

Study and Sizing of a Drip Irrigation System by Photovoltaic Pumping in the District of Bellel, Mamou Prefecture

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Abstract - The objective of this study is to design a drip irrigation system by photovoltaic pumping of a plot distributed in the sector of the plain of vegetable crops (tomato, corn, potato and eggplant) of Bellel, prefecture of Mamou. The various results obtained during this study mainly relate to the determination of the meteorological parameters (temperature, solar irradiation, precipitation and relative humidity) of the site, the daily water requirements (150m³) for the irrigation of 7 hectares, of which 50 m³ for each crop plot (2,333 hectares) divided into 4 sectors, the geometric dimensions of the drip irrigation system (67 booms for each sector for a total of 268 booms, 63 drippers per boom, i.e. 31 pairs of drippers per boom), the dimensions of the pumping system (HMT is 10.45m, daily flow of each pump 58.517 m³ or 14.203 m³/h, energy consumed by each motor pump 4443.586 Wh/d, the power of the inverter 4677.459 Wh/d and the peak power of the PV system 1090.825 Wh/d). The characteristics of the photovoltaic field (type of solar panel Cip-80-315 of unit peak power 315 Wp, total power of the field 4728.24 Wp, voltage per branch 199 volts and total current in the parallel connection 23.76 A). The PV array is made up of 5 modules in series and 3 in parallel, for a total of 15 modules. The installation diagram for the entire system has been completed. It emerges from this feasibility study that the results obtained will serve as a basis for the design and implementation of a drip irrigation system by photovoltaic pumping for market garden crops throughout the plain of Bellel in particular and in general for the Guinea.

Keywords: Sizing, drip irrigation, pumping, photovoltaic.

I. INTRODUCTION

Water and energy are important, essential and indispensable elements for life. Access to water resources and to clean and sustainable energies is one of the major challenges of the 21st century [1]. The galloping demography, the search for well-

being and economic development in sub-Saharan Africa imply an increase in water needs for domestic consumption, for livestock and agriculture and for industry [2].

The development of irrigated agriculture is essential to achieve the objectives of long-term food strategies. Irrigated agriculture faces many challenges in terms of production and profitability. Irrigation is considered to be one of the cultural practices that the farmer has to manage. It has long been an essential component of agriculture. The greatest advances in agriculture have been obtained through irrigation [3].

In Europe, agriculture accounts for 24% of water use [4]. Agriculture is the main sector of activity for nearly 80% of the Guinean population. It is highly dependent on rainfall. In fact, rainfed crops occupy 95% of the sown areas. Irrigated crops occupy only 30,200 ha on a potential irrigable land estimated at 364,000 ha. Family-type farms occupy 60% of the population and represent 95% of cultivated areas. They are generally small, between 0.3 and 1.5 hectares [5].

Drip irrigation remains the most suitable technique for managing water resources. However, the energy resource that it requires for its implementation remains a whole problem. Because this implies an increase in demand for conventional energy of fossil origin which is increasingly drying up. One of the practical, clean and sustainable solutions for acquiring energy in Guinea is the use of renewable energies with unlimited resources from the sun, the wind, the heat of the earth [6].

Photovoltaic energy, the most recent renewable energy, has the advantage of being non-polluting and usable in isolated rural areas far from the urban electricity grids which are in deficit [7]. In Africa, studies have been carried out by several authors on drip irrigation systems using photovoltaic pumping [3].

Drip irrigation or localized irrigation, also called micro-irrigation, is the supply of localized water near the roots of

plants, with reduced doses but at high frequencies. In principle, localized irrigation is in fact only an improvement of traditional techniques [8]. The drip saves water (50 to 70% compared to gravity and 30% compared to sprinkling) and the use of fertigation. It contributes to an increase in yields, of the order of 20 to 40% and to the improvement of the quality of market garden products. Compared to other irrigation systems, drip irrigation allows a reduction in energy expenditure used in pumping, a reduction in the cost of labor involved in irrigation operations, and a reduction in costs. quantities of fertilizers used [9, 10].

In some agricultural areas of Guinea, drip irrigation systems are installed, powered by generators (motor pumps) for pumping water. But today, this photovoltaic pumped drip irrigation system has not been studied. Hence the objective of this work, the study and sizing of a drip irrigation system by photovoltaic pumping in the village of Bellel, Mamou prefecture.

II. MATERIALS AND METHODS

2.1 Materials

a. Presentation of the study area

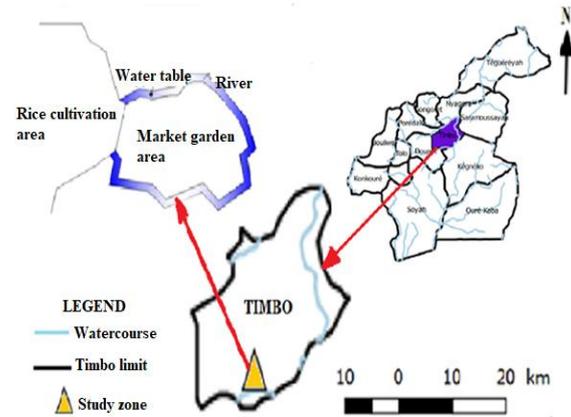
This study took place in the prefecture of Mamou located 270 km from the capital Conakry between 10° 23' north, 12°05' west at an average altitude of 700 m. With a climate characterized by the alternation of two seasons of the same duration, the dry season from November to April and the rainy season from May to October, precipitation varies between 1600 mm and 2000 mm, with an average annual temperature of 25°C. . It covers an area of 8000 km² with a population of 318738 in habitants (2014) [11].

The annual rainfall is around 1681 mm³. The average humidity varies between 65 and 67%. The prevailing winds are harmattan and monsoon. The soils are varied, including ferralitic mountain soils, hydro-morphic soils and skeletal soils. The relief is rugged, made up of a plateau forming the Fouta Djallon massif [12].

The study site is the agricultural market gardening zone of Bellel in the district of Dara, sub-prefecture of Timbo, prefecture of Mamou. It is located 45 km from downtown Mamou. The area of the agricultural site is 14 ha occupied by two (2) groups. The different crops grown on the site are: Rice occupies half of the site and market gardening crops (tomato and eggplant) to which our study relates (figure 1) occupies the other half (7 ha).

The meteorological parameters (temperature, precipitation and relative humidity) of the site are obtained from

calculations of data from the Gbessia meteorological station in Conakry for the Mamou area.



a) Study area



b) Water source for irrigation



c) Tomato cultivation



d) Eggplant culture

Figure 1: Presentation of the study area

b. Work materials

As part of this work, we used the following materials: software (RETScrem, QGIS, AutoCAD), charts and various tools (computer, GPS, decameter, centimeter, string, staff and the level bezel).

2.2 Methods

The methodology adopted for this work is based on: the field survey, the sizing of the drip irrigation system and the photovoltaic pumping system, the sizing of the photovoltaic field. The working hypotheses for this purpose are as follows: the crops on the site are market gardens with a water requirement of 60 m³ / d.ha. Tomato and eggplant are crops chosen for drip irrigation; the pumping system is over the sun; the pressure drops correspond at most to 10% of the total geometric height.

The sizing of the irrigation system, taking into account the rainfall of the drippers (PI, mm / h), the evapotranspiration (Eot, mm / d), the irrigation time per day (tj, h / d) and the water requirement of a crop (Etc, l / s) consists in evaluating: the daily photovoltaic pumping capacity (Cj, m³ / d), as well as the fundamental dimensions: the Length of a boom, the Number of booms per sector, the Total number of booms, the Number of drippers per boom, the Number of pairs of drippers per boom and the Number of drippers per boom [13, 14].

The sizing of the pumping system, taking into account the daily photovoltaic pumping capacity (Cj, m³ / d), the fundamental dimensions included in the Total Manometric Height (HMT) solar irradiation, consists in: determining the maximum peak power, the maximum peak flow and choose a standard pump type and power capable of fulfilling the requirements and calculate the daily energy required for the

operating conditions. To validate the results of the long sizing process of our photovoltaic pumping system, we compared the value of the peak power obtained by numerical calculation and that obtained by measurement in the manufacturer's chart [16].

The sizing of the photovoltaic field and choice of solar panels, consists in choosing the inclination of the field, estimating the minimum sunshine during the period of operation, estimating the approximate efficiency of the field and determining the capacity, in peak watts, that must be have the field and determine the field configuration and readjust according to the specifications of the modules [17].

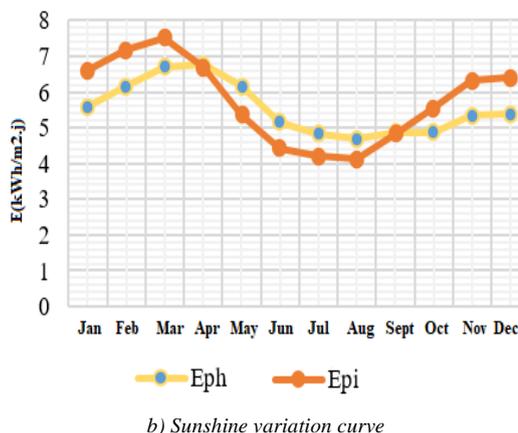
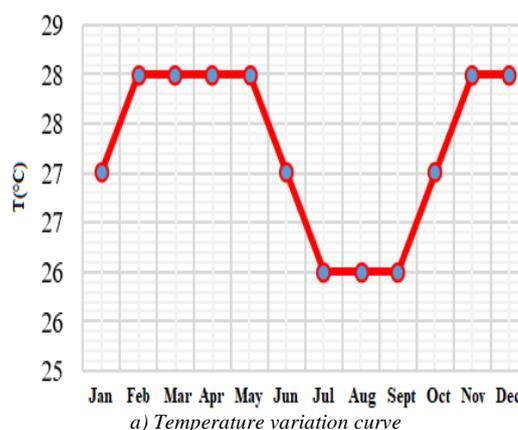
III. RESULTS AND DISCUSSIONS

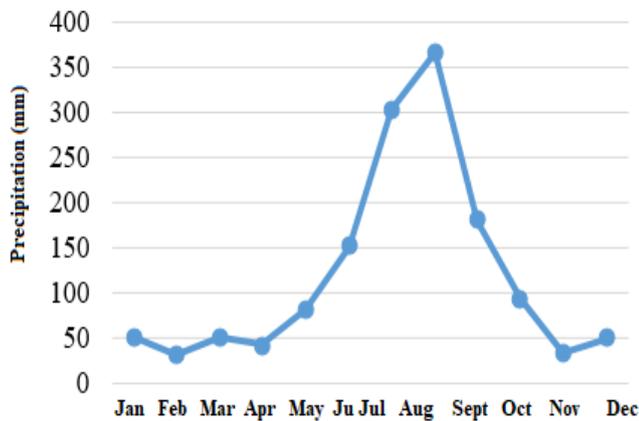
3.1 Results

The various results obtained during this study relate to: the meteorological parameters of the study area, the water requirements, the pumping and storage capacities, the geometric dimensions of the drip irrigation system, the dimensions of the pumping system, the characteristics of the photovoltaic field and the installation diagram of the system.

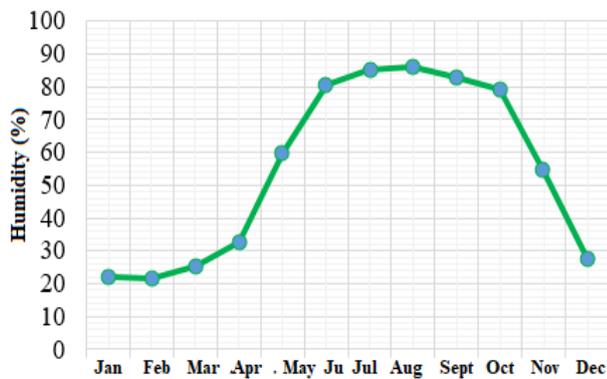
a. Meteorological parameters of the study area

The meteorological parameters of the study area are shown in figures 2, for their proper interpretation.





c) Precipitation variation curve



d) Relative humidity variation curve

Figure 2: Meteorological parameters of the study area

b. Pumping and storage capacities (crop water requirements)

Based on the calculation of the plot unit as well as the number of plots of the 7 ha of the study area made it possible to determine the basic dimensions of the study plot, evaluated at a length of 205 m by 114 m wide, an area of 23,370 m². It is subdivided into four (4) watering sectors. Its fundamental dimensions are as follows: Wetted length of a sector ($L_m = 112$ m), wetted width of a sector ($l_m = 50$ m) and the number of sectors $N_s = 4$, (figure 3).

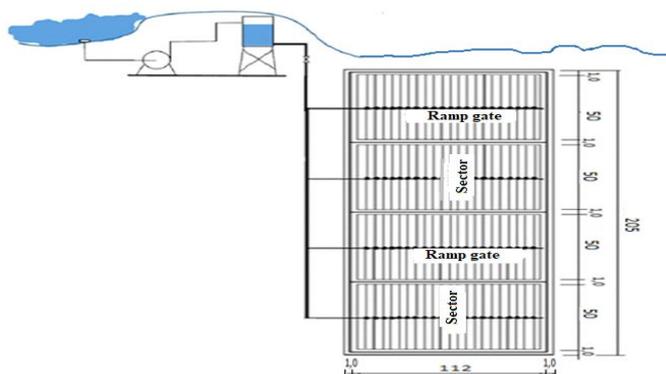


Figure 3: Development plan of a 23370 m² plot of the operating area

The crop water requirements and other technical parameters for calculating these crop water requirements are shown in Table 1.

Table 1: Crop water requirements

Designation	Symbol	Value	Unit
Area of the zone	S	7	ha
Rainfall	P_i	16.67	m ³ /h.ha
Reference potential evapotranspiration	E_{to}	60	m ³ /j.ha
Irrigation time per day	t_i	4	h/j
Water requirement of a crop	B_{ec}	110.83	L/s
Effective flow	Q_e	10.36	L/s
Storage capacity per day	C_{stf}	149.22	m ³ /j
Daily pumping capacity	C_{ip}	175.55	m ³ /j
Hourly pumping capacity	C_{hp}	25.08	m ³ /h
Number of plots	N_p	3.00	sans
Number of tanks	N_r	3.00	sans
Unit storage capacity per day	C_{ust}	50	m ³ /j
Tank volume	V_r	56	m ³
Number of pumping stations	N_{sp}	3.00	-
Daily unit capacity of a pumping station	C_{ujsp}	58.52	m ³ /j

c. Sizing of the drip irrigation system

The determined drip irrigation system sizing parameters are shown in table 2.

Table 2: Dimensions of the drip irrigation system

Designation	Symbol	Value	Unit
Gross area of the plot	S_b	2.33	ha
Gross area of the plot	S	233333	m ²
Number of sectors	N_s	4	-
Number of ramps per sector	$N_{r/s}$	67	-
Total number of ramps	N_{tr}	268	-
Number of drippers per boom	$N_{g/r}$	63	-
Number of pairs of drippers per boom	N_{pg}	31	-

d. Sizing of the pumping system

The sizing results of the pumping system for drip irrigation are given in Table 3.

Table 3: Dimensions of the pumping system

Designation	Parameter	Value	Unit
Total Manometric Height	HMT	10.45	m
Daily flow of a pumping station	Q_{jsp}	58.52	m ³ /j

Hourly flow rate of a pumping station	Q_{hsp}	14.20	m ³ /h
Daily hydraulic energy	E_h	1666.34	Wh/j
Energy consumed by the motor pump	E_{MP}	4443.58	Wh/j
Controller power	P_{cont}	4677.46	Wh/j
Peak power of the PV system	P_C	109082	Wh/j
Peak PV system flow	Q_C	58.52	m ³ /j
Maximum hourly flow rate of the PV system	Q_{max}	7.78	m ³ /h

area. The analysis of the variation of these curves justifies the choice of the period (December to April) of irrigation by the drip system of the selected vegetable crops. This period corresponds to a temperature which varies between 27°C and 28°C, with an annual average temperature of 27.8°C (curve a). The variations in solar irradiation during this period of operation on the horizontal plane and the inclined plane of 15° are respectively (5.38 kWh/m².j and 6.4 kWh/m².j) in December and (6.76 kWh/m².j and 6.69 kWh/m².j) in april. The averages during the period are: 6.12 kWh/m².j on the horizontal plane and 6.87 kWh/m².j on an inclined plane (curve b); which justifies the option of tilting the solar modules at an angle of 15° to the south, thus promoting optimal operation of the photovoltaic field.

The variation in precipitation during the operating period is 49 mm in December and 42 mm in April, it is the season of low precipitation of the site during the year (curve c), which requires the installation of the irrigation system. The annual average precipitation is 119.08 mm. Humidity varies from 27.4% in December and 32.8% in April, with an annual average of 54.73% (curve d).

b. Pumping and storage capacities (crop water requirements)

The cultivable area for irrigation is 2.333 hectares subdivided into 4 sectors, with a daily irrigation time of 4 hours. Thus, the daily crop water requirement for each plot is 50 m³.

c. Sizing of the drip irrigation system

The number of ramps calculated for each sector is 67 with a total of 268 ramps for the entire cultivable area. The number of drippers is 63 per boom and for 31 pairs of drippers per boom table2.

d. Sizing of the pumping system

The Total Manometric Head (HMT) is 10.45m for each pump to be installed, with a daily flow rate of 58.517 m³ or 14.20 m³/h for each pump. The energy consumed by the motor pump 4443.58 Wh/d, the power of the controller is 4677.46 Wh / d. Thus, the calculated peak power of the PV system is 1090.82 Wh/d (table 3)

e. Sizing of the photovoltaic field

The type of solar panel chose the 80-cell Cip with a power range that varies from 315 to 330 Wp (Cip-80-330, Cip-80-325, Cip-80-320 and Cip-80-315). In this work, it was retained the Cip-80-315 of total peak power of the field equal to 4728.24 Wp which is immediately higher than that of the controller. The voltage per branch is UBS = 199 volts and the total current in the parallel connection will then be IBP =

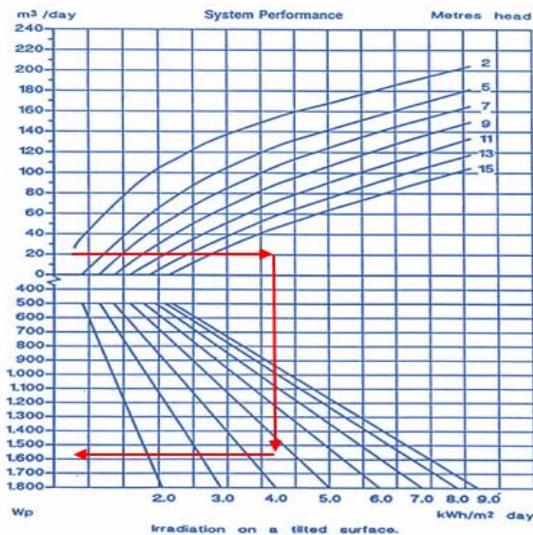


Figure 4: PV pumping system sizing chart

e) Sizing of the photovoltaic field

The type of module chosen being Cip-80-315 with 80 cells, the sizing results of the photovoltaic field are presented in table 4.

Table 4: Sizing of the photovoltaic field

Characteristics	Symbol	Value	Units
Number of panels	N_p	15	-
Series connection	B_s	5	-
Parallel connection	B_p	3	-
Total PV array power	P_{PV}	472	W
Series connection voltage	U_{Bs}	199.00	V
Parallel connection current	I_{Bp}	23.76	A

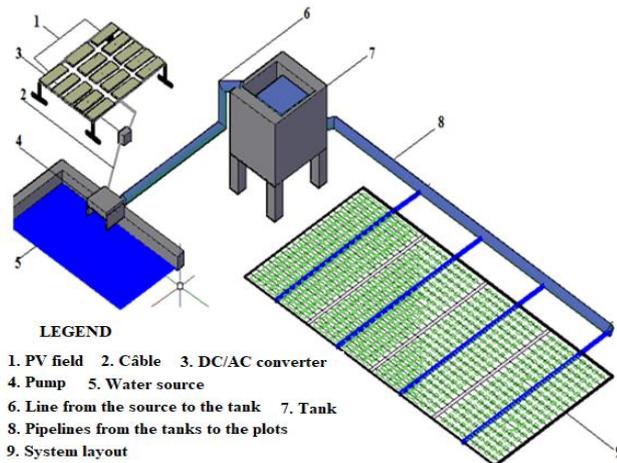
3.2 Discussions

a. Meteorological parameters of the study area

The curves in Figure 3.1 show the annual average variations of some important meteorological parameters of the study

23.76 A. The PV field is made up of 5 modules in series in 3 parallel branches, for a total of 15 modules.

The system installation block diagram is shown in Figure 5.



IV. CONCLUSION

As part of this study, we made a synthesis on irrigation techniques. A field visit was carried out in order to locate the cultivable areas in the area, identify the types of crops and assess the availability of water for irrigation before proceeding to the sizing of the various parameters of the drip irrigation system. Drip by photovoltaic pumping based on certain formulas, software and assumptions. This study showed that the choice and sizing of the elements of a system photovoltaic for drip irrigation requires an estimate of the needs in water. This estimate can be calculated beforehand, but ultimately it will be approached to the fact that we want to obtain autonomy in bad weather.

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