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Modeling and Simulation of a Photovoltaic Field for 13 KW

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ABSTRACT

In the future solar energy will be very important source of energy. More than 45% of needed energy in the world will be generated by photovoltaic module. Therefore it is necessary to concentrate our efforts in order to reduce the application costs .This work investigates on the modeling of a Stand Alone Power System focusing on Photovoltaic energy systems. We introduce the models of the system components Therefore a maximum power point tracking (MPPT) technique is needed to track the peak power in order to make full utilization of PV array output power under varying conditions. This paper presents two widely-adopted MPPT algorithms, perturbation & observation (P&O) and incremental conductance (IC).A complete characterization and simulation model was implemented in the Matlab-Simulink environment. Design complete system is done to analyze its behavior for a typical year, with the aim to evaluate their energetic effectiveness.

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1. INTRODUCTION

The search for reliable, long-lasting sources of energy has been an ever challenging task for mankind. This search is more urgent today than ever before, due to the heavy dependence of modern life on energy from fossil fuels (i.e. petroleum, natural gas and coal), which are being depleted. In addition, their combustion products are causing the global pollution problems [1].

In this paper, a methodology to design each configuration analytically is proposed. It is found that solar photovoltaic modules in parallel and in series, for a power supply of 13 kW_p .A complete simulation model of the system and of the control strategies was realized in the Matlab-Simulink environment. In photovoltaic (PV) power systems, maximum power point tracking (MPPT) is essential because it takes full advantage of the available solar energy. And since the output characteristics of photovoltaic (PV) system is nonlinear and changes with temperature and solar radiation, its maximum power point (MPP) is not constant. Under each condition PV module has a point at which it can produce its MPP. Therefore, maximum power point tracking (MPPT) techniques can be used to uphold the PV panel operating at its MPP and then to increase the PV system efficiency [2]. In our case there is a power to a load in an isolated site (Oran – Algeria), in order to study the proposed system based on climatic conditions.

2. PHOTOVOLTAIC SYSTEM

This is the most common configuration of the autonomous photovoltaic systems,called Stand-Alone systems .The whole is usually in DC. Which is better because simpler. But as soon as we deal with the habitat, there are almost always apparatuses in AC to be fed and because they do not exist in DC. The battery of such system is charged by day and serves permanently as a reservoir of energy.The battery , can easily,receive a loading current and supply a discharging current of different values. The apparatuses are laid to the battery through a charging regulator. When the battery is full, the regulator cuts the loading to avoid an overloading. This has the consequence of the loss of a part of the energy produced in summer ,especially in our climates.This system is as follow in Figure 1.

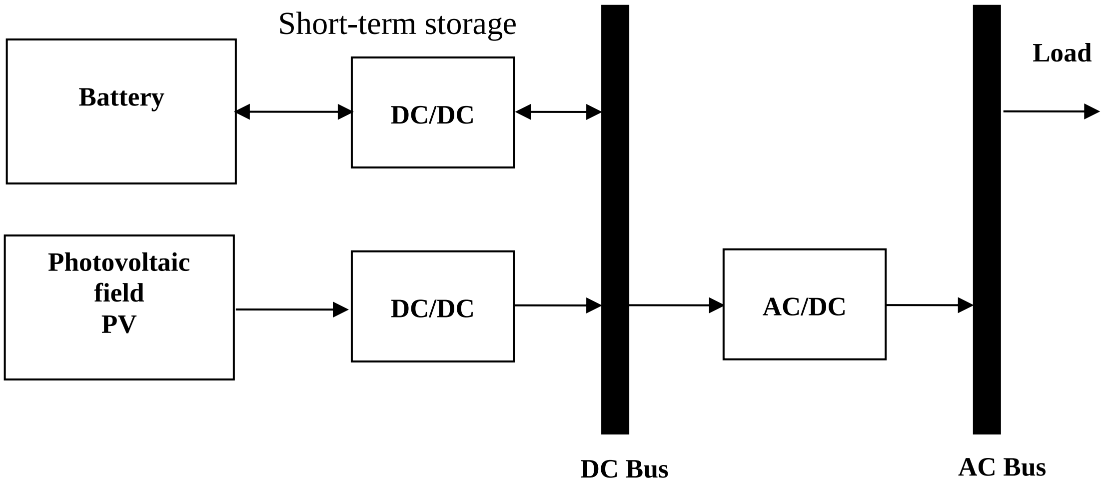

Figure 1. Photovoltaic system

The power load demand for our system is fixed at 1700W. The electrical consumption of the application is evaluated over 24 h, which is equal to the power consumption multiplied by the operating time over 24 h. Total application consumption per day: 1700 * 24h = 40800 Wh.

In order to calculate the power of the solar panels, we devide the lowest daily sunlight consumption by the period of use in the implantation site, as well as in the panels position. (for Oran the average daily average sunshine value is 4.48 kwh / m2).The demonstration is indicated on the following equations:[3]

$$\frac{40800}{4.48} = 9107W \tag{1}$$

Then, this result is increased by a loss coefficient of 0.7 for a first estimate. Real power taking into account losses

$$\frac{9107}{0.7} = 13000W \tag{2}$$

The storage is calculated by the number of days of autonomy required on average 3 days. For oran, to palliate the successions of badly sunny days. We reason then in Ah. The need for capacity is thus theoretically

$$\frac{40800wh*3}{24} = 5100Ah \tag{3}$$

But as the battery will have its capacity reduced by the cold and other technical constraints, it is necessary to divide this result by a coefficient of losses which will be taken equal to 0.7 in this example. The actual capacity required is therefore

$$\frac{5100}{0.7} = 7285Ah \tag{4}$$

2.1. Description of the model of a photovoltaic cell :

The mathematical model of the photovoltaic generator is based on the one-diode equivalent circuit shown in Figure 2. The relationship between the current I and the voltage U of the equivalent circuit can be found by equating the light current I_L, diode current I_D, and shunt current I_{sh} to the operation current I, presented by Equation 5.

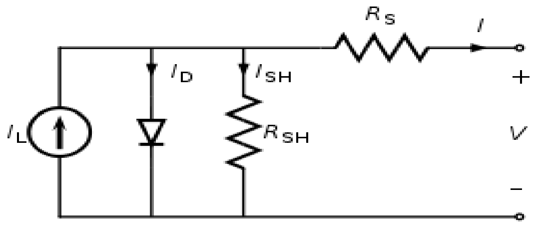

Figure 2. Circuit is equivalent for a model to a diode of a generator statement

The junction forming the basis of the solar cell is a diode, when illuminated appears in the diode photocurrent I_L (A) which depends on the amount of incident light (W/m^2). Indeed, the equivalent electrical circuit of the solar cell is based on a diode, adding two resistors to accommodate internal losses. R_S is the series resistance which takes account of the ohmic losses of the material, of the metallization and metal / semiconductor, a resistor R_P is current leakage from parasitic currents between the top and bottom of the cell, by the edge and in particular within the material by irregularities or impurities ($R_P << R_S$). Applying Kirchhoff's law, the output current of the cell is given by the following relationship [4]:

$$I = I_L - I_D \tag{5}$$

$$I = I_L - I_0\left[\exp\frac{q(U + IR_s)}{akT_C} - 1\right] - \frac{U + IRs}{Rsh} \tag{6}$$

where I current module (A), I_L light current (A), I_{LRef} light current at SRC (A), I_o diode reverse saturation current (A), k Boltzmann's constant (1.38066E+23 J/K), q electron charge (1.60218E+19 C), T_C temperature cell (K), a is the diode ideality factor, It depends on recombination mechanisms in the space charge zone. In the ideal case, Rs tends towards 0 and Rsh to infinity. And in the real case, these resistors provide an assessment of theimperfections of the diode.

For the design of our photovoltaic power system 13 k_w, this field consists of photovoltaic modules 180 W (13modules in parallel 06 modules in series). Table 1 presents the characteristic of selected Panel

Table 1. Electric characteristics of a photovoltaic panel - Blue Solar 180W [5]

peak power	180 W
Open circuit voltage	44.90 V
Intensity shorting	05.50 A
Voltage à Mpp	36.00 V
Current à Mpp	05.01 A

We carried out simulation, to leave standard parameters module SHELL SP180. The following Figure 3 and Figure 4 present the characteristics of a photovoltaic module field :one traced the variation of the current compared to the tension for several intensities of solar irradiation. On the other hand, the other notices that the current is directly proportional to the radiation on these levels of illumination .The tension is not very degraded when the light drops.

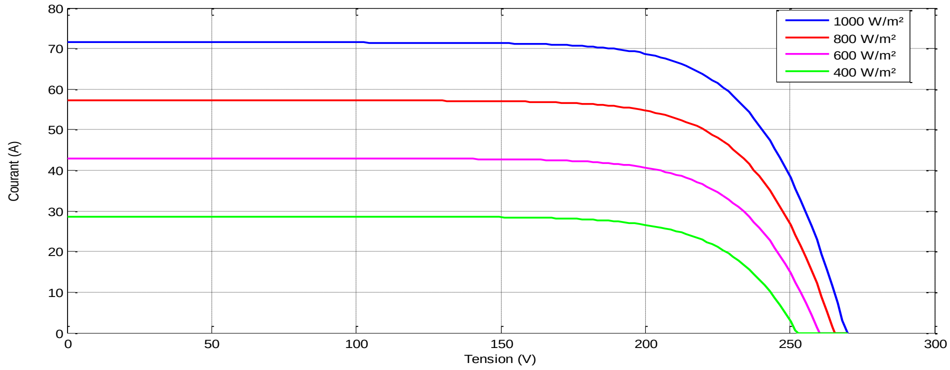

Figure 3. Curves characteristic of a solar field of 13 k_w (Blue Solar 180W) Influence of the sunning at constant temperature (25 °C)

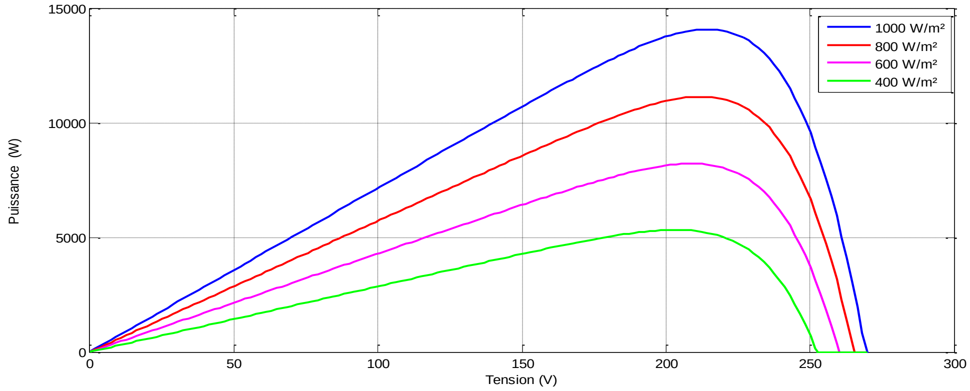

Figure 4. Curves of power of a solar field of 13 k_w (Blue Solar 180W) Influence of the sunning at constant temperature (25 °C)

The Figure 5 and Figure 6 represent characteristics I-V and P-V of the photovoltaic generator for respectively, a variable temperature and a constant sunning (1000W/m⁻). We notice that the site of the point of maximum power in characteristic I-V changes dynamically according to the sunning.

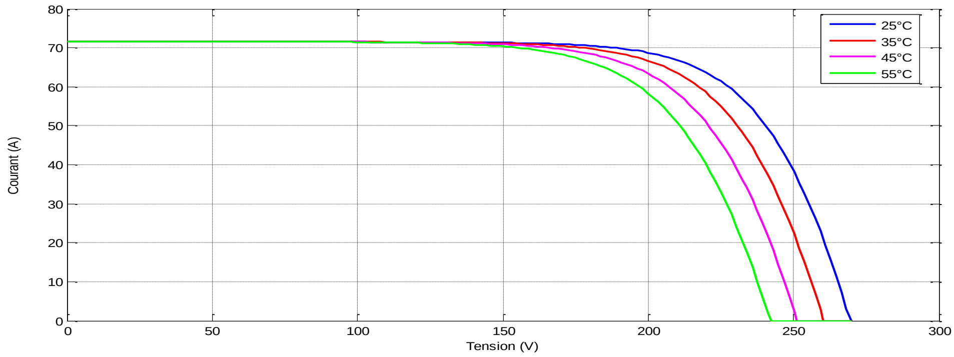

Figure 5. Curves characteristic of a photovoltaic field 13 k_w Influence ambient temperature with constant sunning (1000 W/m ²)

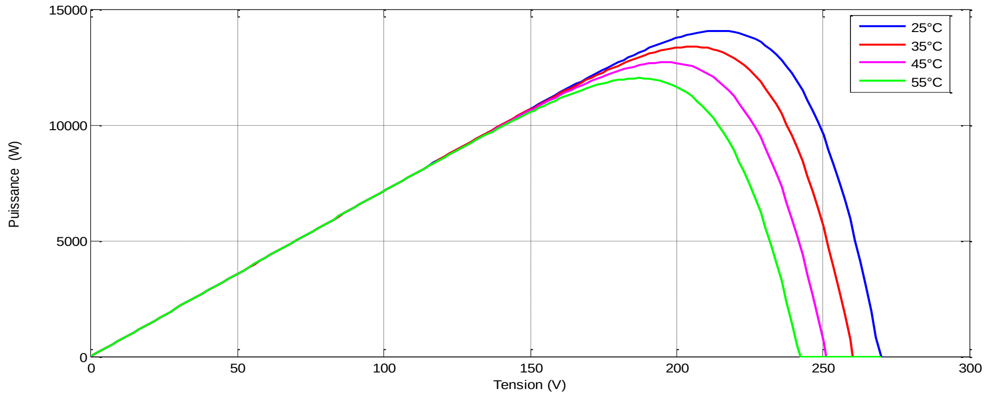

Figure 6. Curves of power of a photovoltaic field 13 k_w Influences ambient temperature with constant sunning (1000 W/m ²)

2.2. DC–DC buck converter

The levels of tension of the apparatuses not being identical, of the choppers (converters DC/DC) series- connected with the apparatuses make it possible to adjust their tension with that of the bus. These converters involve obviously losses of energy in the system which remains however generally weak. The outputs generally lying between 0,95 and 0,99 [6]. One proposes the following values for the outputs at 10% and 100% of Pnom:

$$\begin{cases} \eta_{10} = 0.93 \\ \eta_{100} = 0.98 \end{cases} \quad (7)$$

According to the equations above, the values of n_0 and m are thus:

$$\begin{cases} n_0 = 7.4\times10^{-3} \\ m = 13\times10^{-3} \end{cases} \quad (8)$$

The following figure illustrates the variation of the output of a converter DC/DC according to its standardized output power. This model is illustrated by Figure 7.

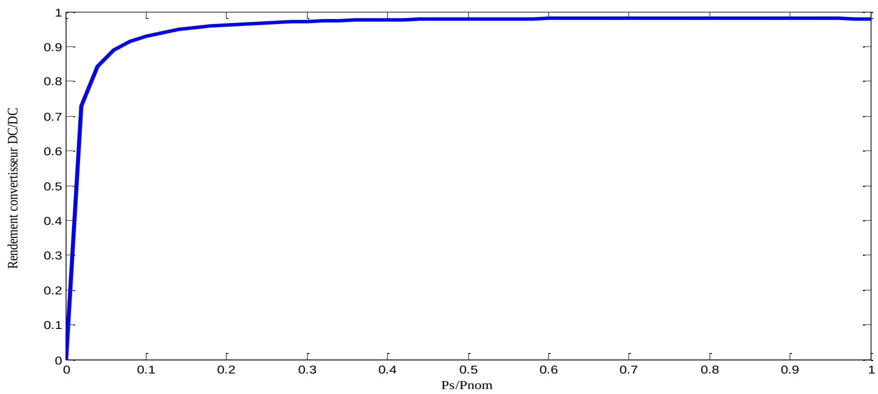

Figure 7. Evolution of the output of converter dc/dc according to standardized output

2.3. Inverter DC/AC

The load being fed in AC current, an inverter is thus present between the continuous bus and the load (Figure 8). There exist various equations to define the output of an inverter according to the delivered power. We use the same formula of Macagnan presented previously in equation (9). For our inverter, the values of the outputs with 10 and 100% of Pnom are:

$$\eta = \frac{P_S / P_{nom}}{P_S / P_{nom} + n_0 + m\left(P_S / P_{nom}\right)^2} \tag{9}$$

$$\begin{cases} \eta_{10} = 0.86 \\ \eta_{100} = 0.97 \end{cases} \tag{10}$$

The values of the parameters n_0 and m are finally:

$$\begin{cases} n_0 = 17 \times 10^{-3} \\ m = 18 \times 10^{-3} \end{cases} \tag{11}$$

The following figure makes it possible to observe that to 10% of its rated power, the output of the inverter reaches approximately 0,85 while with full force, it amounts to approximately 0,96. On the other hand, for low powers (5% of the face value), the output collapses dramatically. This model is illustrated by Figure 8 [7].

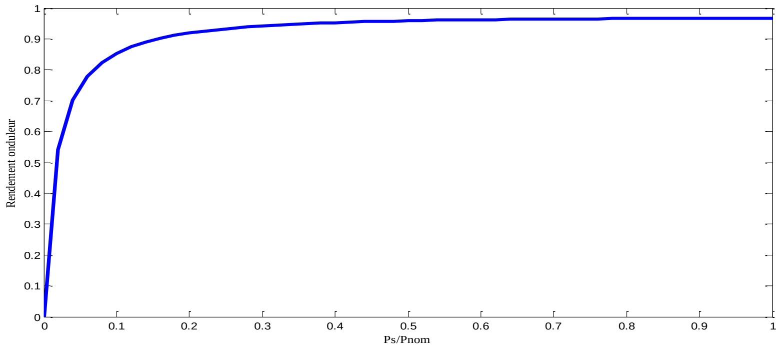

Figure 8. Evolution of the output of the inverter according to standardized output

3. MPPT ALGORITHMS

In order to operate a PV system within its MPP, whatever the irradiance and cell temperature variations, a MPPT method is needed to find and maintain the peak power. This strategy aims to find the voltage or current on which the PV system provides the maximum output power. In this work we will work with 2 methods: [8]

3.1. The perturb and observe method (P&O)

The Perturb and Observe (P&O) method is one of the most commonly used methods in practice. The P&O algorithms operate by periodically perturbing, i.e. incrementing or decrementing, the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the PV array operating voltage changes and power increases, the control system moves the PV array operating point in that direction. Otherwise the operating point is moved in the opposite direction. The operating voltage of the PV system is perturbed by a small increment of V, and this resulting change in P. If P is positive, the perturbation of the operating voltage needs to be in the same direction of the increment. On the contrary, if P is negative, the obtained system operating point moves away from the MPPT and the operating voltage needs to move in the opposite direction of the increment. A common shortcoming of this method is that the array terminal voltage is perturbed every MPPT cycle. Therefore, when the MPP is reached, the output power oscillates around the maximum, resulting in a power loss in the PV system. Furthermore, it sometimes fails to find the MPP under the continuously increasing or decreasing irradiation conditions. The logic of this algorithm and the flowchart are explained in Figure 9 [9].

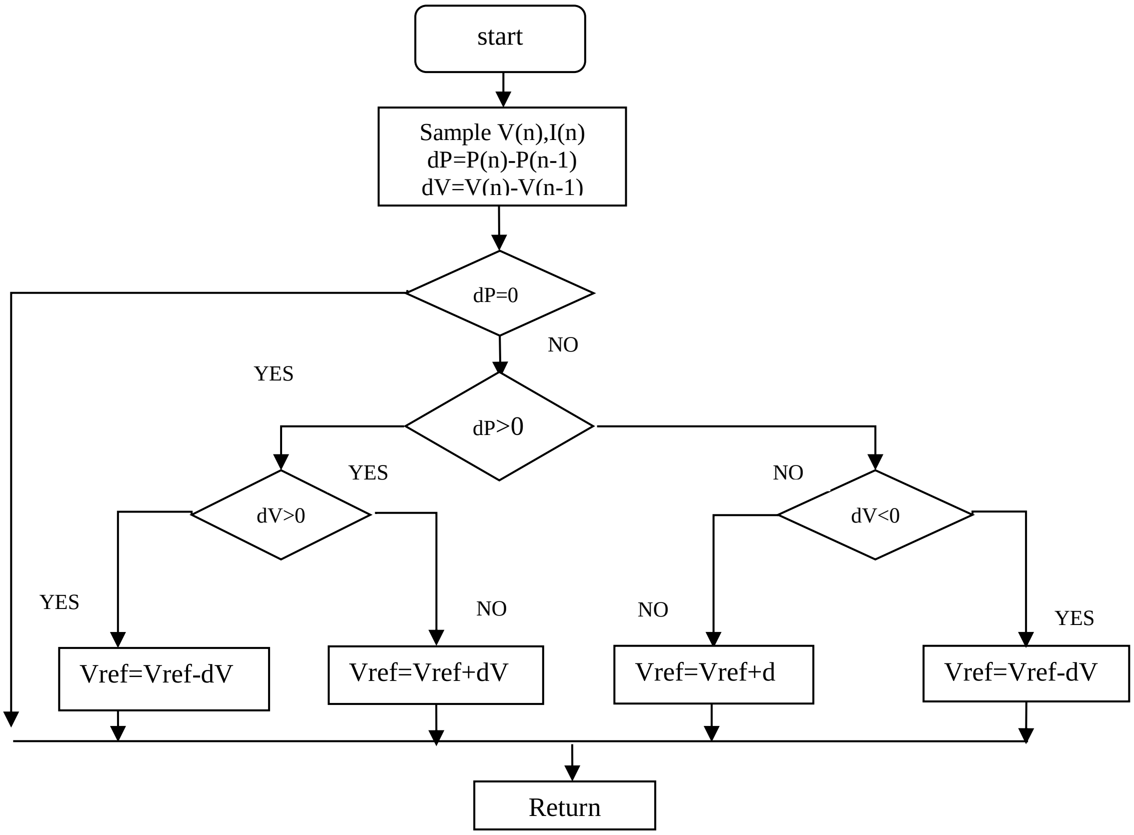

Figure 9. P&O method flowchart

3.2. Incremental conductance Method

The Incremental Conductance (INC-CON) algorithm is based on the observation that the following equations (12) and (13) hold for the MPP. The principle of this method is to judge whether the system work at MPP or work at the left or the right [9].

$$\frac{dP}{dV}=\frac{d(IV)}{dV}=I+V\frac{dI}{dV}=I+V\frac{\Delta I}{\Delta V}=0 \qquad (12)$$

$$-\frac{I}{V}=\frac{\Delta I}{V} \qquad (13)$$

Therefore, by analyzing the derivative, one can test whether the PV generator is operating at its MPP or far from it using equations following.

$$\frac{dp}{dV}>0 \quad \text{for } V< V_{MPP} \qquad (14)$$

$$\frac{dp}{dV}=0 \quad \text{for } V = V_{MPP} \qquad (15)$$

$$\frac{dp}{dV}<0 \quad \text{for } V> V_{MPP} \qquad (16)$$

The MPP can thus be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance (ΔI/ ΔV). V_{ref} is the reference voltage at which the PV array is forced to operate. Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in ΔI is noted, indicating a change in atmospheric conditions and the MPP. The main advantages of the INC-CON algorithm are the fine control the system obtains, and its high stability under rapidly changing atmospheric conditions. The flowchart of this method is as shown in Figure 10.

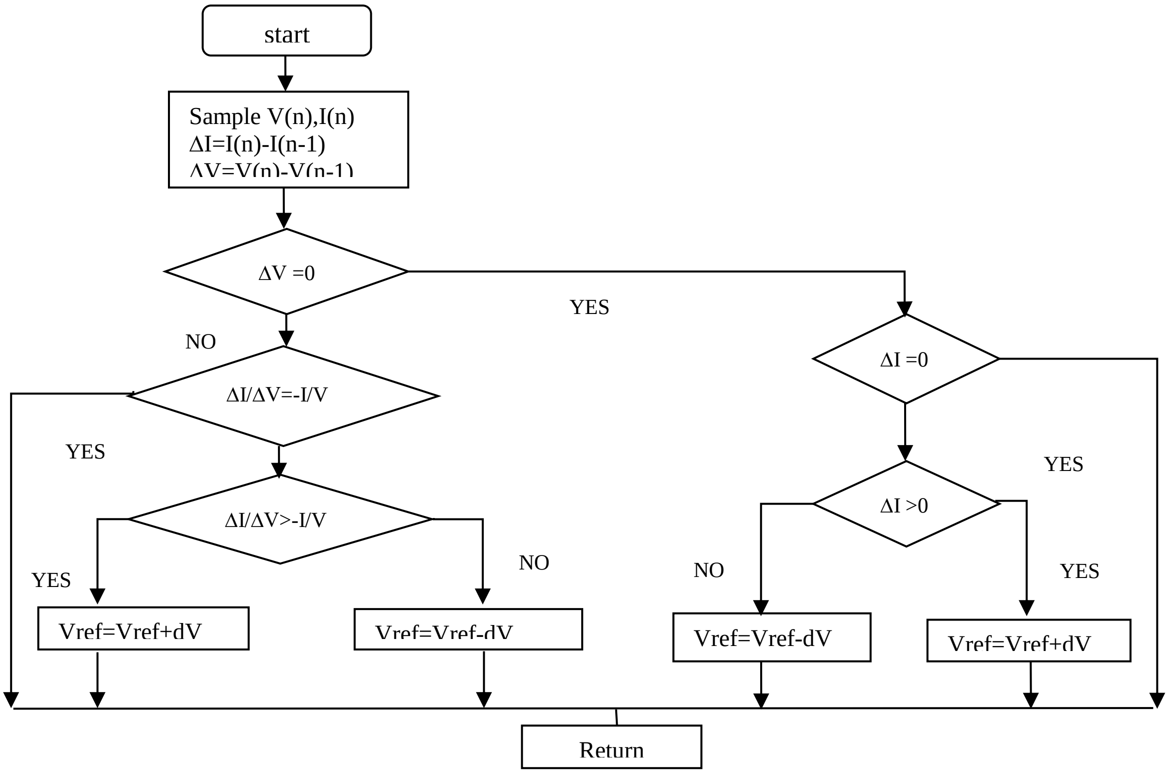

Figure 10. Incremental conductance method flowchart

4. COMPLETE SYSTEM

Figure 11 presents the complete system which makes it possible to calculate the points of operation of each component during one day complete (not of time 10 minutes). This model is made up many algebraic loops: The system is controlled in power. The electric model being the tension according to the intensity, the point of operation must be required to obtain the required power. The other loops algebraic are that of the MPU. Indeed, at the moment T, one knows the power of the statement, his tension and the power requested by the load. Simulink is the ideal tool to solve this type of problem [10].

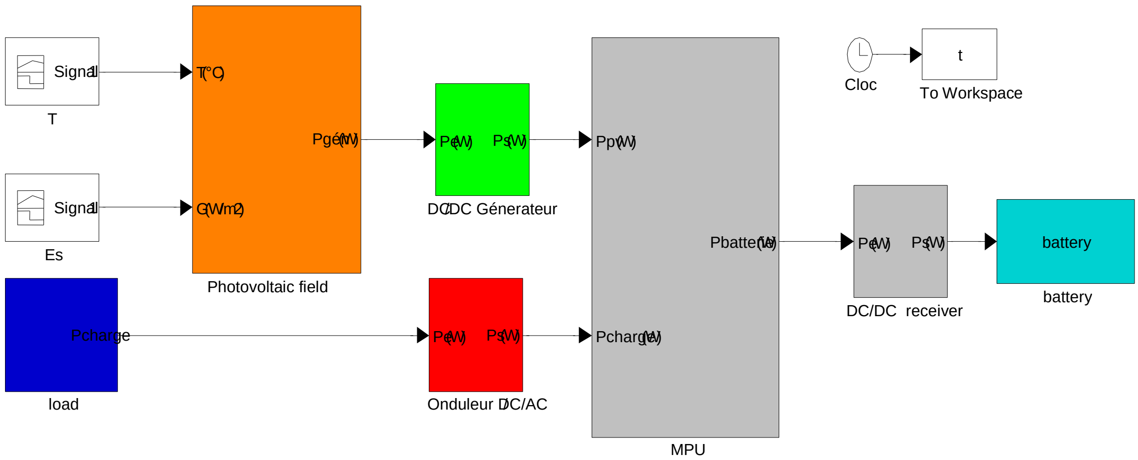

Figure 11. Complete model of our installation

4.1. Power management unit (MPU)

The system is controlled in power, the model allows to define the MPU, P_{pv}, P_{load} , $P_{battery}$ depending on the power output of the PV and that required by the load. An algorithm for power management has been developed for the studied system. Energy balances are always made at the common bus connecting the different components of the energy system. The priority is to provide the energy required by the user from the energy produced by the photovoltaic field. The energy delivered to the user is mainly photovoltaic panels. The algorithm of the energy flow follows these rules:

1. If the power required by the load is less than the power available solar:
   a. The battery is charged in security priority if necessary.
   b. The load can only work if the batteries have a high level of care.
2. If the excess solar can be consumed either by battery or by the battery, the voltage of the solar field increases, thus reducing the intensity and the power delivered by the generator renewable. This method is illustrated by Figure 12.

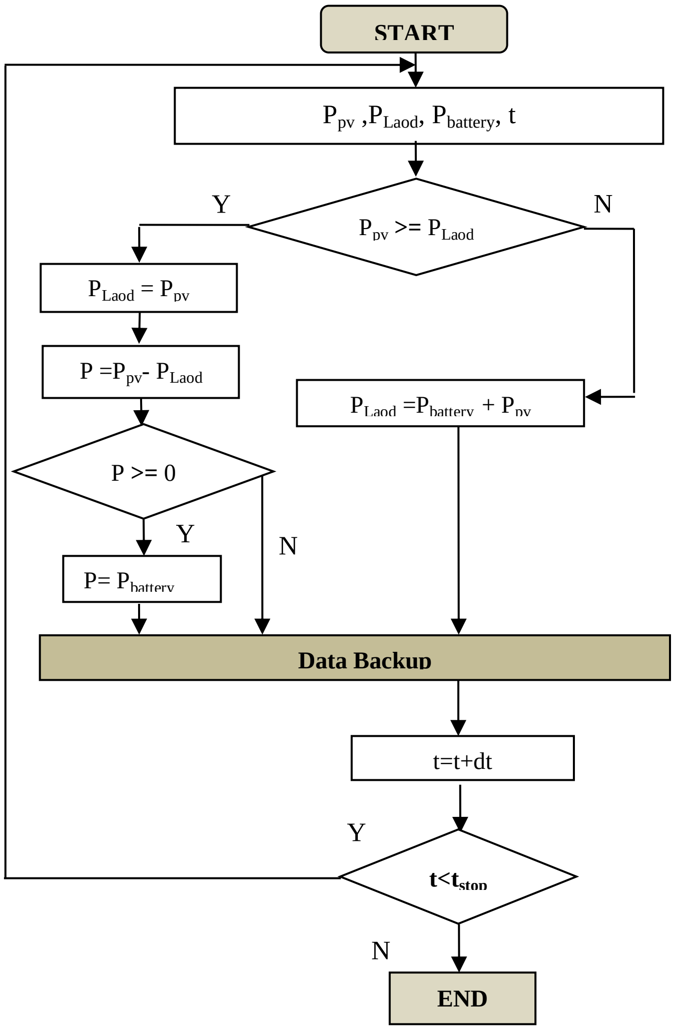

Figure 12. Schematic MPU - Calculation of power of each component on the bus

5. RESULTS AND ANALYSIS

We chose to study the system where it is autonomous over one year of operation. The power of the components being fixed, one determines the average charge available and the volume of storage necessary to the autonomy of the studied system. We will evaluate the influence of the various parameters of the system in order to determine the performance of the system. Selected localization: Oran-Algeria. The average sunning is of 5,2 kWh/m² per day in a plan inclined with 45° (slope of the photovoltaic panels). Figure 13 present describes the evolution of the sunning during the year [11].

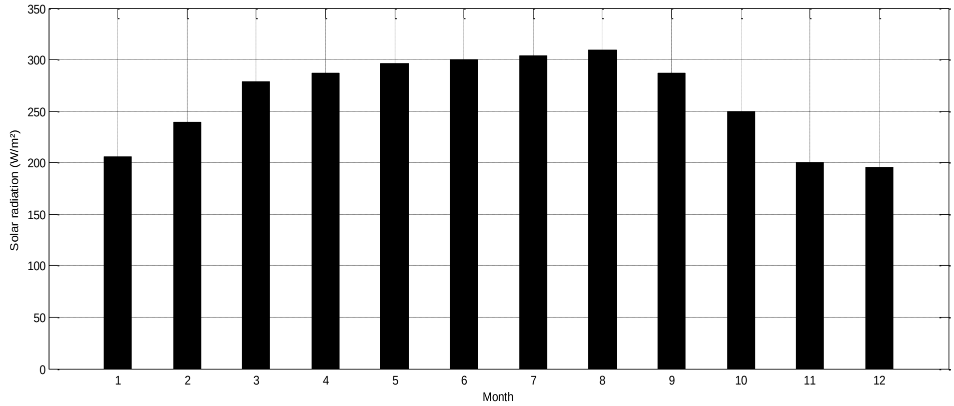

Figure 13. Average daily sunning with Oran (slope 45°) according to the month

Figure 14 following pages shows the distribution of powers involved within the system. The values are powers averaged over a year of operation (Annual Energy = Power x annual average 8760). This diagram allows us to appreciate the energetic point of view the operation of the overall system, providing information at the component level, as their performance. The load annual average in example is fixed at 3000 W, in order to study the behavior of the system according to the average sunning, because the average sunning annual does not exceed 1000W/m ².

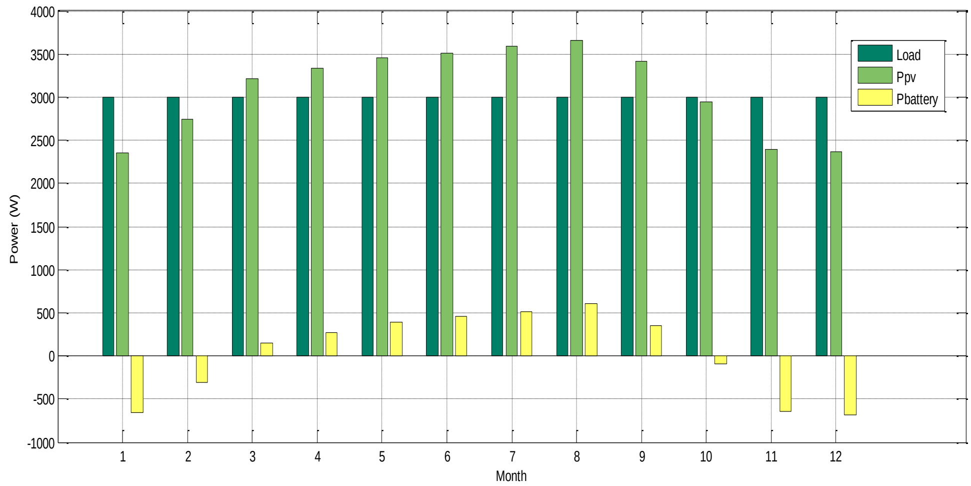

Figure 14. Evolution of the powers exchanged on the level of bus DC for one year of operation of the system

The application considered here is a charge for supplying at the Oran (independent of one year of operation). The power of the system is set to about 1700W. The solar array is installed about 13000Wp. The battery is the same power in order to convert all of the excess solar energy. In order to obtain the maximum power of the PV field, the voltage of the field Solar system avoiding the implementation of a complex control strategy (MPPT). Voltage Input is the nominal voltage of the solar field. In this framework we used two MPPT district methods to evaluate the thermal yield system (The overall system efficiency is 52%). The system with P&O is appreciable compared to the Incremental conductance (48%), over a year of operation. Approach adopted for this study is purely deterministic. The average power is fixed at 3kW. Figure 13 is a simplified diagram to describe the annual power operating PV-Load-Battery. The operation of the system and the influence of the parameters described below, from the analysis of all simulations. The annual energy photovoltaic (PV) is the total energy entering the system. Part of this energy is supplied directly to the load (PV). The second part involves the storage system is reduced by losses in electrochemical cells related to energy efficiency.

Figure 15 Evolution of the global losses the sum of these two energies is further reduced by the loss in the converters. System performance depends on all of these losses. Storage volume is dimensioned so that the energy stored during favorable months is equal to the energy consumed during the month unfavorable. When increasing the loss consumption or loss in the converters, it penalizes the load directly. The storage volume depends only on the annual load profile and raw energy, in the energy supplied by the PV. Half of the energy produced by the PV array is provided to the end user, the rest is lost. Can not use all the electricity produced by the field, the electricity stored in the various storage components incurs losses related to its conversion into chemical energy; different DC / DC or DC / AC generate transmission losses of the current (Joule losses, etc..). Over a year of operation, only 58% of the electricity produced by the PV array is directly supplied to the user. This amount of electricity suffers little loss and should be maximized to increase the overall system performance.

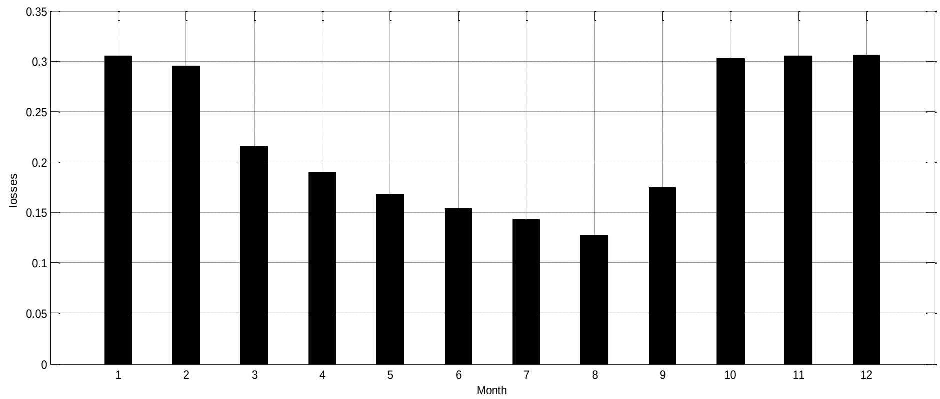

Figure 15. Evolution of the global losses for one year of operation of the system

6. CONCLUSION

Our study related to the analysis of a photovoltaic system of power intended for a site isolated from Oran-Algeria. Simulations of the models realized allow an analysis of the operation of the system during one year. This study takes into account the concept with the solar energy utilization. The taking into account of this important concept has enabled to us to propose a new manner of having and of interpreting the results of dimensioning of a photovoltaic installation. The advantage of this methodological approach is to enable us to better apprehend the solar natural energy of a given site. Solar energy thus presents an private interest for the countries in the process of development: it is likely to improve very quickly and with the help of an optimal cost the productivity and living conditions of the geographically dispersed dwellings.

REFERENCES

[1] S. A. Boudghene, *et al.*, "A review on the renewable energy development in Algeria: current perspective, energy sce-nario and sustainability issues," *Renew Sustain Energy*, vol/issue: 16(7), pp. 4445– 60, 2012.
[2] M. T. Makhloufi, "A Feed forward Neural Network MPPT Control Strategy Applied to a Modified Cuk Converter," *International Journal of Electrical and Computer Engineering*, vol/issue: 6(04), pp. 1421-1433, 2016.
[3] A. Labouret and M. Villoz, "Solar energy photovoltaic," solar energy 2nd edition.
[4] T. U. A. Towsend, "Method for estimating the long-term performance of direct-copled photovoltaic systems," MS Thesis, Solar Energy Laboratory, University of Wisconsin, 1989.
[5] Catalog blue sun group
[6] C. E. Huber, "Study of the operation and optimization of the design of a system combustible battery PEM exploits in cogeneration in the building," *The school of the mines of paris*, 2005.
[7] A. E. Maaty Metwally Aly Abd El-Aal, "Modelling and Simulation of a Photovoltaic fuel Cell Hybrid System," Faculty of Electrical Engineering University of Kassel, 2005.
[8] Amirullah, "Power Quality Enhancement of Integration Photovoltaic Generator to Grid under Variable Solar Irradiance Level using MPPT-Fuzzy," *International Journal of Electrical and Computer Engineering (IJECE)*, vol/issue: 6(6), pp. 2629-2642, 2016.
[9] S. I. Go, *et al.*, "Simulation and Analysis of Existing MPPT Control Methods in a PV Generation System," *Journal of International Council on Electrical Engineering,* vol/issue: 1(4), pp. 446-451, 2011.
[10] V. Salas, "Review of the Maximum Power Point Tracking Algorithms for Stand-alone Photovoltaic Systems," Elsevier, 2006.
[11] Center for the Development of Renewable Energies in Algeria *C.D.E.R.*