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Design and Implementation of a Solar Photovoltaic System to Power a Very High Frequency Omnidirectional Range Station VOR (*vhf omnidirectional range*) in Isolated Area (Case of the Maroua - Salak Airport in Cameroon)

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Abstract*: This work is a design and implementation of a photovoltaic system to power the Very high frequency Omnidirectional Range (VOR) station of the Maroua - Salak airport in the Far North region of Cameroon with electrical energy. The strong solar irradiation favours the implementation of this electric system. Solar photovoltaic energy is a solution to the electrification of isolated areas far from the power distribution network. This system supplies devices of the VOR station which comprises the VOR including 200W power accessories, air conditioner Split of 735,5W and five fluorescent lamps for 90W. The 4800Wp photovoltaic plant consists of 48 modules of 100Wp and occupies an area of 130.65 m². The storage system has a capacity of 243600 Ah composed of 84 batteries of 2900 Ah of 2.1V with a maximum autonomy of 7 days. The energy monthly production of the system on the year of test is included between 528.57 kWh and 768.76 kWh. These results are satisfactory and interesting for the functioning of the station. The system is the appropriate reliable energy solution. It greatly contributes to sustainable development of the remote areas.*

Keywords: Design, implementation, Photovoltaic System, Electricity production, solar irradiation; load, Autonomy

1. Introduction

The internationalization of the Maroua-Salak airport located in Far North Cameroon requires on the renewal and modernization of its infrastructure. Among which the integration of the VOR station which is important and capital equipment for any airport that wants to be international and uses latest technology. In order to prevent any diffusion of an electric transmission network that may affect the operation of the airport system, it is interesting and judicious to set up an autonomous electrical system. Located in an area with a huge solar irradiation, the photovoltaic system is adequate to supply electric power to the VOR station [2]. It's an alternative to the generator which emits greenhouse gases [3]. It also reduces costs of maintenance and transportation [1, 3].

The objective of this paper is to design size and implement the electrification of the VOR station by solar photovoltaic energy.

2. Presentation of the Station

2.1 Site Location

The Maroua - Salak airport is located 18 km from the Maroua city at an altitude of 424 m above sea level and has an average annual temperature of 40° C. Table 1 shows the geographical coordinates of the site. The VOR station is 6 km away from the buildings of the airport runway. It is thus isolated from the electrical supply of the airport. The panels are located 52 m from the VOR equipment to avoid congestion or obstruction of the solar irradiation.

Table 1: Geographical and meteorological data of the Maroua - Salak airport

Geographic data	
Latitude	10,6'N
Longitude	14,3'E
Altitude	394 m
Meteorological data	
Average maximum temperature	29,6°C
Average minimum temperature	23°C
Absolute maximum temperature	41°C
Absolute minimum temperature	21°C
Average sunshine duration	8 h/day

2.2 Station description

The VOR (abbreviated VHF omnidirectional range) is a radio electric positioning system used in aerial navigation operating with frequencies. It's two beacons transmit on 108.00 to 117.95 MHz band with a pitch of 50 and with a power of 200 W. Therefore the need of an energy system is capital for its operation [6].

Power requirements are estimated based on the list of the device's components, their characteristics and their running time (Table 2). Different geographical, technological and budget constraints are also taken into account. For reasons of safety and maintenance, we integrate into the assessment five fluorescent lamps and an air conditioner. This meets with the requirements of the operation of the various products for which certain well defined conditions of temperature and relative humidity are essential. The device also requires converters, regulators, and the inverter because the powers demanded by the alternating current loads are supplied with direct current by the PV system and the storage system.

Table 2: Characteristics of equipment of the station

Equipment	Number	Power (W)	Tension (V)	Average usage time per day (h)
Equipment VOR	1	200	220	24
air-conditioner	1	736	220	18
fluorescent lamp	5	18	220	12

3. Equipment

The wireless station Vantage Pro2 Plus of Maroua - Salak (10,6N, 14,3E) is located 423 m above sea level in an opened area free from any shading or impediment. This weather station includes two modules namely the Integrated Sensor Suite (ISS) powered by battery and solar photovoltaic energy, and a remote console that records and analyzes data from the ISS. The latter includes several probes of which the global solar radiation sensor, the solar irradiation sensor of the company Davis Instruments. The Vantage Pro2 Plus station enabled the record of solar irradiation every day 24h/24 [2].

To validate the solar irradiation data, the software RETScreen is also used by introducing geographic coordinates of the place.
The sizing of solar panels is made by the software PVSYST version 5. It also helps to get energy production, the cost and area required for installation depending on the irradiation.

The design and simulation of diagrams from a library of component are performed by the CHEMAPLIC software. It is in charge of managing the characteristics of the components and calculations of currents and powers [16].

From the location and the illustrated needs of the VOR station, the selected photovoltaic system wants itself independent (Figure 1) [8]. It includes as base components the array of PV modules, the valve diode, the controller, batteries, inverters, converters and the load.

The size of component of the system is according to the system's technical constraints [15]. The characteristics of these components are determined in the system's operating range (Figure 1) [14].

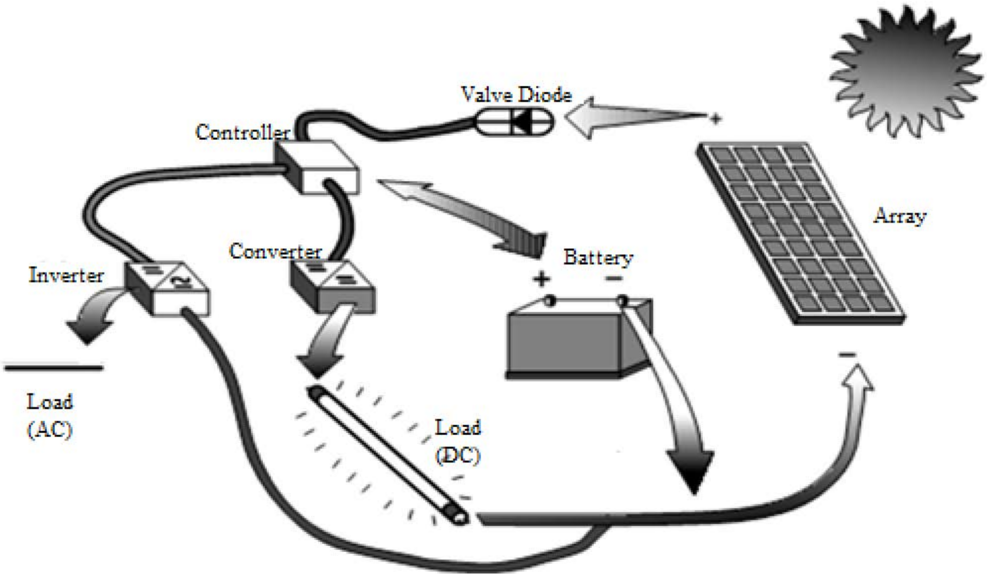

Figure 1: Block diagram of an autonomous system with battery [16]

4. Sizing

4.1 Sizing of the PV array

It is complex to predict the energy consumption and the specific efficiency of the VOR station as the operating conditions vary. This work is done using the method of the average total incident energy of the worst month enabling to size the system with an acceptable degree of accuracy. Nevertheless, the results are processed on the monthly average of the year for a reliable study of the device. The three most important factors of this approach namely daily consumption, storage capacity and daily irradiation are carefully estimated for a satisfactory sizing [4].

The total daily electric energy consumption is obtained by determining the sum of energy balances of AC and DC devices and the number of operating hours.

$$Bj_{TDC} = Bj_{DC} + \frac{Bj_{AC}}{\eta_{ond}} \quad (1)$$

With Bj_{TDC} the total daily consumption of the DC device (Wh/d) ; Bj_{DC} the daily consumption of DC loads (Wh/d) ; Bj_{AC} the daily consumption of AC loads (Wh/d) ; η_{ond} is the efficiency of the inverter - charger.
Note that the inverter charger has a power greater than the active power of AC loads.

The estimation of the storage capacity depends on the desired backup. The battery backup time takes into account the consumption of the number of days (d) and battery technology for the degree of discharge [15].

$$C_{Tbatt} = \frac{Bj_{DC}.\tau}{U_{bat}.d_m.\eta_{batt}} \quad (2)$$

Where C_{batt} is the total battery capacity in ampere - hours ; τ represents the number of days autonomy (d) ; d_m is the battery discharge depth ; U_{bat} is the voltage at the terminals of one battery (V) ; η_{bat} the battery efficiency.

The estimation of the voltage and current of the batteries is made based on the PV system's operating voltage and the load. It takes into account the number of branches of the modules in series and in parallel by the mathematical relationships (3) and (4).

$$N_{bs} = \frac{Us_{bat}}{U_{bat}} \quad (3)$$

With N_{bs} the number of batteries in series ; Us_{bat} the battery voltage in series.

The number of branches N_{bp} is obtained by the relation 4:

$$N_{bp} = \frac{C_{Tbat}}{C_{bat}} \quad (4)$$

With C_{bat} being the capacity of one battery.

The total number of batteries N_{bT} is expressed is expressed by the equation 5 :

$$N_{bT} = N_{bs}.N_{bp} \quad (5)$$

The minimum daily irradiation Hmin (kWh/m²/day) of PV panels is estimated based on the inclination and orientation while avoiding shading [8,-10]. The inclination depends on the latitude in the range between 10 ° to 30 ° and the orientation is due South, South-East since the station is located in the Northern Hemisphere.

The determination of the peak power is based on consumption, the minimum irradiation and product of the different efficiencies taking into account technological options. To avoid overload risks in case of extension of the VOR station, we apply a 10% extension factor [5]. Hence the final peak power is obtained by equation 6.

$$P_p = \frac{1,1Bj_{TDC}}{H_{\min}.\eta_{batt}.\eta_{reg}.\kappa} \quad (6)$$

With $P_{crête}$ is the peak power corresponding to the load of the device in (Wp) ; $H_{\min}$ is the solar irradiation of the worst month on the PV panels (kWh / m² / day) ; η_{reg} the efficiency of the controller ; κ correction factor.

The system voltage used is made according to the peak power installed. The estimation of the tension and current of the PV array takes into account the number of branches of modules in series and in parallel by the mathematical relationships (7) and (8).

$$N_S = \frac{Us}{U_{\text{mod}}} \quad (7)$$

Where N_S is the number of PV modules in series; Us is the system voltage (V); U_{mod} is the voltage of a PV module (V);

$$N_P = \frac{P_{crête}}{P_{c\,\text{mod}}.Ns} \quad (8)$$

Where N_P is the number of parallel branches of PV panels in series;

$P_{c\,\text{mod}}$ is the peak power of a module.

The total number of the PV modules $N = N_P.N_S$ **(9)**

The theoretical energy produced by a photovoltaic generator is obtained from the data of the global irradiation on an inclined plane, the ambient temperature and the manufacturer's data for the photovoltaic module used. It is given by the equation 10.

$$E = \eta_{gen}.A_c.\mathrm{P}_f.H_{\min} \quad (10)$$

Where Ac represents the total surface area of the photovoltaic generator (m²); η_{gen} the yield of the PV generator and $H_{\min}$ the solar irradiation on inclined plane (kWh / m^2).

The yield of the PV array is represented by the following equation:

$$\eta_{gen} = \eta_r.\left[1-\gamma\left(T_C - 25\right)\right] \quad (11)$$

$$T_C = T_a + H_{\min}.\left(\frac{NOCT-20}{800}\right) \quad (12)$$

γ is the coefficient that takes into account of the variation of the yield of the photovoltaic module according to the temperature, which is (0.0045 / ° C) ; η_r is the reference yield of the PV generator; T_a the average daily room temperature; T_C the average daily cell temperature (°C); NOCT is the nominal operating temperature of the cell and P_f which is the filled factor of the PV module, equals to 0.9 [5].

The sizing of the electrical circuit is made by the charts. These include choosing the electrical protection equipment, cables cross sections and their ducts. They are chosen on the basis of limiting to the maximum losses by the Joule effect.

4.2 Methods of sizing cross sectionnal areas of cable.

The calculation of the conductor cross section takes into account the rated load current, or distribution; the type of conductors (multi-conductor or single conductor); the method of installation (cable layout) and the type of insulation (polyvinyl chloride PVC, rubber, PR polyethylene reticulate, EPR butyl, ethylene reticulate) .

The selected letter is chosen depending on the cable type and installation method using charts (determination of the selection letter).

The K1 correction factor is based on the method of installation and the selection letter. It is established by chart. As for the correction factor *k2* it's also obtained by chart and selected based on the letter selection and the type of laying joined or not. The correction factor *k3* is also determined depending on the type of insulation and the ambient temperature.

The correction factor k is the product of various factors. It is expressed by the equation 13

$$k = k1.k2.k3 \quad (13)$$

The current intensity I'z is the maximum current the conductor can permanently convey without prejudice on the cable's life span:

$$I'z = \frac{Iz}{k} \text{ [3]} \quad (14)$$

Iz corresponds to the normalized value of the operating current in (A) .

The determination of the cross section is chosen according to the insulator, the number of loaded conductors and the selection letter. The summary of the minimum cable cross section determination method is shown by the flowchart in Figure 2.

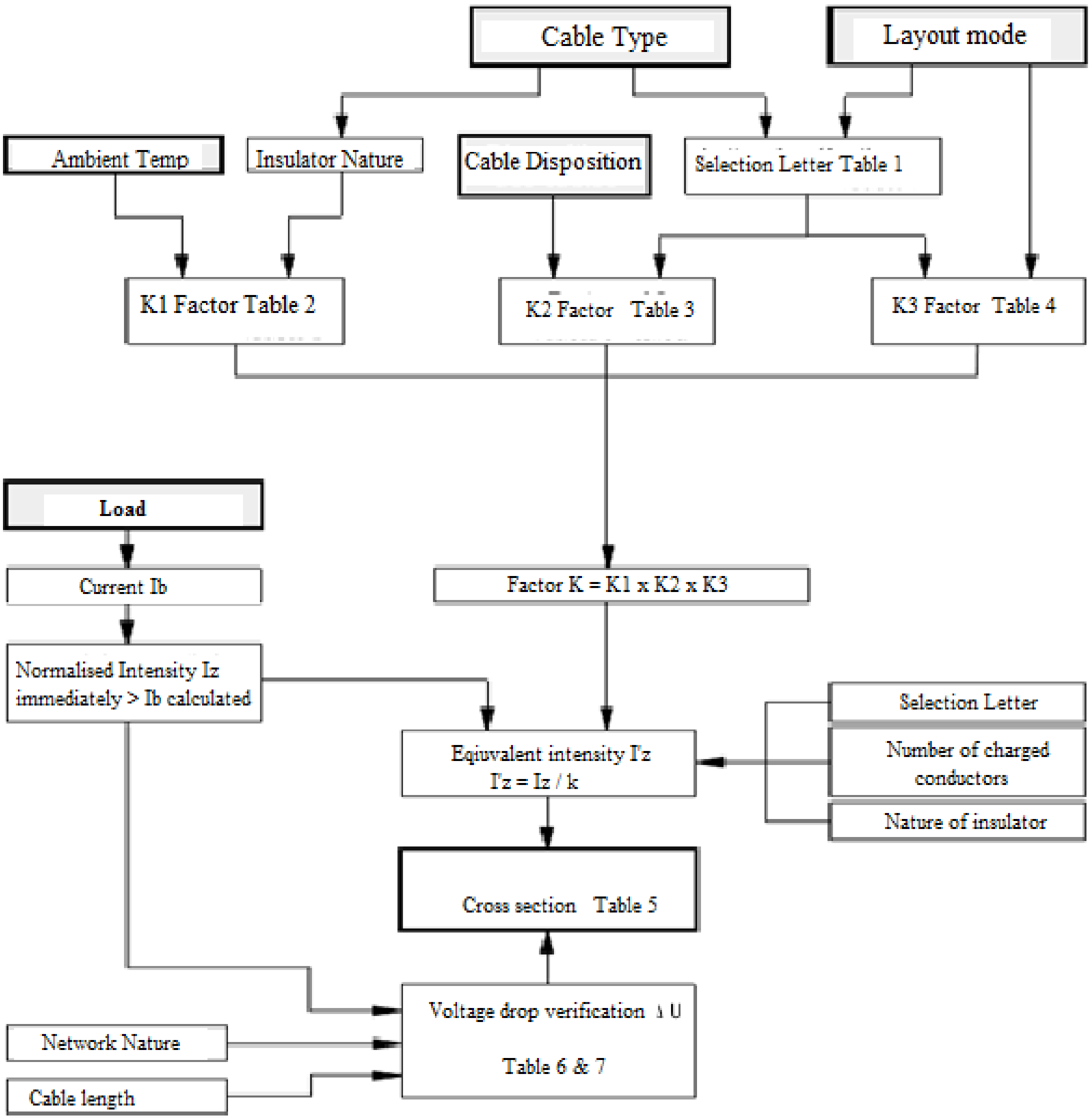

Figure 2: Summary of the method according to "the low voltage distribution guide [8]

5. Results and Discussion

5.1 Solar irradiation of the Site

The curves in Figure 3 are taken from the Vantage Pro2-Plus wireless weather station of Maroua-Salak and the satellite RETScreen software over a period of ten years. These curves show the monthly average solar irradiation of the site and have almost the same evolution. The observed shift is due to the satellite distance and weather pertubations. These results are similar to those obtained on the same ten-year period in the near solar cycle literature [2]. It appears that the average solar irradiation is 6.1 kWh / m² / day. The average solar irradiation results of the satellite RETScreen software are also close to those of the weather station and confirms the solar radiation situation of Maroua-Salak. We note that the month of August has the lowest irradiation value that is 4.92 KWh /m2/ day as opposed to March that has the highest value which is 7.15 kWh / m2 / day. The average daily irradiation is important in two periods February-June and September-November. It exceeds in these months 5.4 kWh / m2 / day.

Figure 4 shows the average monthly temperatures recorded at weather stations and inside the VOR station. The average monthly temperatures of the site vary between 23 ° and 40 ° C. They are favorable for the production of electrical energy by solar panels. At these high external temperatures, the station requires a cooling (internal temperature) which varies between 20 ° and 23 °C. Therefore the solar irradiation and temperature motivate the implementation of the PV system at the station.

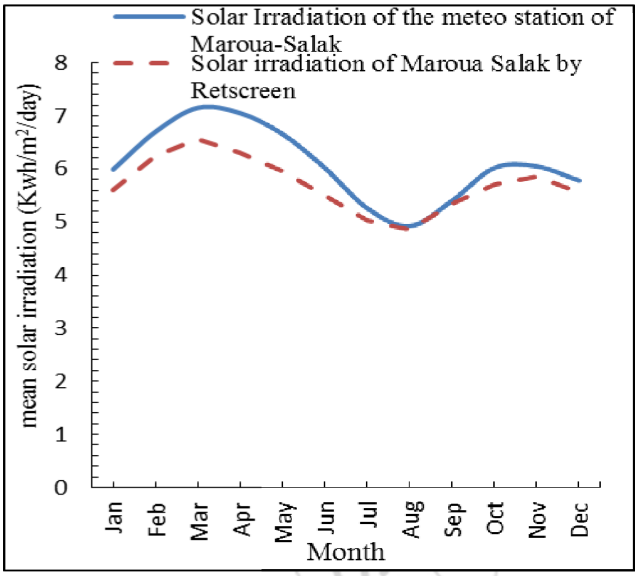

Figure 3: Average sunshine incident on Maroua - Salak per month.

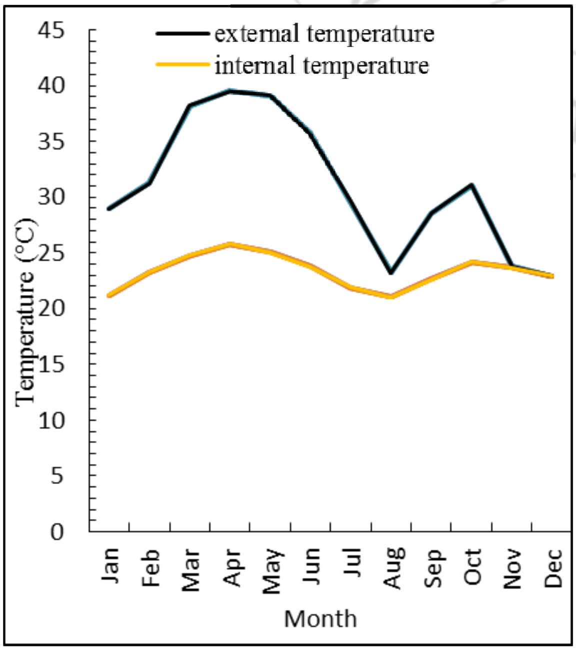

Figure 4: The temperatures in the VOR station Maroua Salak

5.2. Calculation of daily consumption (Wh / d)

The census of loads, their operating time and of course their technical specifications have led to daily consumption assessment established in Table 3. Taking into account the charge of the storage system, it appears that the energy consumption in AC at the station is 19128 Wh per day. This considered in the installation of the PV array with a surplus margin.

Table 3: Results of the daily consumption of the station

Equipment	*Number*	*Power Demand (W)*	*Average operating time per day (h)*	*Consumed energy in (Wh)*
VOR Equipment	1	200	24	4800
Air conditioning	1	736	17	12512
Fluorescent Lamp	5	18	12	1080
Total				18392

Depending on consumption, battery technology and the required autonomy of 11 days, the estimation of the regular storage capacity in Ampere-hour is made from the equation 2 to a storage value of 243504 Ah with a nominal battery voltage of Vacc= 2.1V, battery yield and the discharge cutoff limit are 80% and 35% respectively. The storage system of 84 batteries of rated voltage of 2.1 V and a capacity 2900 Ah consists of mixed assembly of 12 in series and 3 parallel branches. The storage capacity of the installation is of 243600 Ah. It is obtained by applying the mathematical expression 5 to the batteries (Figure 5).

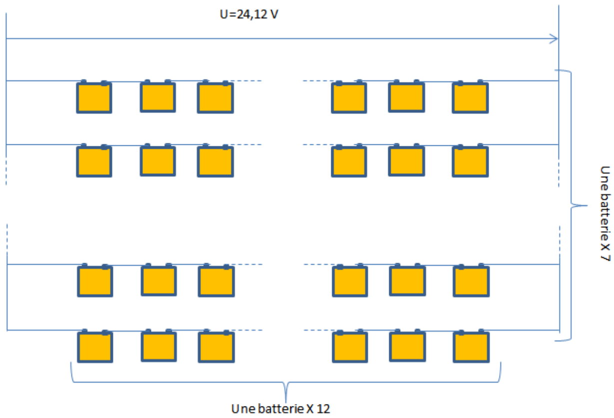

Figure 5: Battery Installation diagram

5.3 Sizing Results of the solar PV array

Knowing the values of the monthly daily irradiation, determining the necessary peak power (Pp) is established based on the less insulated month, in order to avoid all risks of under sizing [2-5]. The average daily solar irradiation of the Month of August 4.87 KWh/m2/d determines including the expansion factor, the total peak power. It is estimated at 4764 Wp using equation 3. The photovoltaic system consists of 48 PV modules of 100 Wp/12V. According to equation (4) we mount 3 PV modules in series and 16 branches of PV modules in parallel (Figure 6). At the end of the photovoltaic system has 4800Wc from the equation 5. The bypass diodes are integrated in each PV module at installation. Figure 4 shows the installation of the system:

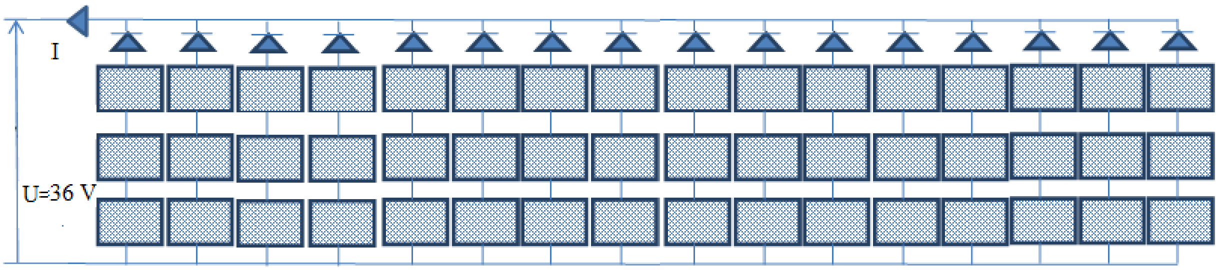

Figure 6: PV modules Arrangement

5.4 Cable sizing Results

Figure 7 shows the distribution pattern of the electric circuits and provides a panoramic view of the installation. It allows the passage for the design and also presents the progress of work. The choice of cables depends on several parameters (temperature, resistivity, durability, length etc.). The ambient temperature of the cables is 43 ° C. In this work, the installation of various cables meets the installation method (Table 4)

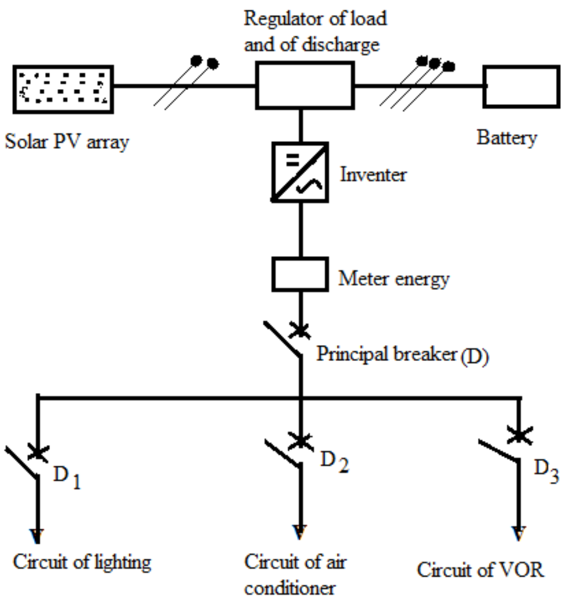

Figure 7: General distribution diagram of the installation

Table 4: Laying method of the different cables of the installation

Reference of the cables	Cross section (m^2)	Length (m)	Laying method
C_0	S_0	55 m	PVC cables multi conductor buried directly under gutter on cable trays or perforated shelf horizontal path and walking to one side
C_1	S_1	5 m	PVC multi conductor cables installed in apparent conduit
C_2	S_2	7 m	PVC multi conductor cables installed in apparent conduit
C_3	S_3	10 m	PVC multi conductor cables installed in conduit
C_4	S_4	2 m	PVC multi conductor cables installed in apparent conduit
C_5	S_5	2 m	PVC multi conductor cables installed in apparent conduit
C_6	S_6	2 m	PVC multi conductor cables installed in apparent circuit

According to studies and charts configurations selection letters B and E which are established, respectively characterize multilayer cables embedded in the material and suspended. The correction factors k1, k2, k3 are determined by the coefficients of the letters of selection C, B and E. The global correction factor k is determined by the equation 6. The current consumed by the equipment Iz and the correction factor k which enables to obtain the admissible current I'z is given by equation 8. Thus, cross sections of the cables are defined in table 5. From Tables 3 and 4, the choices of circuit breakers for protection of the various circuits are done in Table 6.

Table 5: Letter selection for different cables

Reference of the cables	C_0	C_1	C_2	C_3	C_4	C_5	C_6
Selection letter	B	E	E	E	E	E	E
Length in m	54	5	7	10	2	2	2
k1	0,95	1	1	1	1	1	1
k2	1	1	1	1	1	1	1
k3	0,87	0,87	0,87	0,87	0,87	0,87	0,87
k	0,82	0,87	0,87	0,87	0,87	0,87	0,87
Iz	44	44	44	44	3,75	26,06	14,16
I'z	53,65	50,57	50,57	50,57	4,31	29,95	16,27
Cross section in (mm^2)	16	10	10	10	1,5	4	1,5

Table 6: Selection of circuit breakers for different circuits

Circuit breaker's Reference	D	D_1	D_2	D_3
Rated Current (A)	50	10	32	16
Brand and Reference	C60PV-DC	C60PV-DC	C60PV-DC	C60PV-DC

5.5 Implementation of the Installation

The panels are screwed to metal brackets which are fixed to the concrete supports located on the ground. They are orientated due south as they are found in the northern hemisphere and have an inclination of 15° with respect to the horizontal ground with its known latitude as in table 1. Its foundations also provide protection of the panel against the wind and ensure the maintenance of the tilt and orientation of the latest (Figures 8).

Figure 8: Foundation for the implementation of the solar panels

The PV array is divided into three rows, each consisting of 16 modules sufficiently spaced so as to avoid shadow effect on them. They are mounted at a height of about one meter from the ground to enable cooling by convection (Figure 9).

The assembly is done respecting the designation of terminals and their polarities. The panels of the array are connected starting from the lowest voltage. The connections are made in small groups, so as to push the achievement of higher voltage circuits as close to the final connections. Good tightening of the cables are made [11].

The PV modules are covered during the connection of the different components of the installation. The switch of the charge and discharge controller is in the off position. The cables are coded by color or number for better identification. A red cable indicates the positive, black wire indicates negative and green-yellow the earthling cable (Figure 10). After positioning all the components and fastening the cables, first we connect the power cable supplying the VOR, and then that of the cables at the terminals of the photovoltaic panels (Figure 9). After a thorough check of each of the connections, we put the system on, at midday while solar irradiation is constant. Tension is found using a voltmeter whose maximum open circuit voltage (Voc) is normal. The switch is then positioned. After about 10 seconds, the station starts operating (Figure 11).

Figure 9a: Fixation of PV panel cables

Figure 9b: Fixation of PV panel cables

Figure 10: Distribution boards of the various circuits

Figure 11: The photovoltaic system and the VOR station.

5.6 Experimentation and annual operating

Figure 12 illustrates the monthly peak powers demands and installed by the PV array. They are a function of solar irradiation and different yields for operation of the electric loads of the VOR station. The relevant and interesting observation is the superiority of the value of the peak power installed compared to the peak power of the worst insulated month. Figure 13 presents the curves of the theoretical and actual electrical power produced from average records conducted in PV array of the VOR station per month at the test year. The theoretical power produced taking into account the solar irradiation and the panel tilt varies between 2.03 and 2.75 kW while the actual power varies between 1.88 and 2.75 kW, which largely meets the demand of the weather station. The two curves having substantially the same pace, still differ at some points. This difference can be explained by the laying of dust and inclination of the PV modules that alter the output power and causes a real power output with lower values recorded, not in accordance with the expected theoretical values. A consideration of maintenance of the PV panels and tilt can alleviate the observed difference.

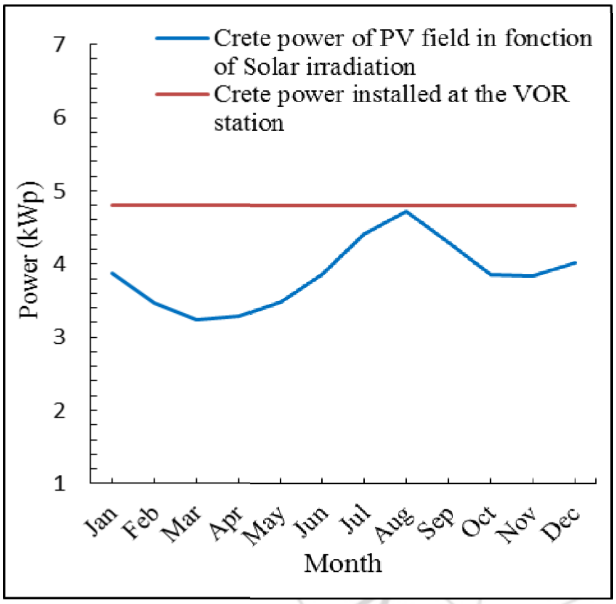

Figure 12: Peak power demand installed according to month in the VOR station

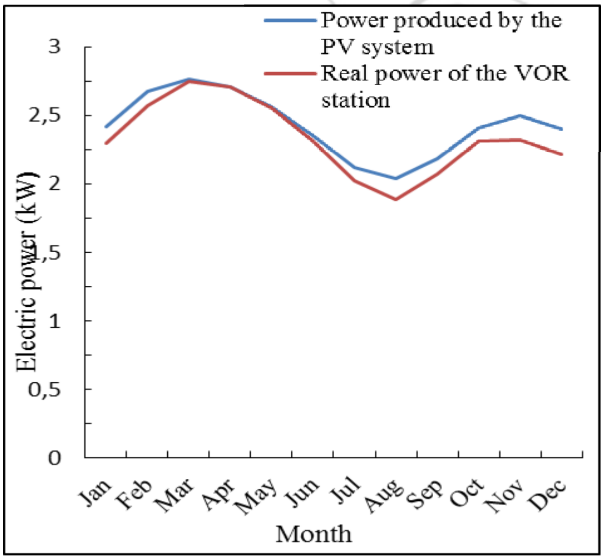

Figure 13: Theoretical and actual electric Power outputs according to months

Figure 14 presents the actual and theoretical energy produced by the PV system based on the energy consumed by the loads. The theoretical energy produced is between 571.13 and 774.11 kWh, while the electric meter shows the actual energy which is between 528.57 and 768.76 kWh (Figure 14). The months of July and August have low production. Usually these two months experience low solar irradiation and temperatures. The electric power consumed by the loads in operation by excluding the battery charge is around 521 kWh. The analysis always confirms the relationship between the different energies produced, stored and consumed with losses.

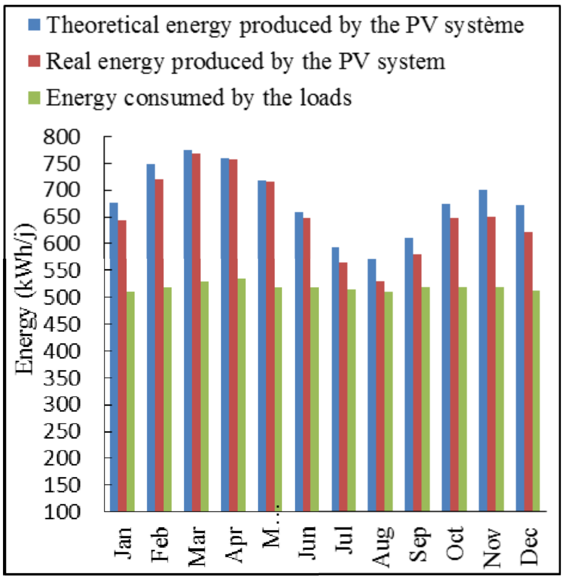

Figure 14: Monthly energies at the VOR station.

The battery storage capacity is satisfactory per day. The number of days of autonomy operation differs per month (Figure 15). The percentage of days with fully charged batteries varies from 48.2% to 100% that is from 3 days to 16 days of autonomous operation. The storage capacity exceeding 11 days of autonomy is not necessary since it calls for an increase in storage. Above this value there is an impact on the storage system. It also corresponds to the month with highest solar irradiation. To ensure the longevity of the batteries which is closely related to their charges and discharges, the stored energy is returned during the nights and days without sunshine. This ensures careful protection against overcharging and deep discharge.

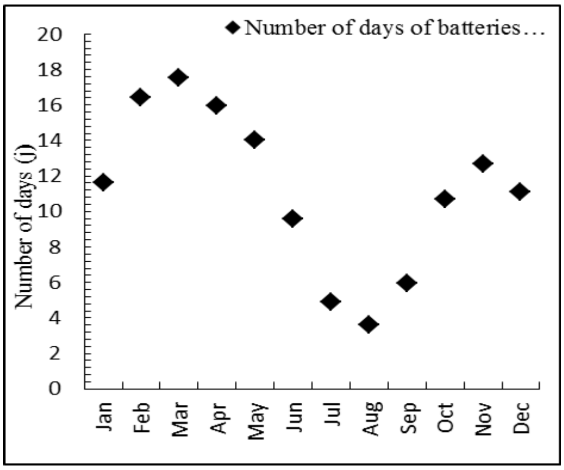

Figure 15: Number of days of the month with autonomous power of the batteries.

6. Conclusion

This work consisted in the study of the design and implementation of the PV system to power the VOR station of Maroua-Salak airport. The design methods and analysis that have been implemented in this work, reveal interesting results by establishing an effective system capable of significantly powering the VOR station. The photovoltaic system of 48 modules installed occupies a surface area of 130.65 m² for a 4800 Wp power. For the demand of the VOR station is always less than 1.098 kW and its equipment, the power produced by the PV system varies between 1.88 and 2.75 kW which largely meets the demand of the weather station. This system operating independently, has an energy storage system capacity of 243600 Ah which can ensure 3 to 16 days autonomy depending on the month. This work on system needs to be installed for electrically isolated systems and for other airports in the Sahelian zone. It contributes to sustainable development in these isolated and remote areas by reducing the use of thermal generators which increase air pollution due to the emission of greenhouse gases.

7. Nomenclature

AC: Alternative currrent
DC: Direct Current
CCAA: Cameroon Civil Aviation Authority
DAC: Civil Aviation Directorate
DC: Direct Current
DME: distance measuring equipment
FM: Frequency Modulation;
PWM Modulation in Pulse Width;
MPPT: Maximum Power Point Tracking
PV: Photovoltaic;
PWM: Pulse Width Modulation;
PVC: Polyvinyl chloride;
VHF: Very High Frequency;
VOR: VHF omnidirectional range

8. Acknowledgments

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References

[1] Belhamel M., Moussa S.et Kaabeche A., (2002) "Production d'Electricité au Moyen d'un Système Hybride (Eolien-Photovoltaïque-Diesel)", Revue des Energies Renouvelables, Numéro Spécial, Zones Arides, pp. 49 – 54.
[2] Fotsing Talla C., Njomo D., Cornet C., Dubuisson P., Nsouandele J. L.(2015), "Acquisition and Study of Global Solar Radiation in Maroua-Cameroon", International Journal of Renewable Energy Research", Vol. 5, No. 3, pp. 910 – 918.
[3] Ricaud A., (2006). "Modules Photovoltaïques: les Filières Technologiques", Editions Sciences et Techniques de l'Ingénieur, www.techniques-ingenieur.fr.
[4] Flèche B. & Delagne D. (2007). "Production d'énergie électrique, Energie solaire photovoltaique", STI ELT.
[5] Hamidat A., Hadj Arab A., et Belhamel M., (2007). "Etude et réalisation d'une mini centrale photovoltaïque hybride pour l'électrification du refuge Assekrem" Revue des Energies Renouvelables Vol. 10, N°2, pp 265 – 272.
[6] *VHF* omnidirectional range, www.wikipédia.fr, Consulté le 07 septembre 2015 à 17h30.
[7] Stoyanov L., Notton G.et Lazarov V., "Optimisation des systèmes multi-sources de production d'électricité à énergies renouvelables", Revue des Energies Renouvelables, Vol. 10, N°1, pp 1 – 18, 2007.
[8] NFC-15-100, "Installations électriques à basse tension", Document Hager, Décembre 2002
[9] Ould Mohamed Yahya A., Ould Mahmoud A. et Youm I., (2007). "Modélisation d'un système de stockage intégré dans un système hybride (PV / Eolien / Diesel) ", Revue des Energies Renouvelables Vol. 10, N°2, pp 205 – 214.
[10] Belatel M., Benchikh F., Simohamed Z., Ferhat F.et Aissous F.Z., "Technologie du couplage d'un système hybride de type photovoltaïque-éolien avec la pile à combustible pour la production de l'électricité verte", Revue des Energies Renouvelables Vol. 14, N°1 pp 145 – 162, 2011.
[11] Schiller E., (1998) "Le pompage photovoltaique": Manuel de cours à l'intention des ingénieurs et des techniciens, IEPF/Université d'Ottawa/EIER/CREPA. Edition 1998.
[12] NF C-15-100, Canalisations et conduits, Le pavillon Septembre 2013.
[13] Lonchampt A. et Gatine G. (1990), "Distribution électrique à haute disponibilité", Cahier Technique Schneider Electric n°148, édition décembre 1990
[14] Schneider Electrique,(2012) "Distribution électrique basse tension et HTA", Edition 2012 ;
[15] Schneider Electrique,(2012) "Catalogue résidentiel et petit tertiaire".
[16] FITEC, (2013). "Logiciels de Simulation : CHEMAPLIC".
[17] Mazille D. et Boitier V., "Documentation pour l'utilisation du logiciel PVSyst V5", Edition 2011.