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Realization of Remote WebSIG of Photovoltaic Micro-Networks in Conakry (Guinea)

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ABSTRACT
In Conakry, Guinea, the development of solar energy is still in an embryonic state. With this in mind, the popularization of photovoltaic energy seems to be the right alternative to sustainably improve access to electricity for residents of Conakry. This study proposes to provide a solution to the energy deficit of the population of Conakry. It aims to implement a Web GIS remote monitoring of photovoltaic micro-networks using low speed mobile GSM / GPRS networks to centralize the data collected. The tools used for this purpose in particular are the PostgreSQL / PostGIS couple, the Apache server, the free QGIS GIS software, the LizMap cartographic servers and web portal, the Win `Design software, etc. have effectively controlled the photovoltaic stations. It also aims at making thematic maps relating to the sun, the stock and the energy consumption, as well as the shedding statistics and finally to understand the causes of their dysfunction so as to remedy them by taking effective corrective or preventative measures to contain the anomalies.

Keywords
Photovoltaic energy, Web GIS, Web mapping, Conakry, Guinea.

1. INTRODUCTION
Africa has various renewable resources (biomass, wind, hydro, solar PV, etc.). However, these sources of energy are under-exploited in relation to their real potential. Among all these renewable energies, solar photovoltaic offers the most potential (Korsaga and *al*., 2018) [1]. Just like water and air, the sun is at the base of life on Earth, to which it brings warmth and light. Inexhaustible, available, non-polluting, solar energy provides enough to meet the consumption of the Planet (Total, 2015) [2]. Despite this providential gift, most countries have a rather centralized and "vertically integrated" electricity system (Kanchev, 2014) [3]. However, in the current environmental and political context (climate change problem, greenhouse gas emissions, etc.), the use of renewable energies as energy of Republic of Guinea (Conakry) is a coastal country in West Africa. Its capital Conakry is the object of this study, (Figure 1).

The future becomes crucial (Houari, 2012) [4]. The challenge is to collect even a small share of this caloric and radiant energy (TOtal, 2015) [2]. Guinea Conakry faces this challenge. Indeed, with a solar potential, estimated at 4.8 KWH / m^2 / day, Guinea does not manage to satisfy its population in electricity. Untimely, load shedding has favored the extension of generators as the first alternative to power cuts (Kpegné, 2017) [5]. Moreover, despite the commissioning of the Kaleta dam with a capacity of 240 MW, Guinea cannot satisfy its population in electricity. Relying on these observations, the expansion of photovoltaic energy seems to be the good alternative for sustainably improving access to electricity for the inhabitants of Conakry (Kpegné, 2017) [5], hence the purpose of this study which proposes to realize a Web GIS of remote supervision of the photovoltaic micro-networks, with the aim of providing sustainable electricity to the inhabitants.

1.1 Objectives
The main objective assigned to this study is the establishment of a decision support tool in the field of photovoltaic energy to ensure the control, monitoring and maintenance of photovoltaic installations.

It will specifically:

1- Register the solar stations of Conakry in order to create a spatial database of Web mapping;

2- Model the data acquisition and centralization system of the photovoltaic stations observed in order to feed the database;

3- Set up a remote-control system for photovoltaic stations in order to correct or prevent anomalies and malfunctions.

1.2 Presentation of the Study Area
Most of the vector files on the administrative division of

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Guinea came from the National Institute of Statistics of Guinea (INS Guinea) format shapefile. The raster file for the Conakry region in TIFF format was downloaded from the OpenStreetMap virtual map server.

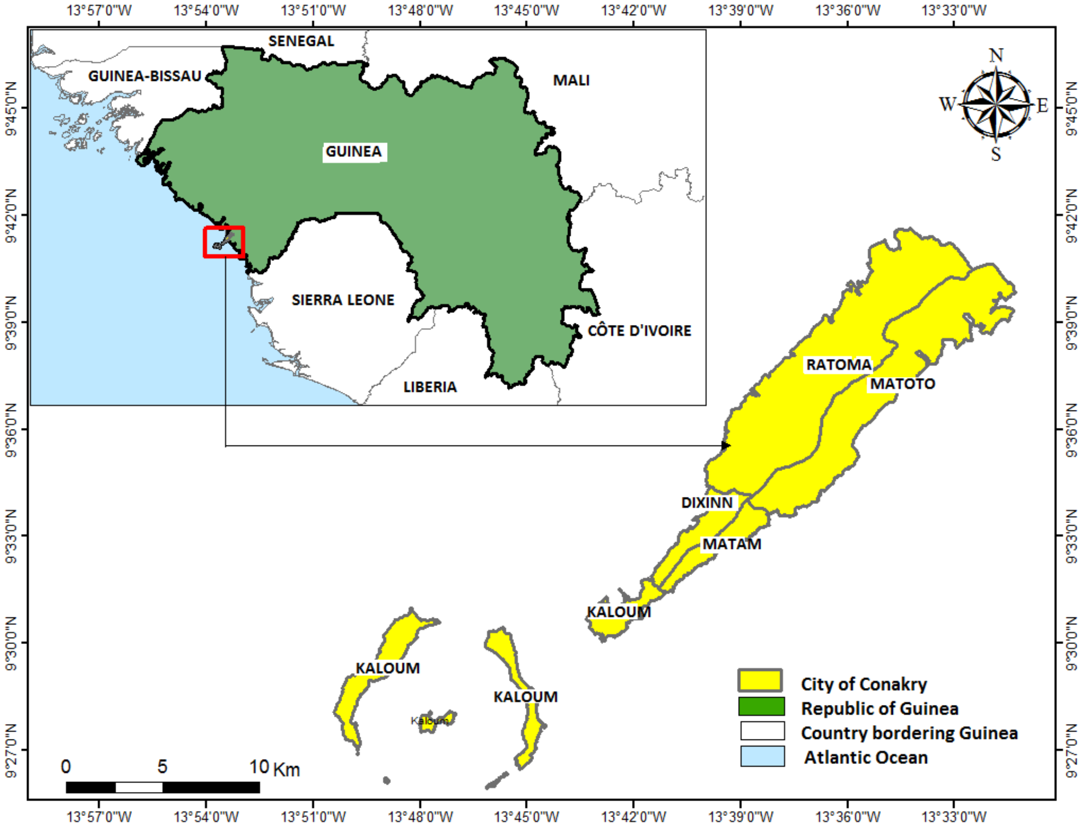

Fig 1: Location of the city of Conakry in the Republic of Guinea

2. MATERIALS AND METHODS

2.1 Equipment

2.1.1 Digital data

This study required the use of several vector and raster data. To these cartographic files, it is necessary to add digital maps relating to the administrative division of Conakry as well as Guinea exploited during the field surveys. Other data processed in this work were collected on the different sites distributed in the study area via measuring instruments. These are customer data and PV system data.

2.1.2 Field Equipment

The materials chosen to carry out this study, consists of: a GARMIN 62 GPS, a camera, survey form to collect data on photoelectric installations.

2.1.3 Software

The implementation of a Web GIS involves the use of several important software presented below : The PostgreSQL / PostGIS pair as RDBMS software, Apache server, QGIS Desktop 2.12.0 and LizMap Plugin.

2.2 Methods

2.2.1 Census and mapping of solar stations in Conakry

The process of creating the web mapping spatial database began with the identification of photovoltaic sites and the integration of customer data with Web GIS (Figure 2).

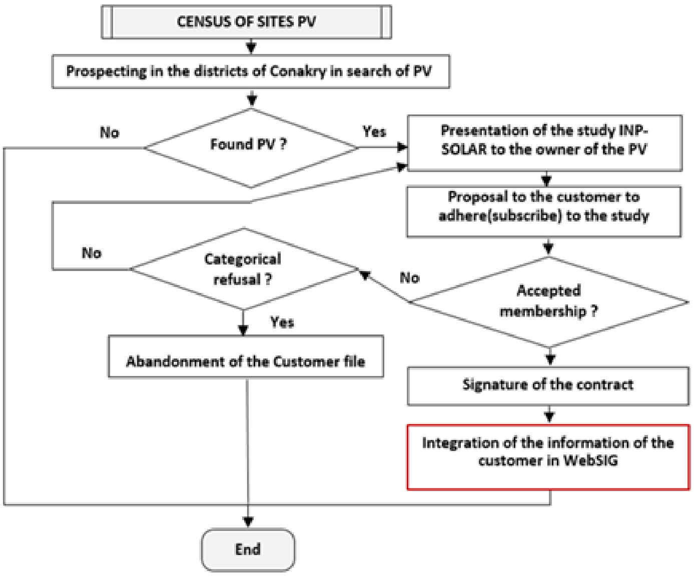

Fig 2: Process of integrating customer information into WebSIG

This process was completed by mapping solar stations or photovoltaic generators with the integration of their technical specificities in GIS (Figure 3). Thus, using a GPS, the geographical coordinates and the geographical location of each photovoltaic installation were noted. These geographical coordinates were then introduced into the Quantum GIS software for the realization of the spatial distribution map of the solar stations.

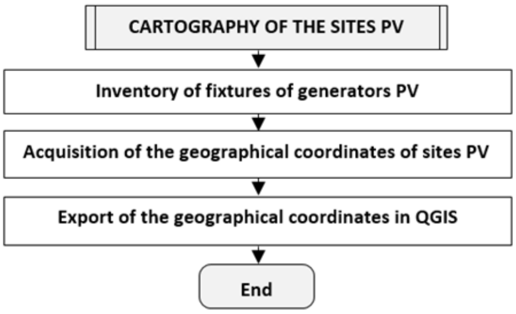

Fig 3: Mapping process of PV sites identified in the study area

The design of web mapping is based on the five basic functionalities of a GIS (Abstraction, Acquisition, Archiving, Analysis and Display) called "5A".

2.2.2 *Method of modeling the data acquisition and centralization system of photovoltaic stations*

The UML is the best adopted modeling language in our study because the GIS application manages complex data and requires precision and exploitability (Roques, 2008) [6].

To achieve the MERIS Conceptual Data Model (CDM) with the UML notation, an Object-Oriented Model (OOM) is required as a class diagram (Figure 4). This class diagram defines the different management rules of the Web SIG INP-SOLAR.

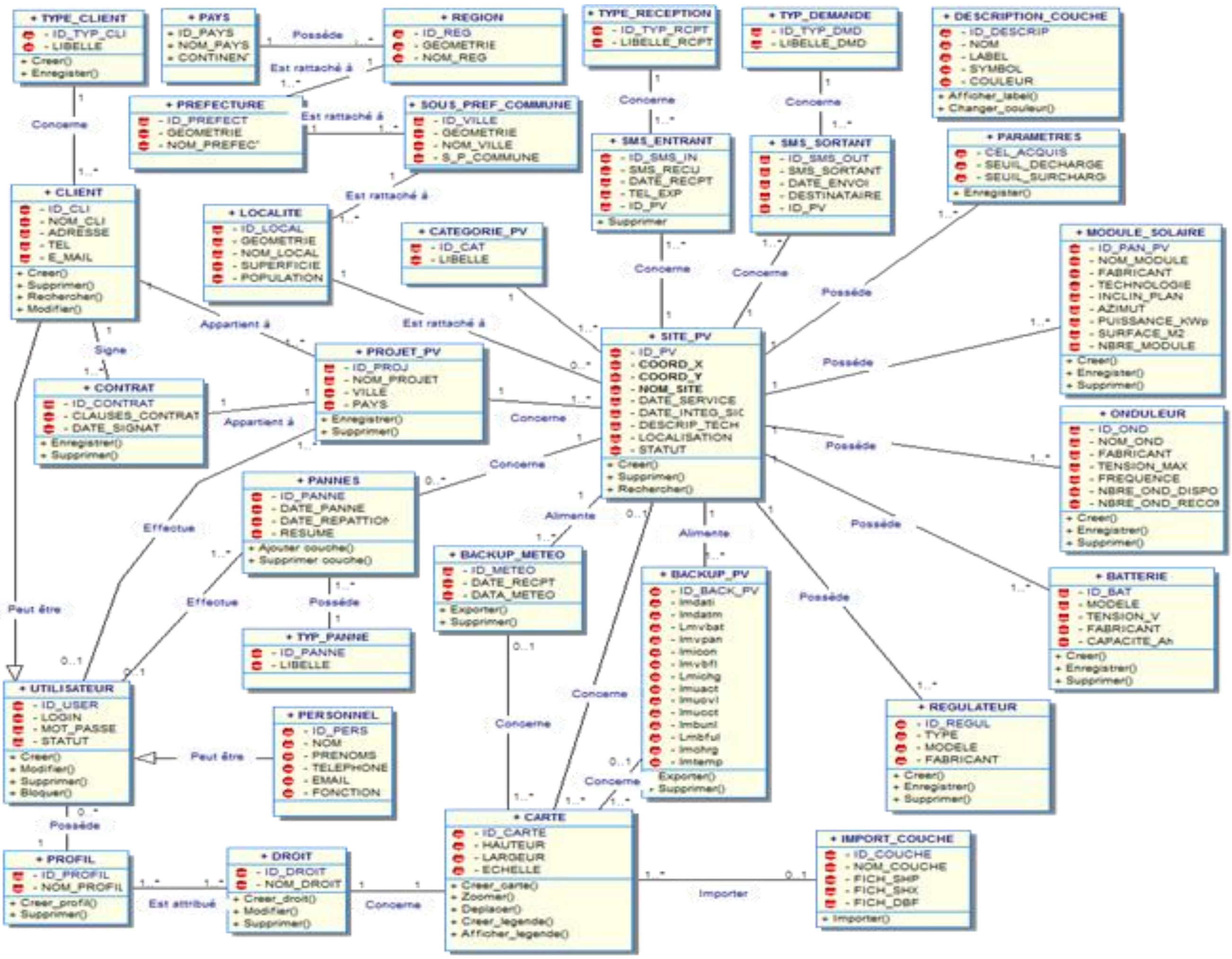

Fig 4: Diagram of classes (UML) equivalent of the Conceptual model of data (MERIS)

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The modeling process was completed with the implementation of a data acquisition system in the GIS which took place in two phases:

a) The design phase of the experimental data acquisition system.

Figure 5 below shows the conceptual diagram of the data acquisition system.

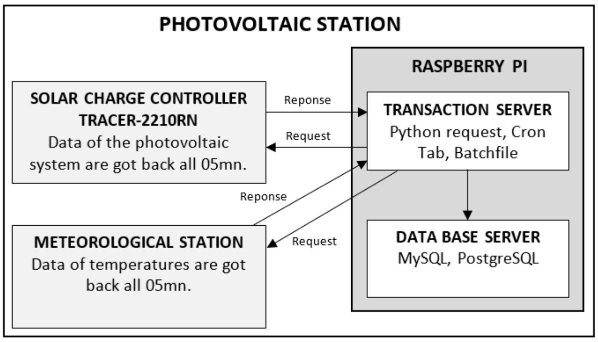

Fig 5: Diagram of classes (UML) equivalent of the Conceptual model of data (MERISE)

b) The centralization phase of the data collected

The Web GIS has a centralized management. To do this, all the data measured on each photovoltaic generator must be transferred to the central map server. Figure 6 below shows the overall view and operation of the system.

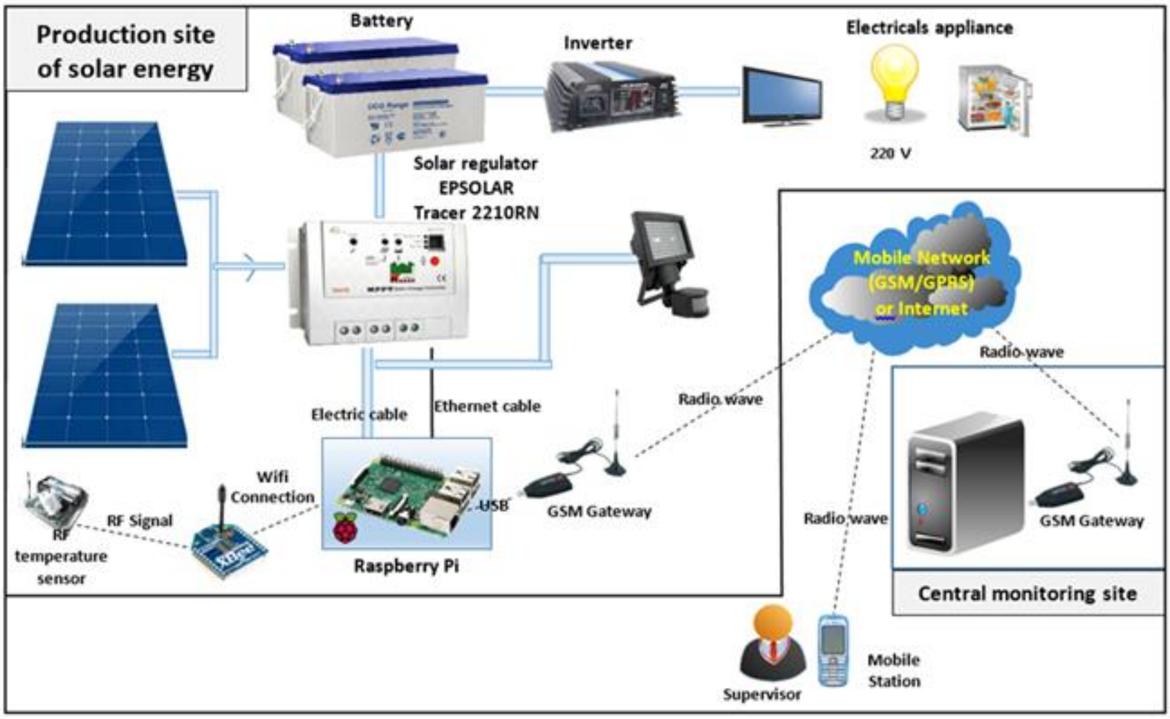

Fig 6: System of the centralization of collected data on the server.

The GSM / GPRS mobile network, which is widespread in rural and urban areas, is used as a means to transfer measurements collected from the photovoltaic production site to the central map server in the form of a formatted SMS. This requires a computer system coupled with a GSM gateway (Figures 7 and 8) on each site. The number of SMS that can be handled by a GSM modem per minute is about 5 to 6 SMS per minute which is more than enough.

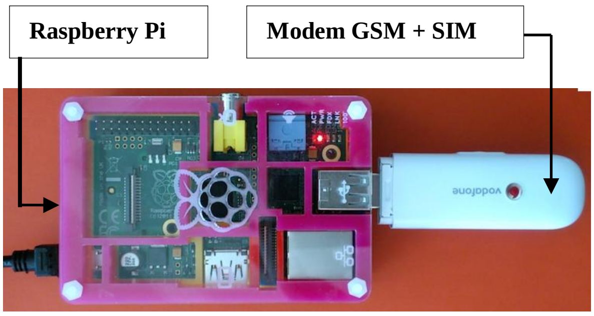

Fig 7: Hoop of the data acquisition system

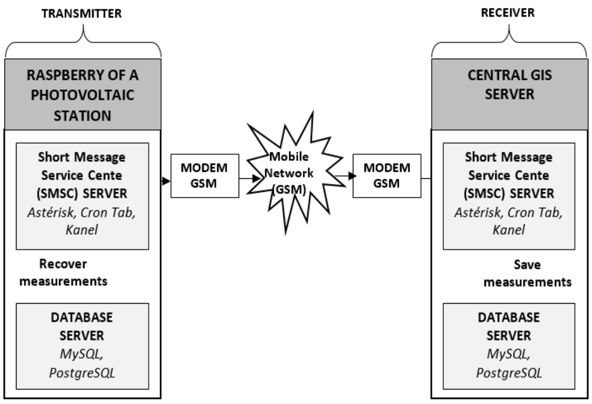

Fig 8: Synoptic diagram of the system of centralization of collected data

SMS packs have been loaded into the different GSM gateways in order to transfer the data collected and formatted at regular intervals to the central server GIS. The sizing of the total SMS pack of the various photovoltaic production sites is obtained by the following formula:

$$Pack\ SMS = \frac{Transfer\ Period\ (mn)}{Frequency\ of\ sending\ (mn)} \times NPV$$

Or NPV= Number of PV.

In this study, ten solar generators were observed over four days (5,760mn) with five (05) minutes per sending interval. This makes a total SMS pack of 11 520 SMS or 1 152 SMS to satisfy the data transfer of each PV station.

2.2.3 Remote control method

To control the photovoltaic stations, it is imperative to know their detailed operation at a distance. The realization of this last step of the implementation of the GIS involves the archiving, analysis and display of data on an interactive map. These are the latest features of the functional principle of GIS based on the "5A" that remain to be implemented.

2.2.3.1 Archiving of data

Archiving has made it possible to store the acquired data in order to find them easily. For this, it was necessary to use a DBMS (Geographic Database Management System) to facilitate the storage, organization and management of data according to the class diagram or the conceptual data model. We chose PostgreSQL 9.6 with its PostGIS 2.2 spatial component, which is the best database for free software. This software made it possible to import geographic data. The shapefile layers were then integrated from the database created via the PostGIS Plugin.

They can also be integrated from QGIS via the Spit Plugin accessible in Qgis Desktop through the menu:

$\boxed{\textbf{Database}}$ => $\boxed{\textbf{Spit}}$ => $\boxed{\textbf{Import shapes in PostgreSQL}}$

2.2.3.2 Data Analysis

The selected QGIS Server free map server has enabled geographic data to be formatted so that it can respond to users' multicriteria queries. Its role is to draw information from the database and other resources to generate images that will be transmitted to a client via a web server.

2.2.3.3 Display of Data

The display can be done on different media. Most of the time, the GIS installed on a fixed machine is capable of reading one or more image formats and manipulating databases in order to display the desired information on the screen. Today, it becomes possible to install the software directly on its machine and to realize its requests and the display of the results directly via Internet. Cartographic data can only be displayed on a computer, tablet or mobile phone if browsers are installed. These map states can be printed on paper or generated in PDF format.

3. RESULTS

3.1 Census and mapping of photovoltaic generators in Conakry

On-site surveys made it possible to identify the geographical coordinates and the geographical situation of each photovoltaic installation thanks to a GPS and a digital map of the district of Conakry. Table I lists the PV installations visited and Figure 9 shows their spatial distribution.

Tableau I: List of photovoltaic installations observed in Conakry

ID	Wording	Customer type	City of Conakry	Long	Lat
1	BELA LEKKOL_PV	School	RATOMA	**-13.641**	**9.603**
2	SENNADE_PV	School	RATOMA	**-13.612**	**9.606**
3	ELISABETH_PV	School	KALOUM	**-13.704**	**9.509**
4	KOUMANDIAN KEITA_PV	School	MATAM	**-13.682**	**9.526**
5	MAGUETTE TRAORE_PV	School	MATOTO	**-13.601**	**9.591**
6	LAVOISIER_PV	School	DIXINN	**-13.665**	**9.552**
7	TRANSCO_PV	Entreprise	KALOUM	**-13.711**	**9.510**
8	INOVATECH_PV	Entreprise	RATOMA	**-13.640**	**9.604**
9	SIDIBE MARIAM_PV	Private Home	DIXINN	**-13.678**	**9.546**
10	TITAN SECURITE_PV	Entreprise	RATOMA	**-13.603**	**9.640**

3.2 Modeling the Web DIS Database

The analysis of the information system made it possible to model the geospatial database of the Web mapping of monitoring and tele-supervision of photovoltaic sites.

This database is then created in the PostgresSQL / PostGIS spatial SGBBR in a Linux environment and then connected to Qgis Desktop by the database manager.

3.3 Record of data acquired at PV station

The first results were made possible after the production systems of the various photovoltaic sites were put into production. Table II presents the results of a week of operation of Web mapping.

3.4 Remote Control

The administration tool pgAdmin 4 (Figure 10) provides an overview of the created database. This database uses the model "template_postgis" which generates two tables to manage the geometry, "geometry_columns" and "spatial_ref_sys" (stores an exhaustive list of the projection system and their parameters).

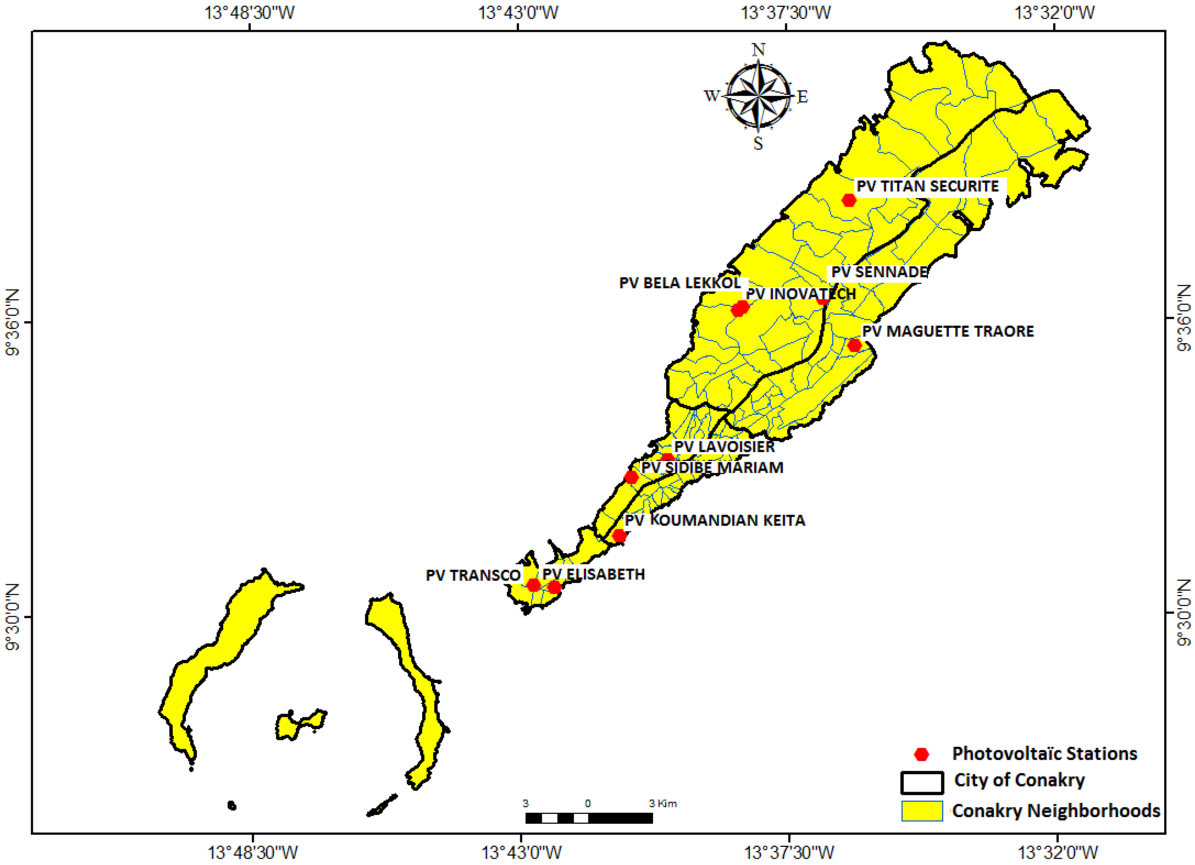

Fig 9: Distribution of photovoltaic solar generators in the city of Conakry

Tableau II: An extract of the recorded measures at the polyvoltaic station of INOVATECH

ID_Site	Date	Vbat	Vpan	I cons.	I chg.	Power	SOC %	Temp.	Statut
8	30/03/2016 10:40	11,060	12,467	90	117	1,294	0	20	Raspb
8	...								
8	30/03/2016 20:40	11,477	0,200	90	0		12	18	Raspb
8	30/03/2016 20:35	11,530	0,175	110	0		13	18	Raspb
8	30/03/2016 20:30	11,535	0,162	92	0		14	18	Raspb
8	30/03/2016 20:25	11,545	0,187	102	0		14	18	Raspb
8	30/03/2016 20:20	11,540	0,187	97	0		14	18	Raspb
8	30/03/2016 20:15	11,575	0,200	115	0		15	18	Raspb
8	30/03/2016 20:10	11,870	0,162	100	0		23	18	Raspb

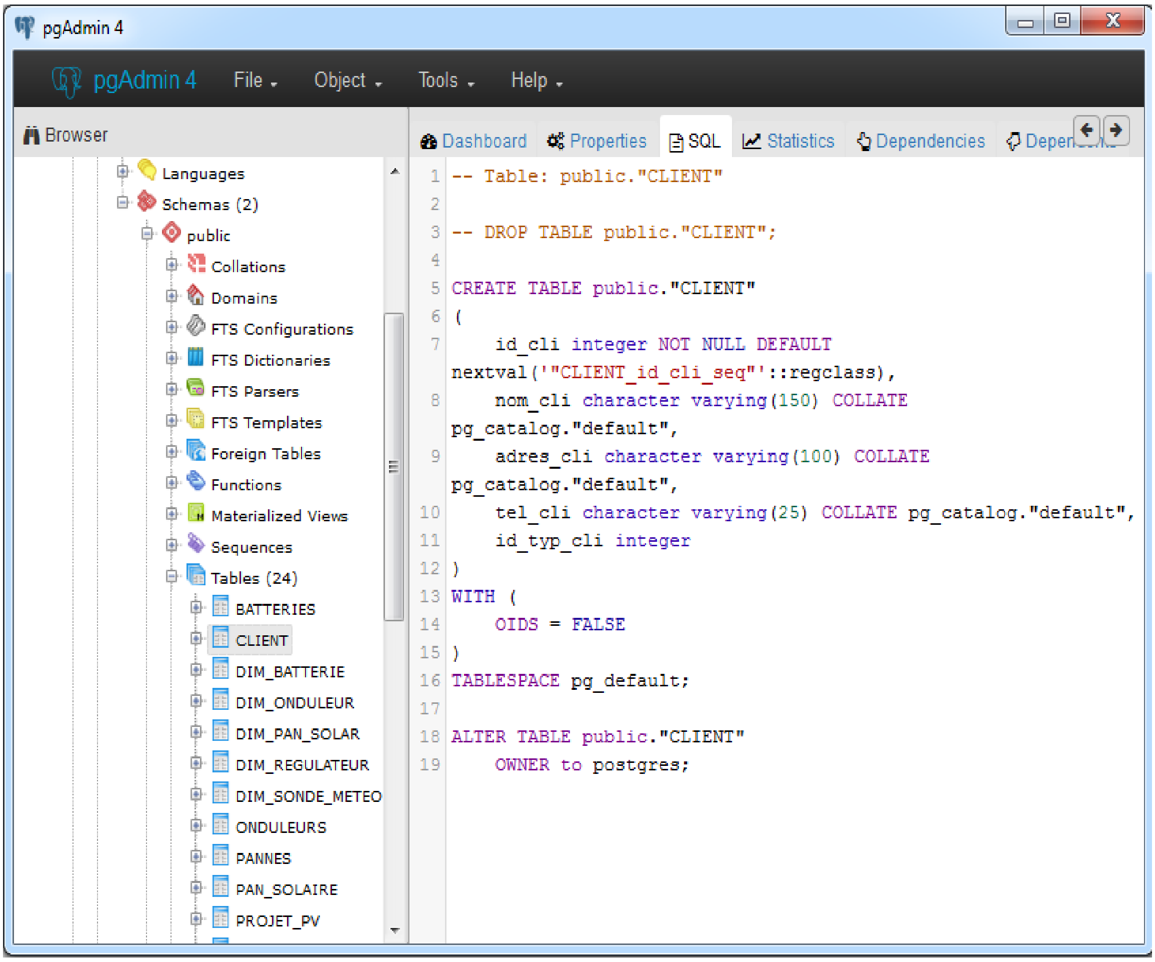

Fig 10: Presentation of the project database

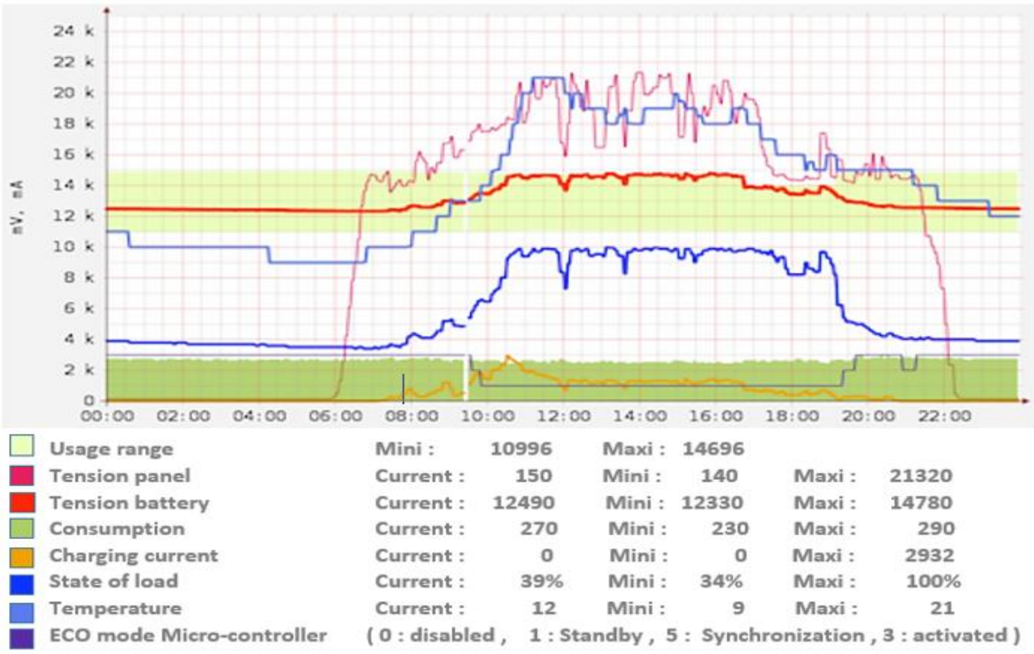

Fig 11: Daily INOVATECH Photovoltaic Generator Survey Curves of 31/03/2016 from 00: 00 to 22: 00

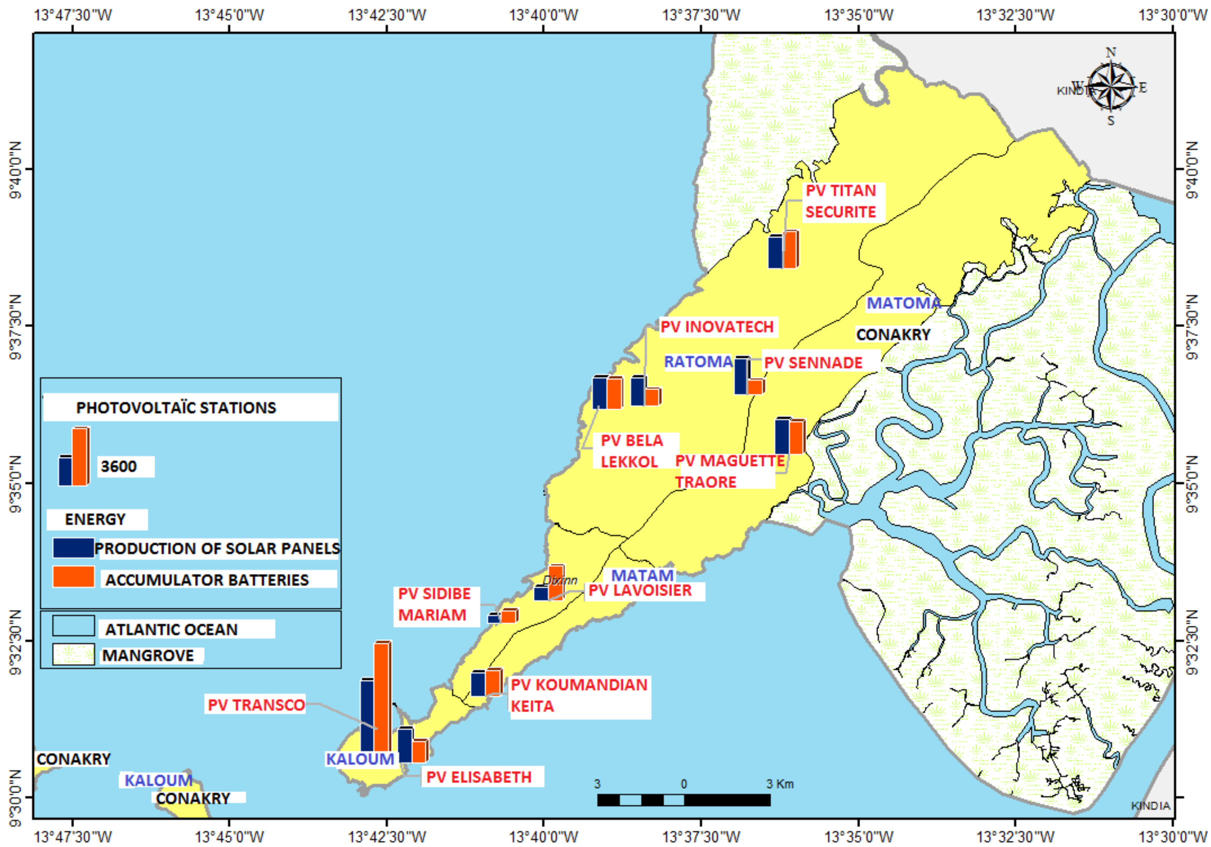

Fig 12: Daily INOVATECH Photovoltaic Generator Survey Curves of 31/03/2016 from 00: 00 to 22: 00

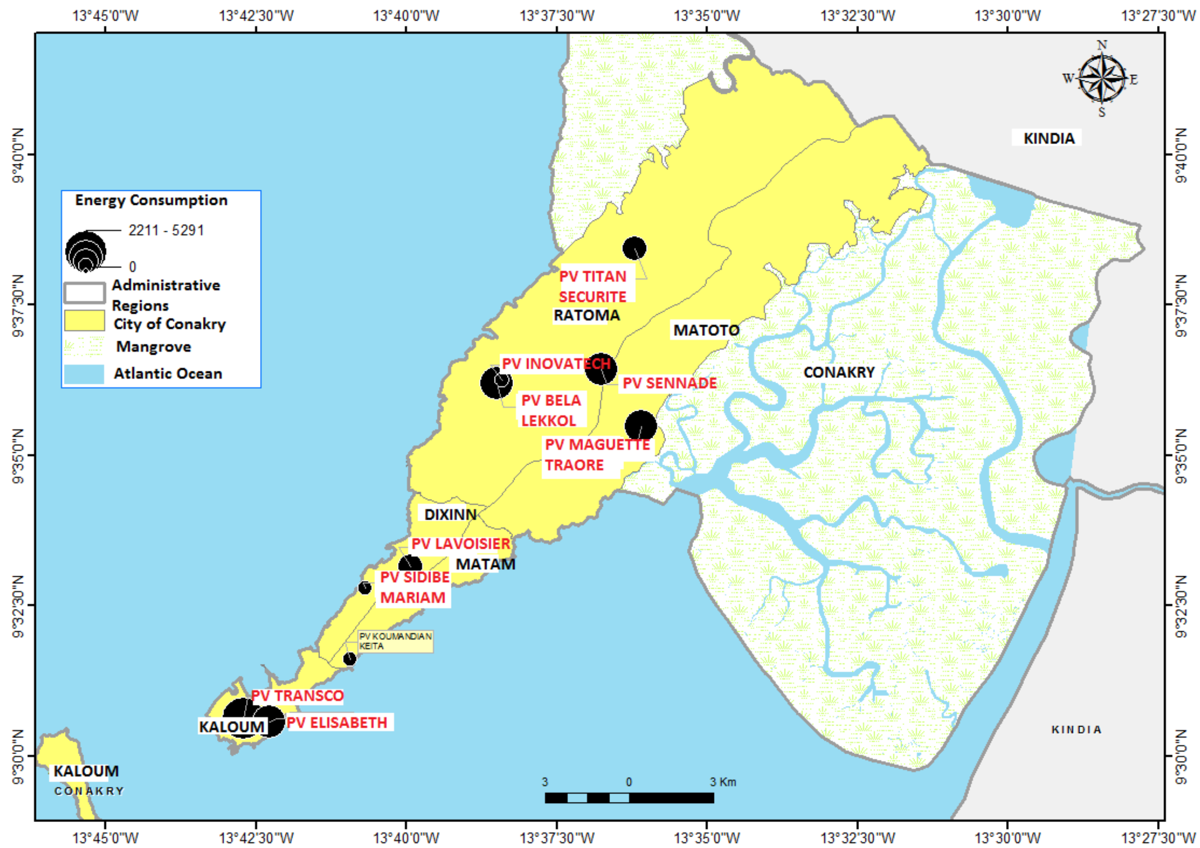

Fig 13: Map of photovoltaic energy consumption

4. DISCUSSION

The methodology adopted during this study led to the realization of a remote centralized control Web GIS of photovoltaic micro-grids in the Conakry region of Guinea. To produce a software system such as a quality Web GIS that meets the needs of its users in predictable times and costs, a modeling approach should be chosen. This approach is not specific to geographic information systems, but is part of the larger framework of software engineering, software development, from which it borrows methods and tools. With the progress of software engineering several methods have emerged, notably the Merise method (Dionisi, 1994) [7] which is a sequential method and UML (Soutou, 2012) [8] which is rather an iterative method.

The choice between the two is based on three axes namely accessibility, precision and exploitability. For the first axis (accessibility) MERISE presents the interest of having logical models, less programming language, less detailed and easily understandable. While UML is designed to adapt to any object-oriented programming language (OOP), it presents several models (diagrams) whose understandings require great attention. Regarding the second criterion (precision), MERISE is less preferable. Despite its clarity, it lacks precision because it is far from the language and therefore difficult to implement.

While the UML integrates the common elements of the different languages, it seeks to be faithful to the final realization. It is much more complete with its different diagrams. To finish with exploitability, MERISE is a more general method. It gives an overall view of the solution without going into the details. Unlike UML which is designed for object implementation with its different details and portability (fits any platform) it is therefore more exploitable. Either has advantages and disadvantages. It is up to the designer to choose the most suitable method for his case.

If we look for accuracy and usability UML is ahead of MERISE. While, if it's clarity and accessibility that we are in for, MERISE is better. For our study, the application is supposed to manage complex data based on the precision and the exploitability making UML the most appropriate, seeing that it will be true to the final realization. This modeling language was built from the fusion of several existing methods namely: the OMT (Object Oriented Modeling and Design) method of Rumbaugh and Blaha. (1995) [9], the Booch method (Booch, 1993) [10] and the OOSE (Object Oriented Software Engineering) method of Jacobson (1980) [11].

The realization of this study was not carried out without difficulties. First, photovoltaic technology is a new science in Africa. As a result, scientific work in this area is virtually non-existent in our countries and unique in Guinea. Also, for the census of the stations, the non-mastery of the renewable energy technology and the scarcity of the photovoltaic installations to observe almost slowed down the realization of the project of study. It was necessary to carry out numerous investigations to list about ten photovoltaic sites in the Conakry area in order to constitute a basic sample to start the study.

Finally, in the implementation of Web GIS, it was question of using data acquisition systems available on the market. Unfortunately, we did not find any because they are rare, expensive and proprietary. In the absence of an acquisition device, we had to design one. The hardware and software design required a lot of technical and financial inputs. In addition, it was necessary to adapt the photovoltaic generators identified on site to the data acquisition system. Despite the lack of mastery of photovoltaic technology, the limited number of stations and the financial constraint, the credibility of the results was not tainted. Better it shows that Guinea can invest in solar energy production to have energy self-sufficiency.

This study is in compliance with Bressan (2014) [12] concerning the implementation of a remote centralized supervision tool for photovoltaic systems. It is also in accordance with Aydin and *al*. (2013) [12] with regard to the use of decision-making tools in the work on the photovoltaic system. In addition, it participates in the improvement of their work because, it complements the work of Bressan (2014) [12] with GIS integration, and on the other hand it proposes GIS / Internet coupling where Aydin et *al*. (2013) [13] used GIS / Multicriteria Analysis / Fuzzy Logic coupling. Finally, this study completes alongside Camara (2011) [14], the number of African studies on the photovoltaic system.

This study has the advantage of proposing the use of low-speed mobile networks such as GSM / GPRS to set up an observatory based on geographical information systems of solar energy installations more or less isolated to ensure their centralized remote supervision.

This photovoltaic technology also has the advantage of minimizing the cost of installation and profitability compared to other types of energy such as hydropower. In addition, unlike other modes of production, photovoltaics can adapt to any site, fallow land, roofs of buildings, etc.

With a scalable investment, the size of the photovoltaic production unit has little impact on the cost per KWh. It makes it possible to design an extensible network of small units, scattered geographically. Photovoltaics also offers investment flexibility and security of supply through diversification of production sites. Accessible in remote areas not covered by the electricity grid, PV works both on-grid and off-grid, where it is the cheapest option for generating electricity. This concerns all uses in isolated sites and particularly rural electrification.

This study is therefore a real ambitious development project for Guinea and any developing country. It is especially a boon for the people of Conakry and other parts of the country to see their standard of living improve. It is up to decision-makers to seize this development opportunity.

Recent renewable energy studies (CROS and PINSON 2018 [15]; KORSAGA and *al*., 2018[1] ; SAHBANI, 2018 [16]) provide even more opportunities for Africa to begin energy independence and sustainable development.

5. CONCLUSION

Despite their significant potential in West Africa and their adaptation to local conditions, renewable energies are still very little exploited. In Guinea, Conakry, photovoltaic (PV) installations currently account for only a small percentage of total electricity production. However, the major challenges, in terms of the Millennium Development Goals and the fight against poverty, require in terms of energy, an increase in access to energy services both for the creation of wealth and the improvement of living conditions. However, the technology of exploitation of solar energy remains a very heavy alternative in terms of investment for the country, because, production costs are very high compared to the hydraulic or the gas. This alternative can thus be reasonably considered only in certain specific areas, such as the capital Conakry and supported by a real political will.

This study therefore offers Guinea's public authorities the opportunity not only to take up the challenge of solar energy but also the opportunity to catch up in this field compared to the Western countries, which are not very sunny but very advanced in this technology. For example, the Guinean government and decentralized communities are using these results as part of solar energy self-sufficiency projects to fight poverty and to reduce environmental degradation.

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