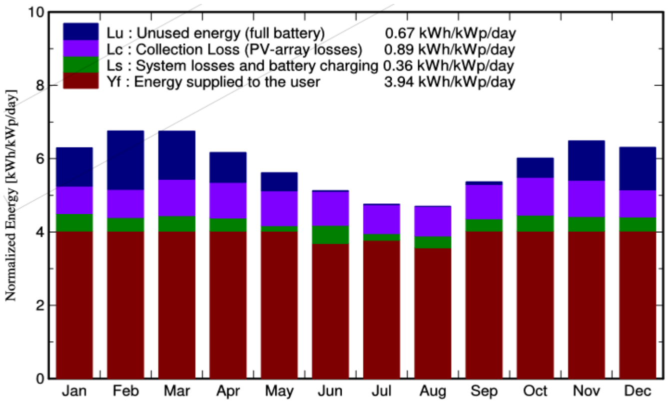

Fig. 14: Normalized productions (per installed kWp)

3.8. Diagram of the solar MFP losses throughout the year

Fig. 15 gives the energy balance sheet of the solar MFP with all the losses obtained at every subsystem. This balance sheet is obtained using PVsyst software.

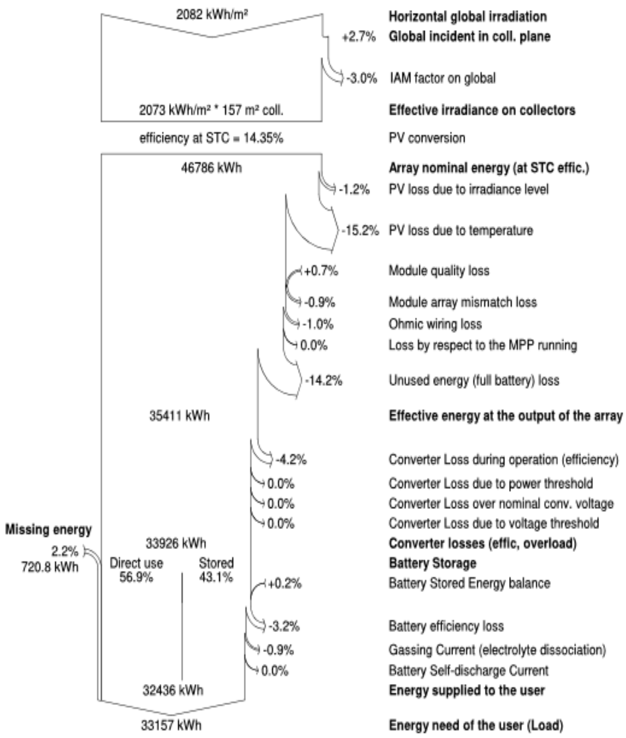

Fig. 15: Diagram of the solar MFP losses throughout the year

The actual energy received on the plane receiver is dependent on the inclination of the PV modules (gain of 2.7%) and of the IAM factor (-3%). Thus, for the radiation received on a horizontal plane with a value of 2082 kWh / year, effective energy is obtained 2073 kWh / year on receiver plane.

In nominal condition, the energy of the PV array taking into account the yield (14.35%) of the modules and the surface of the module: we obtain an annual energy of 46,786 kWh.

The effective energy at the output of the PV array estimated at 35411 kWh/ year, takes into account the losses due to the level of irradiance (-1.2%), losses due to the temperature field (15.2%), loss due to quality of the modules (+ 0.7%), loss due to the field by set match (-0.9%), wiring ohmic losses (-1.1%), losses due to unused energy (-5.6%).

The converters losses reduce the effective energy at the exit to the PV array -4.5% giving the value of the energy at the output of the converter.

This energy, 58.3% will be directly used and 41.7% will be stored. The stored energy will suffer losses due to battery efficiency (-2.5%) and losses due to electrolyte dissociation current (-3.1%). Hence the energy supplied to the user is estimated at 32184 kWh.

Knowing that the annual energy needs are estimated at 33157 kWh, there is a lack of energy supplied of 972.4 kWh that is 2.9%. This shortage of energy is explained by the fact that, since the software PVsyst sizes and simulates in real time and given that the meteorological conditions in the rainy season is not good, the production system cannot correctly meet the energy demand in such periods as shown in Fig. 16.

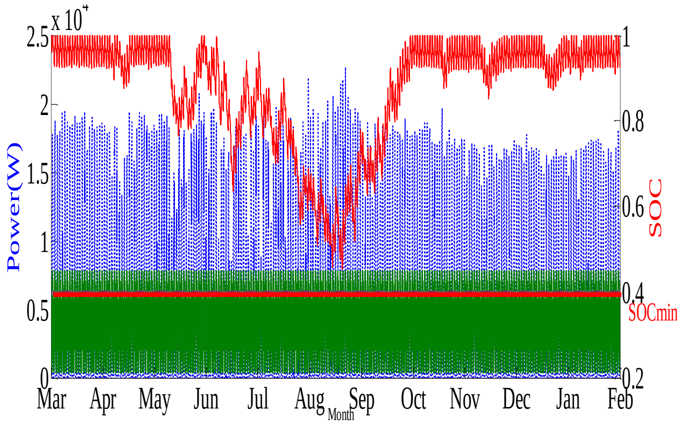

Fig. 16: Simulation of the operation of the solar MFP during a year.

The performance ratio (PR) is 0.673. This is the measure of the general quality of the system which is the global efficiency as a function of the installed power. It is the ratio of the standardized quantity of energy supply to the user to the reference nominal quantity of energy received by collectors. This ratio is more or less considerable during the raining season than the dry season (See Fig. 17).

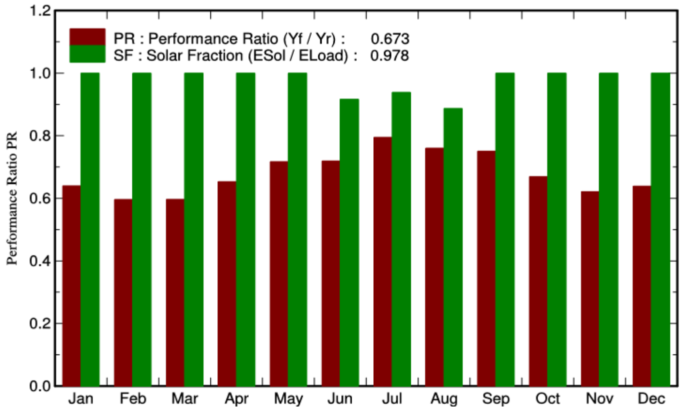

Fig. 17: Performance Ratio and Solar fraction of Solar MFP

The annual solar fraction is 97.1%. This is the ratio of the energy supplied to the user to the user's energy need. This ratio just defines the equilibrium of the energy supplied to user and the energy need of the latter. This ratio is equal to 1 throughout the year except for the months of July (0.825) and August (0.83) where the energy production is not optimum.

As regard to the state of charge of the batteries, it is averagely 86% of its nominal capacity as shown by Fig. 18

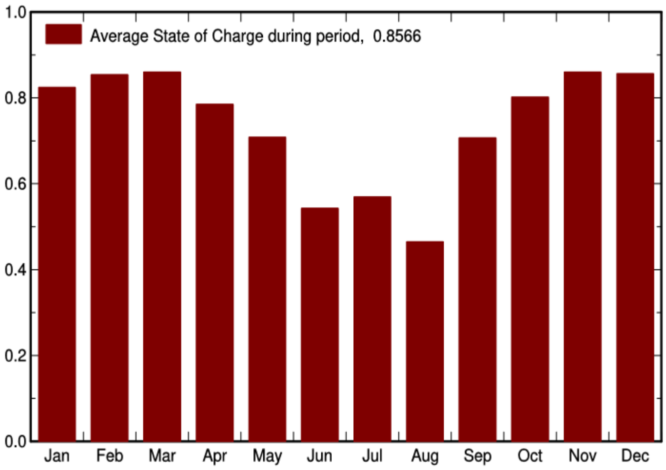

Fig. 18: State of charge of solar MFP during one year

3.9. Comparative analysis of a solar MFP and a diesel MFP

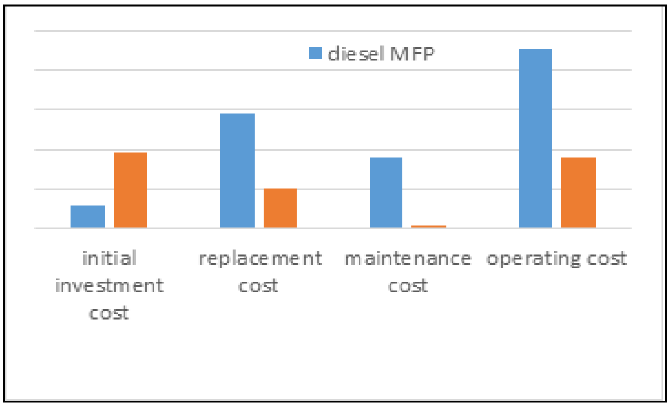

Fig. 19: Comparative analysis of a solar MFP and a diesel MFP

3.9.1. Initial investment cost criteria

The initial investment cost of a standard MFP of 10 to 12 CV is 11,211$ (6,600,000 FCFA) [6]. This cost is multiplied values found between 4 and 10 when the electric and pumping systems are taken into account; this is based on the flexibility of the MFP not only because the engine's power goes from 12 to 22 CV but also that the MFP is extended by the addition of certain equipment. In these conditions, our calculations show that the initial investment cost of the solar MFP is four (04) times greater than the diesel MFP (Fig. 19).

3.9.2. 20 years economic operating cost criteria

For the diesel MFP of 22 CV, replacement and maintenance are more costly than that of the solar MFP. Our calculations show that the replacement cost of the equipment of a standard MFP is trice that of a solar MFP. These costs of replacement can help in setting up 01 solar MFP and 02 diesel MFP. As for the maintenance cost, that of a standard MFP is thirty (30) times that of a solar MFP. The maintenance of a diesel MFP for 20 years can help in setting up 01 solar MFP and 04 diesel MFP. Thus, the operating cost that is the maintenance and servicing of a diesel MFP with water pumping system and electricity for a period of 20 years can be used to set up 03 solar MFP (Fig. 19).

3.9.3. Environmental impact criteria

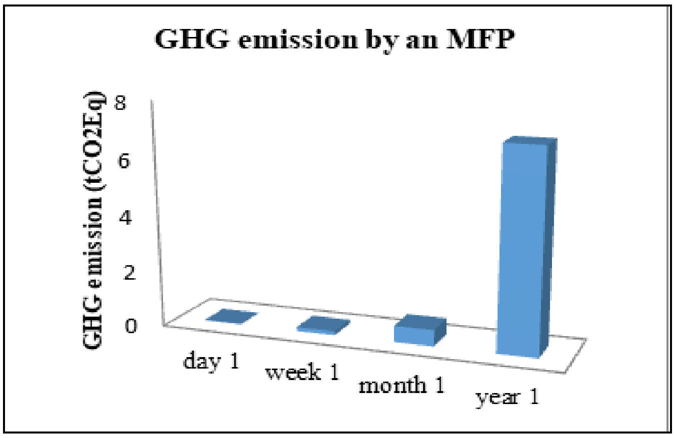

Fig. 20: Estimated GHG emitted by a diesel MFP in different time sequences.

Supposing the diesel MFP runs averagely 5 hours per day with a fuel consumption of 7 litres and a solar MFP which does not emit GHG after being installed, the quantity of GHG avoided is about 7.07735 teq.CO2 (see Fig. 20).

Solar MFP produces less noise so it respects our sonorous environment.

3.9.4. Availability and performance criteria

This MFP criteria concerns the satisfaction of the user's energy needs. It is evaluated in terms of the blackout which is a situation where no energy is supplied to the user though the latter is in need. It is of two (02) types energy and temporal.

The energy blackout is the lack of energy supplied to the user though the latter is in need. Given the availability and the abundance of solar irradiation in Africa, there is no blackout for a well sized and well managed PV system. For the diesel MFP, the system stops running at times due the lack of gasoil. Indeed, the sites on which are set these MFP are located in rural areas which are at time very far from places where the sell gasoil. In these conditions, energy blackout is more pronounced for diesel MFP.

The advantages of MFP include the following: addressing environmental concerns; reducing dependence on fossil fuels; energy security; reliability of electric power systems; energy quality; better quality of life; conservation of natural resources; assisting in local development; and creating new jobs. Disadvantages include changes in the aesthetics of the landscape and visual intrusion of facilities, impacts on flora and fauna, noise pollution, and high installation costs

IV. CONCLUSION

To contribute to the improvement of living standards of the rural populations in sub-Saharan Africa which are situated far away from the electricity distribution network, we have proposed solar energy system which uses the most abundant and available energy resource (sun) in the locality in order to provide them with modern energy services. As regard to the energy services present, we can say that these areas are usually found in an energy poverty situation. This makes the locality to depend on biomass and petroleum products thus an energy vulnerability situation. The behaviour of the multifunctional solar platform in its different operational scenarios indicates that the mastery of the solar resource, of the energy need and of the components of the PV system is indispensable for its good operation. A comparative analysis shows that the investment for a solar multifunctional platform is greater than that of a diesel multifunctional platform, the maintenance and repairing (servicing) costs for a diesel multifunctional platform for 20 years can cover the investment cost of 3 solar multifunctional platforms. Environmentally, a solar multifunctional platform avoids the emission of about 7 teq CO_2 of GHG.

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