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Rural Electrification in the Democratic Republic of the Congo by a System Hybrid (Solar PV) in the Case of ISCED Urbano-Rural Bumba/Mongala

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ABSTRACT

The city urbano-rural Bumba (Province de la Mongala), although the lung of the domestic agricultural production (rice, corn, peanut), and suffers from a failure of critical access to electrical energy. The thermal power plant managed by the electricity board (an engine Deutz V16 630 kVA only provides power to summarily 21 avenues for approximately 4 hours per day, with a daily consumption important fuel. This energy crisis is hampering the socio-economic activities and discourages investment.

To compensate for the intermittency of sunlight due to the humid tropical climate of Bumba, the study proposes a hybrid system combining solar photovoltaic panels and the tidal stream of river. The combined use of the sun and of the hydraulic potential local ensured the continuity and stability of the power supply.

On the basis of a site that is not operated 60,000 m2 120 m x50m: Photovoltaic Modules: The choice of panels Sunpower 225 Toilet requires an installation of 464,756 modules.

Energy and power: The peak power of the generator reaches 104,568 MWc to meet the energy consumed an estimated 30 MWh.

Storage and Conversion: installation requires approximately 29,411 batteries 48 V 2500 Ah to ensure the autonomy of the network, as well as 232,378 regulators and inverters adapters.

Wiring: The standardized section calculated minimum for the driver between the park to the batteries and the inverter is 70 mm2.

The budget estimate of essential equipment (solar panels, controllers, batteries, inverters and unexpected) for the development of the entire site is approximately 163,85 million USD or about 17,81 million USD according to an assessment of project adjusted/reduced).

This project demonstrates that it is technically feasible to exploit the resources for local primary (sun and water) to permanently solve the energy crisis to Bumba, allowing to regulate the connection of electricity and boost the local economic development.

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KEYWORDS: *rural Electrification, Central photovoltaic, energy, hybrid system, photovoltaic Field.*

I. INTRODUCTION

Water and solar energy are two of the most fundamental and most necessary to life. Increasing need for electrical energy, combined with the inevitable exhaustion of traditional energy sources, requires the search of alternative energy sources; such as renewable energy. Because of many advantages, solar energy and hydropower are widely used despite the high cost of the 2nd energy for its operation.

With the wet tropical climate that in the city urbano-rural de Bumba, the sunshine is not permanent, that is why we have associated with the network, solar pv tidal river so that the electrical power is permanent. The tidal rivers are a safer solution to maximise the use of renewable energy while optimizing the available local resources.

The determination and the sizing of the physical parameters for the installation of a central tidal

turbine requires consideration of several technical factors, which are:

- Analysis of local resources;
- Design of turbines turbines;
- Economic and environmental Aspects.

The development of the activities of the city urbano-rural Bumba as a whole is experiencing serious problems related to the lack of easy access to electrical energy. The energy crisis led to the meeting that the cityurbano-rural Bumba does not offer the option to raise the socio-economic activities, and to appeal to investors; and especially that the city which is the capital of the territory of Bumba and who is also the national lung agricultural production: rice, corn, peanuts, ...

To remedy this situation (disadvantage), we will make use of renewable energy sources (water and solar) to solve the problem of electrification and ensure continuity of service in the wide limits with precision.

Being concerned by the situation of non-easy access to electrical energy in the city urbano-rural de Bumba, which is caused by the total lack of a distribution network is reliable and that this situation does not allow the population to have access to electricity and yet, there are green spaces for the implementation of a large photovoltaic field and a river to install a tidal turbine.

This situation prompts us to ask a few questions.

For this, we formulate our questions in the following way:

- How to generate electricity for the accessibility of our people is easy from primary energy local ?
- Can we determine the energy parameters for the optimal functioning of the system put in place ?

In order to improve and guarantee the service of electric energy in the city urbano-rural de Bumba, we formulated our hypotheses of the following:

Mainly on scientific and technical, we believe that it is possible to generate electricity with our energy sources are local by a hybrid system, solar pv and tidal electrification (to feed) the city urbano-rural de Bumba.

It is possible to determine the energy parameters for the optimal functioning of the system to be implemented;

This research work has the following objectives:

- The adjustment of the electrical parameters;
- The determination and calculation of the physical parameters of a power plant tidal turbine ;
- The optimum power efficiency and stable parameters of the distribution network;
- The staffing of the city urbano-rural Bumba solar pv and tidal.

In the writing of this work we used the following methods: The descriptive method, analytical, comparative.

Which we have associated with the following techniques: The technique of observation and interviews.

II. Theoretical framework on renewable energy

2.1. Energy

The energy is of fundamental importance in the life of a human being and thanks to the energy, we can carry out more complex work. Therefore, energy is the ability of a system to perform work or to cause a transformation.

2.2. Principle of conservation of energy

The energy is manifested mainly by the production of a work, or conversion into another form of energy, according to the principle of nature, it is established that the energy cannot be lost or destroyed; it only transforms into another form of energy: it is the principle of the conservation of energy. The transformation of one form of energy to another is not full, the losses that take place during this conversion often take the heat.

2.3. Forms of energy

The energy manifests itself in various forms in the world around us. Originally it is the heat energy that has attracted the attention of mankind. The domestication of fire (combustion) has allowed in a first time of cooking, then heating. After only appeared the mechanical energy that is taken in a purely physical, energy occurs in many forms: Energy: mechanical, electrical, magnetic, radioactive, chemical, and nuclear.

2.4. Primary energy Sources

The primary energy is the form in which the nature of the book. The production of electrical energy, a secondary form of energy requires that you have a source of primary energy that must be transformed by the technological means. All during this is the form in which the man is consumed.

2.5. The main sources of renewable energy (re)

Renewable energy is our scale of time, those that are delivered continuously by nature. They are the result of solar radiation, the earth's core, the gravitational interactions of the sun and moon with the oceans. These renewable energies are inexhaustible in the time scale. They are also called the clean energy of the absence of the pollution in the process of their transformation into electrical energy.

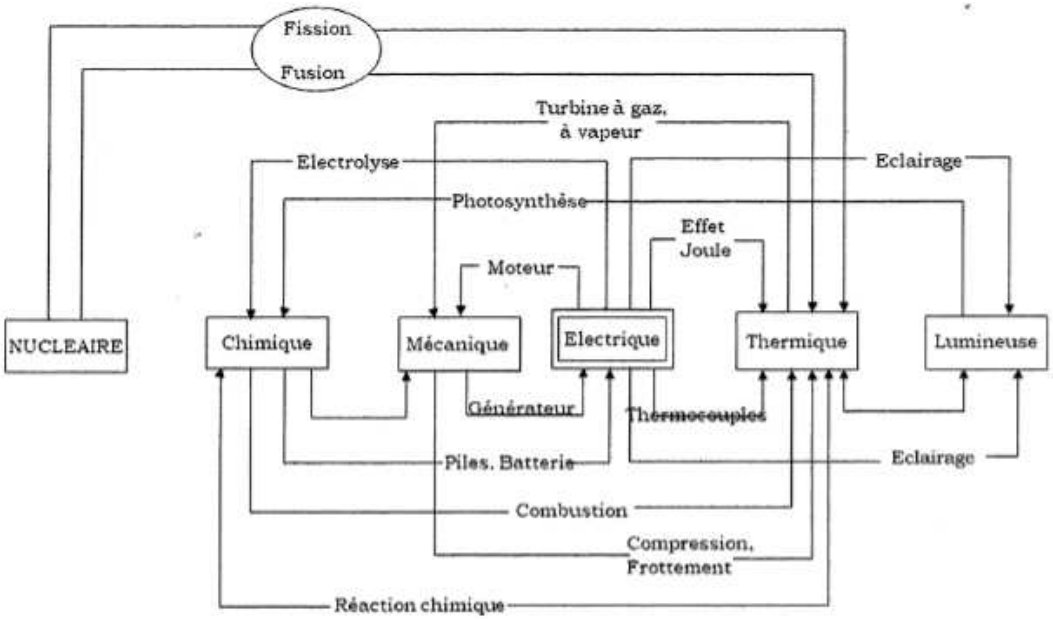


Figure I. 1: Schematic of the different effects (different energies) of the production to the consumption of different plants

III. Photovoltaic solar energy

A photovoltaic solar power station is formed by the set of photovoltaic solar panels based on silicon, which are interconnected in series or in parallel and connected to one or more inverters.

3.1. Solar energy

Located at an average distance of 149594 km of the earth, the sun is a star of spherical shape and the diameter reaches 1.391.000 km. It is a huge source of power available constantly that burn hydrogen from 4.6 billion years ago. When the hydrogen atoms combine to form heavier atoms formed by releasing a lot of energy in the form of heat radiation. This is nuclear fusion.

3.2. Solar radiation

In passing through the atmosphere, the solar radiation is absorbed and broadcast. We therefore distinguish between:

- The direct radiation that is received from the sun, directly without scattering by the atmosphere. These rays are parallel to each other. The radiation, therefore, two shadows, and can be focused by the mirrors.
- The diffuse radiation, which is composed of the light scattered by the atmosphere, radiation is the isotope that is to say that one receives radiation is identical in all directions of the heavens.
- Albedo is the part that is reflected by the soil depending on the environment of the site.

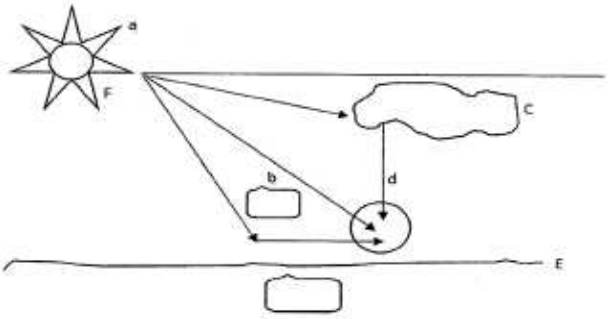


Figure 1.2: solar Radiation on the ground a. Sun, b: direction, c: atmosphere, d: limit of the atmosphere, e: Ground and F: diffuse

3.3. Photovoltaic energy

The word photovoltaic comes from the Greek photos that mean light and the volta of the name of the Italian physicist who, in 1800, discovered the battery. Photovoltaic energy is a direct conversion of the solar motion in the electricity from the photovoltaic cell is a direct conversion of the solar motion in the electricity from the photovoltaic cell.

3.4. Photovoltaic cell

The cell or solar cell photovoltaic system is a component opta-electrical composed of a semiconductor material that absorbs the light energy and converts it directly into electrical energy. The principle of operation of this cell uses the properties of solar radiation and to those of semi-conductors.

IV. Existing energy of the current network of the city urbano-rural Bumba that the electricity board manages

A. Type in the thermal power plant: S.

- Engine brand Duetz, this engine is V -, and 16 cylinders (V16), created in 1982 in Germany

- Transformer of 630 kVA
- Power alternator: 630 kVA (0.63 M Watt)
- Voltage comprising: 450 V
- Simple voltage: 240 V, cosφ = 0,8

B. Daily consumption is 240 L/4 h, i.e. (60 L/h)

- She (thermal power plant) fuels 21 avenues, avenue of the river up to the avenue Monduka (2nd avenue).
- Source center Snel/Bumba, the 11/10/2025

V. Sizing of the pv plant

A. solar Radiation and the estimate of the sunshine

A solar system is a system in equilibrium, the quality of energy supplied by the solar modules, should, at least, offset the amount of energy consumed. This will depend on the location of the facility, season, and special conditions of consumption and use.

B. solar Radiation

The sun emits electromagnetic radiation in a band of wavelengths ranging from 0.22 to 10 microns (µm). The energy associated with the solar radiation breaks down roughly as well; 9 % in the band of ultraviolet light (≤0.4 µm), 47 % in the band of visible (0.4 to 0.8 µm), 44 % in the infrared band (0.8 µm). The solar radiation it emits in the direction of the earth is intercepted by the atmosphere, these borders, a certain amount of solar radiation or photons are absorbed, some is reflected back into space and some of the crosses.

C. solar Constant

The solar energy received per unit time to the upper limit of the atmosphere, on a surface unit perpendicular to the sun's rays and to an Earth – sun distance equal to its average value is called the solar constant. The solar constant C was estimated to 1367 W/m2 by Claus Fröhlich and Christoph Wehrli centre radiometric world of Davos (Switzerland), with an uncertainty of the order of 1 % of this value has been adjusted by the commission for instruments and methods of observation (C/MB) of the world meteorological organization (WMO) in October 1981. In a first approximation, we can calculate its value based on the number of the day of the year n:

$$Gb = 1367\,(1 + 0{,}033\cos(0{,}9856\,n)\ W/m2 \quad (1)$$

n: is the number of the day of the year, counted from the first of January

D. air Mass

The solar radiation passes through the atmosphere during the day depends on the relative position of the sun in the sky, to take account of this position, which changes the thickness of atmosphere traversed by the rays of light, we can define a coefficient m is called the mass air or air mass defined by:

$$m = \frac{P}{1013 \sin A} exp\left(\frac{-Z}{7{,}8}\right) \quad (2)$$

7.8 km: the vertical thickness average standard atmosphere
Zkm: the thickness of atmosphere traversed by the sunlight;
P: atmospheric pressure in N/m2
A: elevation of the sun in degrees

VI. Calculation of books photovoltaic

The size of an installation depending on the surface available, and consumption; and the proper sizing of the installation is a vital step to master. Two methods of sizing, it goes without saying that, in addition to the available area and the electric energy consumption for the case of the city urbano-rural de Bumba, the available area is the determining factor for the sizing of the pv plant.

The city has two sites for which the 2nd site is not operated, and the city has the geometries of 60,000 m2 that is to say, (120,0 m x 50.0 m).

A. Calculation of pv modules

The determination of pv modules, takes into account several parameters including:

- The slope of the roof and oriented in the X°C;
- The minimum distance between the edges of the roof and the installation (1 to 2 tiles) in order to avoid too strong constraints on the wind;
- The surface of a module including the dividers;
- The surface of roof available, due to a security dashboard.

For the choice of the module, there exists in the market, various technologies of the pv module.

For the choice of the module, there exists in the market, various technologies of module photovoltaic. We hold to our work are two brands which are:

- Sun power 225 with as the model of 225 Toilet with specific dimensions are (1559 mm/798 mm);
- Solar 3125U with as a model 125 Wc with specific dimensions are (859 mm/388 mm).

B. Calculation of the surface area of a module

To calculate the surface of a photovoltaic module including the indexes, we use the following expression:

$$S_{MPV} = (L_M + ki).\left((L_M + ki)\right) \quad (3)$$

With:
SMPV: surface of the pv module
LM: length of the pv module
lM: the width of the pv module

ki: coefficient of interlayer (20 cm)
SMPV = (1559 + 20). (798 + 20) [mm] = 1,292 m^2

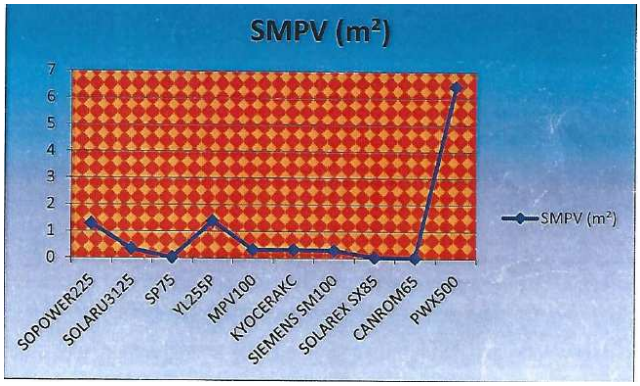


Figure 1: Representation of surfaces of pv modules

The realization of calculation shows that the surface of the pv module is in a range between 0.02 m2 6.45 m^2 as a function of the peak power which varies in the range of 65 to 500 depending on the manufacturer.

C. Calculation of roof surface area

To determine the surface area of the roof of the photovoltaic field, it is necessary to take into account, first, the security of each side, on the surface is obtained by the following expression:

$$S_{tcpv} = (L_t - (2.k_s)).(L_t - (2.k_s)) \quad (4)$$

With:
Stcpv: surface of the roof of the photovoltaic field
Lt: length of the roof of the photovoltaic field
Lt: the width of the roof of the photovoltaic field
ks: safety factor (30 cm)

Application
Stcpv = (1.200.000 – (2.0,3) . (500.000 – (2.0,3)) = 600.000 m^2

D. Calculation of number of pv modules

To determine the number of pv modules in a field, it is necessary to take into account the surface of the roof of the pv module chosen; on this, the surface is obtained by the following expression:

$$N_{MPV} = S_{tepv}/S_{MPV} \quad (5)$$

With:
$Stepv$: surface of the roof of the photovoltaic field
$NMPV$: number of pv modules
$SMPV$: surface of the pv module

$$N_{MPV} = \frac{600.000}{1,291} = 464.756\ modules$$

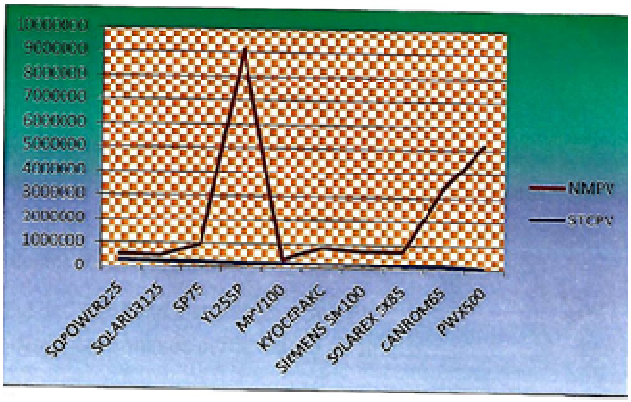


Figure 2: Representation of the modules in the surface of the photovoltaic field

The previous calculation (NMPV) shows that the number of pv modules to be implemented is between 325,14 to 514,66 as a function of the surface of the available field, taking into account the environmental impact.

E. Calculation of the power of the pv generator

To calculate the power of the pv generator, it is necessary to take into account the number of pv modules and the peak power of the pv module. On this, the power is obtained by the following expression:

$$P_{GPV} = N_{MPV}.P_{CM} \quad (6)$$

With:
PGPV: power of the pv generator
NMPV: number of pv modules
PCM: peak power of the pv module
(cfr. Sun power 225 – model 225 - Wc)
PGPV: 464,75 .225 = 104.568,75 MWc

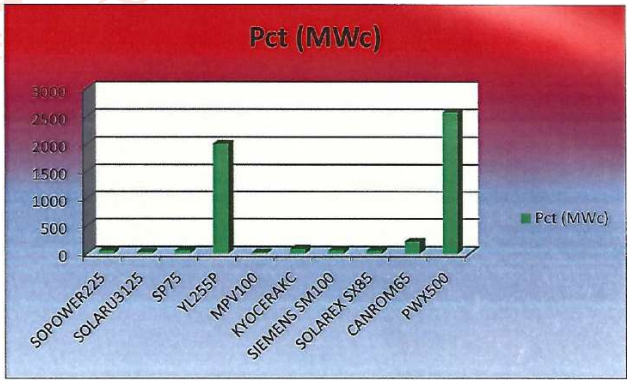


Figure 3: Representation of the power of the pv generator

F. Calculation of the electrical parameters of the CPV

Calculation of energy consumed by the electrical grid, since the peak power of the photovoltaic field is known, the energy consumed is a function of irradiation summer mean of operation of the network and the k-factor, and this energy is obtained by the following formula:

$$E_{cr} = P_{ct}.I_r.k \quad (7)$$

Which Rct: energy consumed by the electrical network
Pct: peak power
Ir: irradiation
k: coefficient
Rct = 7,10 x 6.5 x 0.65 = 29,9975 MWh ≃ 30 MWh

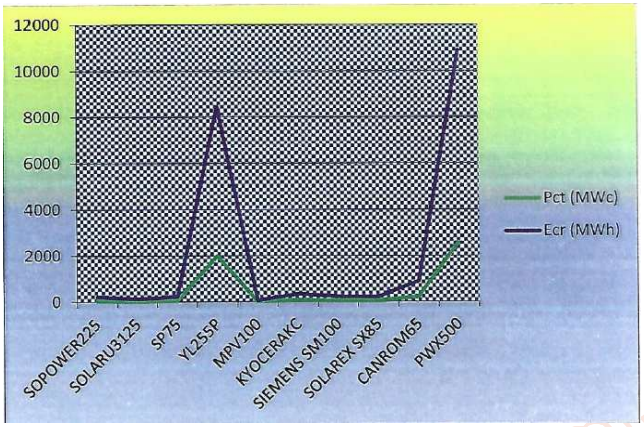


Figure 4: Representation of the energy consumed by the electrical network

G. Calculation of the capacity of park BC

The capacity of the batteries needed for the photovoltaic field is given by the following formula:

$$C_{bc} = \frac{E_c.N}{D.U} \quad (7)$$

Cbc: battery capacity in ampere-hour (Ah)
Ec: energy consumed per day (Wh/day)
N = number of days of autonomy
D = discharge maximum permissible (0.85 for lead-acid batteries)
U = voltage of battery (V)
Cbc=30.100,85.48=7,35294117 MAh $soit$ 735294,117 Ah≃735294,11 Ah

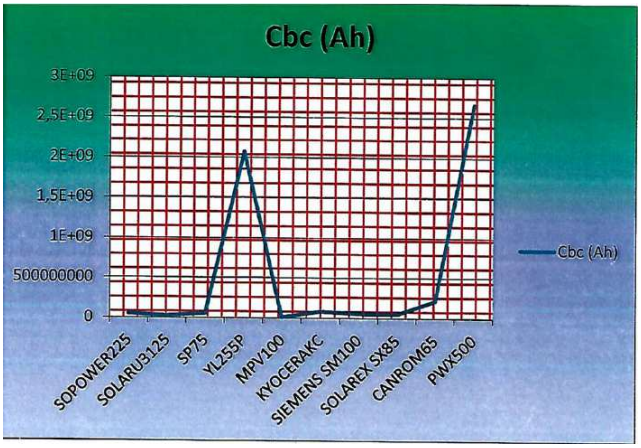


Figure 5: Representation of the ability of parks batteries (BC)

H. Calculation of number of batteries

The park of the batteries will be made up of batteries 48 V each, the system that is running a 48-V battery are connected in parallel. In this case the number of batteries is first of all a function of the choice of the unit capacity of battery and this is obtained by the following formula:

$$N_{bc} = \frac{C_{bc}}{C_{ubc}} \quad (8)$$

With:
Nbc: number of batteries;
Cbc: the capacity of storage battery;
Cubc: unit capacity of battery.

Nbc=73529411,765/2500=29411,765≃29411

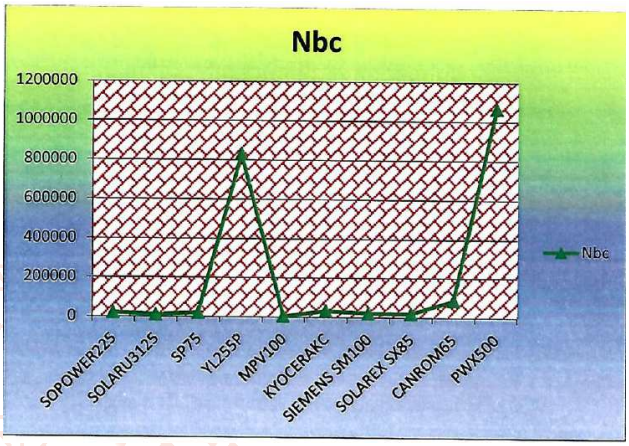


Figure 6: Representation of a number of batteries

I. Calculation of the power of the inverter

To our knowledge, we know very well that the inverter is a key element in the functioning of the SPV in alternating current, the sizing of inverters of a PV-system is often a source of confusion because it is necessary to distinguish the peak power of the power plant and its real power during operation.

Finally, care must be taken to the tension of the strings connected to the inverter.

A under sizing of the inverter can drastically decrease the performance of the entire system. This power inverter is obtained from the following expression:

$$P_{ond} = P_{ct}.k_{ck} \quad (9)$$

With:
Pond: power inverters
Pct: peak power
kd: coefficient of overload
Pond = 7,10.0,65 = 4.615 kwp

J. Determination of the cross section of the conductor between BC and IT

By applying the law of Pouillet, the cross section of the conductor between BC – ONE is determined by the following formula:

$$S_{BC-ON} = \frac{\varphi.L}{R_{PBC-ON}} \quad (10)$$

With:

$SBC-ON$: cross section of the conductor between park of the batteries and the inverter;

$RPBC-ON$: resistance of the conductor between the park of the batteries and the inverter;

φ: resistivity of the copper conductor;

L: length of the conductor between the park of the batteries and the inverter.

$$S_{BC-ON} = \frac{(1{,}6.10^{-8}.50)}{0{,}00208} = 38.10^{-6} m^2 = 38\ mm^2$$

By taking the standardized value of the section between BC-ON, it will become 70 mm^2

K. Estimation of the price of some equipment from the PV installation

Table 1: estimates of the cost of some equipment from the PV installation

N°	Désignation	Nbre	PU ($)	PT ($)
1	Panneau solaire sunpower 225 Wc	464.756	2.124	987.141.744
2	Régulateur solaire	232.378	204	47.405.112
3	Batterie	29.411	560	14.705.500
4	Onduleur	232.378	1.895	440.356.310
5	Imprévu (10 %)			148960866,6
Total				**1638569532,6**

NB: the number of regulators with a coupling parallel panels is equivalent to half of the number of solar panels used.

The above table gives us the information for a site; because the 2nd site is not operated. The installation of this site would require a cost of approximately 17.814.819 USD (seventeen million, eight hundred and fourteen thousand eight ten-nine thousand us dollars).

L. Tilt of the field PV

The study of the orientation and the tilt sensor is very important for estimation of the energy captured by a photovoltaic array simulation has shown that the orientation facing south (sensor fixed) promotes a capture maximum energy daily and annual. The slope close to $\beta = \varphi$ promotes the capture maximum annual energy of a site.

M. Characteristic of a module

To determine the energy delivered to each moment of the day and of the year of a module consisting for example of 36 identical cells of approximately 78,5 cm2 of surface area, with a series resistance Rs = 0,7 Ω and a parallel resistance Rp = 103 Ω, we have developed a simulation program to describe its performance and to determine its optimal adaptation on the photovoltaic field.

Block diagram of a photovoltaic solar energy plant for the city urbano-rural de Bumba

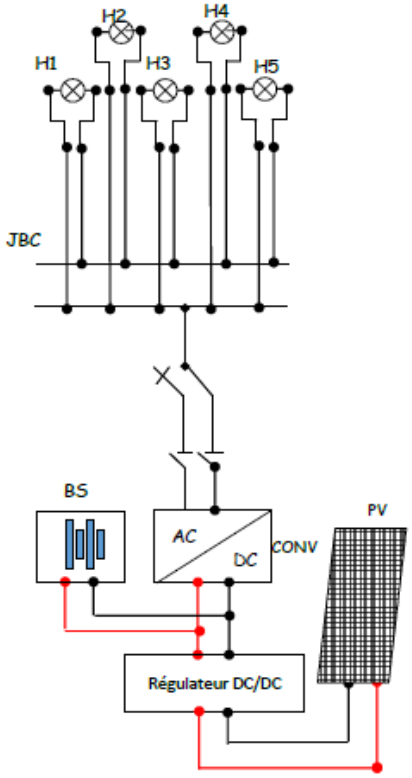


Figure 8: block Diagram of a photovoltaic solar energy plant for the city urbano-rural de Bumba

Legend:

- H1 to H5: lamps representing the different cabins MT/BT
- JBC: games bar city
- D, Q: circuit Breaker and disconnector converter
- QBD: disconnector bar and circuit breaker
- BS: batteries, accumulators
- CONV: converter
- PV: photovoltaic
- AC: alternating current
- DC: direct current

Conclusion

Access to electrical energy is an essential lever for socio-economic development and attractiveness to investors. In response to the lack of a distribution network is reliable and the shortcomings of the central thermal current Bumba chief-place of the territory of the Mongala , and a major center of agricultural production, the use of renewable energy resources, local imposed as a sustainable alternative. The objective of this study was to design a hybrid system combining solar photovoltaic power plant tidal river, in order to ensure continuity of service that is stable, efficient and adapted to the constraints of the local climate. The evaluation and sizing of pv devices have helped to define the technical parameters necessary for the optimum functioning of the installation. To exploit the available area of 60,000 m^2, the implantation of $464,756$ solar modules (type Sunpower 225 Wc) will generate a peak power for a total of over $104 MWc$, coupled with a fleet of batteries designed to meet daily consumption estimated at 30 MWh. The economic analysis shows that the total cost of the solar equipment essential for the development of a first site is about 163,85 million of US, or nearly 17,81 (USD million) for a project adjusted on a smaller scale). Ultimately, the coupling of the field of photovoltaic technology, tidal offers a concrete response to compensate for the intermittency of sunlight, and guarantee the energy autonomy of Bumba. The implementation of this hybrid plant will contribute significantly to the recovery of the local economy and to the improvement of the quality of life of the population.

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