



Sizing of a Standalone Photovoltaic Water Pumping System of a Well in Ngoundiane Site

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Abstract. In this paper, the sizing and design of a standalone photovoltaic water pumping system in Ngoundiane, a village located in Senegal is investigated. An intuitive sizing method is firstly applied to get approximate information on the sizes of the various components. In this method, the capacity of various components is separately computed and any relationship between them are considered. To improve the results, a new sizing approach based on numerical methods is developed using the Average Loss of Power Supply Probability (ALPSP) criterion. Empirical simple models are used to model the components of PV system. From the energy generated by PV array, the different states of charge of the battery storage are estimated. A simple algorithm has been elaborated to determine the different PV and battery combinations for various ALPSP levels. The proposed model has been applied to the meteorological average data in Ngoundiane site and conducted using MATLAB software. The results showed that the numerical method proposed allows a 50% reduction of the storage capacity when compared to the intuitive method. However, we noticed that the values of ALPSP are particularly high with a smaller value of 0.3, probably due to the underestimation of input parameters and the nature of meteorological data used in the model. In order to show the importance of the developed approach, a comparison with literature has been performed.

Keywords: Photovoltaic water pumping system · Numerical method · Average loss of power supply probability

1 Introduction

Solar energy is one of the cleanest among renewable resources and has lower maintenance costs compared to other alternatives, e.g. wind, biomass (Olcan et al. 2015). The use of solar photovoltaic energy for water pumping is a relative new technology with reasonable costs. Photovoltaic water pumping system is a very significant application of solar photovoltaic energy. Indeed, it is economically difficult to extend the electrical network in remote zones, which have some difficulties to accede to drinkable water.

However, the main drawback of the solar energy is its random and intermittent nature, which require an exhaustive technico-economic study to obtain an optimal PV system. So different methods of sizing have been developed and presented in the literature. They differ in terms of simplicity and reliability and can be categorized as intuitive, numerical, analytical, Artificial Intelligence and hybrid methods (Sidrach-de-Cardona et al. 1998; Khatib et al. 2016; Sadio et al. 2018; Sadio et al. 2019; Anwar 2017; Hontoria et al. 2005).

Intuitive methods consist of using simple equations to calculate the different component sizes of the system. They include the most disadvantageous month and average data approaches. These methods establish no relation between the components of the system, and they are not accurate.

In analytical methods, the sizes of system components are expressed as a function of the reliability and the system cost by mathematical equations with coefficients depending on the geographic positions. These methods are simple and accurate; however, they are not so flexible.

The numerical methods are based on simulations that allow the calculation, for each period of time, of the energy balance of the system. These methods are more accurate and can evaluate the system reliability, which is quantified by the Loss of Power Supply probability (LPSP). The LPSP is also known as the Loss of Load Probability (LOLP), the Loss of Power Probability (LPP), and the Load Coverage Rate (LCR) (Sadio et al. 2018). It represents the load dissatisfaction rate (Sadio et al. 2018). It requires meteorological data recorded on a long time period. These data are not available in the most areas (Sadio et al. 2017).

The Artificial Intelligence techniques can be an alternative for overcoming the limits of the classic methods when meteorological data are not available (Jakhrani et al. 2012). They include the Genetic Algorithm and others. They can solve a complicated optimization problem with a great number of parameters to handle. They are accurate and reliable; they can also treat incomplete data but require lot of memories during computations. The hybrid methods are a combination of the positive aspects of the previous methods (intuitive, analytical, numerical and Artificial). Many researchers work in this field aim to improve results of PV systems sizing. Hence, Jakhrani et al. (2012) developed a novel analytical model for optimal sizing of standalone photovoltaic systems. These authors used different equations and load demands to determine the optimal section of PV array and useful capacity of storage, for various values of LPP. The technical and economic criteria used to evaluate the system performance are the cost and the LPP. The comparison of some results showed a similarity between the iso-reliability curves of the proposed model and the ones found in the literature. This method is very accurate with minimal cost. In the Cabral and Filho (2010) study, a stochastic method for the sizing of standalone photovoltaic systems is developed. Authors performed a comparative study between the proposed model and a determinist method, in order to verify the best way for modelling standalone photovoltaic systems. They concluded that the best method is the stochastic one. Indeed, these methods consider the variability of solar irradiation, load demand, and provide the most accurate result. The simulation showed that the determinist method leads to an oversizing with a LPSP of 0.0%. Khatib et al. (2016) reviewed the sizing methodologies of PV array and storage batteries in a standalone

photovoltaic system. Several software used for the optimal sizing of standalone photovoltaic system have been presented. Compared to others, the authors concluded that the numerical sizing methods are more accurate and simpler. These methods consider the random variability of meteorological data. In Shen et al. (2009) work, the optimal sizing of solar array and battery in a standalone photovoltaic system, in Malaysia, is investigated. The sizing is based on the energy effectiveness model and LPSP. This model has been applied by using the solar irradiation data of year 1999, of Kuala Lumpur and a load demand assumed to be constant for all year. The results obtained from this method have been compared to the one calculated with a hybrid system. It has been shown that the hybrid system reduces the size of PV capacity. Nogueira et al. (2014) proposed the sizing and simulation of a photovoltaic/wind system, using batteries, applied on a small rural area located in the South of Brazil. The developed model is based on the LPSP and the time of critical period. Results showed that for a set LPSP, yielded energy decreases if the critical period increases and for a set critical period, the energy produced decreases if the LPSP raises. In the work presented by Al-Falahi et al. (2017), the recent size optimization methodologies for standalone solar and wind hybrid renewable energy system have been reviewed. They presented several energy systems combining hybrid PV/wind systems with other renewable (RES) or conventional (CES) sources. The authors reported that the combination with RES are widely used in standalone applications. Indeed, they ensure a continual electricity supply to the load. The drawback of CES is the high investment cost and emission of harmful gas. The authors discussed different techniques (classic and modern methods) and software tools (HOMER, IHOGA, TRNSYS), used to improve the hybrid system reliability. Kaushik et al. (2016) reviewed the modelling, design methodology, and sizing optimization of photovoltaic based on water pumping, standalone and grid connected system. They presented the technical and economic parameters and the different sizing methods used in optimization process of PV system.

Olcan et al. (2015) developed a multi-objective analytical model for optimal sizing of standalone photovoltaic water pumping systems. Supply probability and the life cycle cost are used as technical and economic criteria, respectively. This model integrates several improvements such as changing of tilt angles, accurate estimation of water demand, use of irradiation and temperature data sequences, etc. It allows a complete optimization of photovoltaic water pumping system. The comparison between the proposed model and calculation method showed most appropriate results of sizing than the calculation algorithms. Chaabene et al. (2009) investigated an energy management algorithm for an optimum control of a photovoltaic water pumping system. The algorithm aims to extend the period of operating of the pump by controlling a commutation unit that connect the system components in relation to the multi-objective management criterion. The implementation of this algorithm showed that the proposed approach allows the extension of the pumping period up to 5h per day and provides a 97% daily average improvement of the pumped water quantity. Bakelli et al. (2011) treated the optimal sizing of photovoltaic pumping system with water storage tank using LPSP concept. The developed model consists of three sub-model: sub-model of pumping system; technical sub-model based on LPSP; economic sub-model based on Life Cycle Cost (LCC). A set of configurations corresponding to the desired LPSP can be generated from this model. Benyoucef and

Hamidat et al. (2009) studied systematic procedures for sizing photovoltaic pumping system, using water storage tank. Results of this study showed that the performance of photovoltaic pumping system depends on the total height and the photovoltaic nominal power. Based on the literature the numerical sizing method have been the most accurate method used for sizing the solar PV system. In addition, a good size optimization algorithm must handle small step meteorological and load demand time series data (hourly or smaller) Anwer et al. (2017). In this study, the optimal sizing using intuitive and numerical methods for designing a standalone photovoltaic water pumping system of a well situated in the village of Ngoundiane in Senegal is investigated. Average data of solar irradiation and load demand of Ngoundiane site and Average Loss of Power Supply Probability (ALPSP) concept are used to validate the proposed method and assess the technical reliability respectively.

This work is divided into three parts. In first part, we evaluate the different input parameters. In second part, the two developed sizing methodologies are presented: an intuitive method using average data approach and a numerical method based on the determinist approach. In the third part, we exhibit the results and discussions. Finally, this paper is completed by a conclusion and some recommendations.

2 Materials and Methods

The main input parameters used in the design of photovoltaic water pumping system are the daily requisite water demand, the total pumping height and the available solar energy.

2.1 Estimation of Daily Water Demand

The well is situated in the village of Ngoundiane in Senegal. Ngoundiane is far from Thies by 30 km and is positioned to 14°50 North and 17°06 West. The well supplies water to the families and the livestock. The water requirement has been assessed during the period of high drink. Table 1 gives human and livestock water requirements:

Table 1. Domestic and livestock water requirements respectively (Hadj Arab et al. 2005).

Human water flow		Livestock water flow	
Family	10	Family	10
Number of persons per family	10	Number of animals per family	20
Used daily water quantity per person	50 L	Mean used daily water quantity per animal	45 L
Total	3.5 m ³	Total	9 m ³

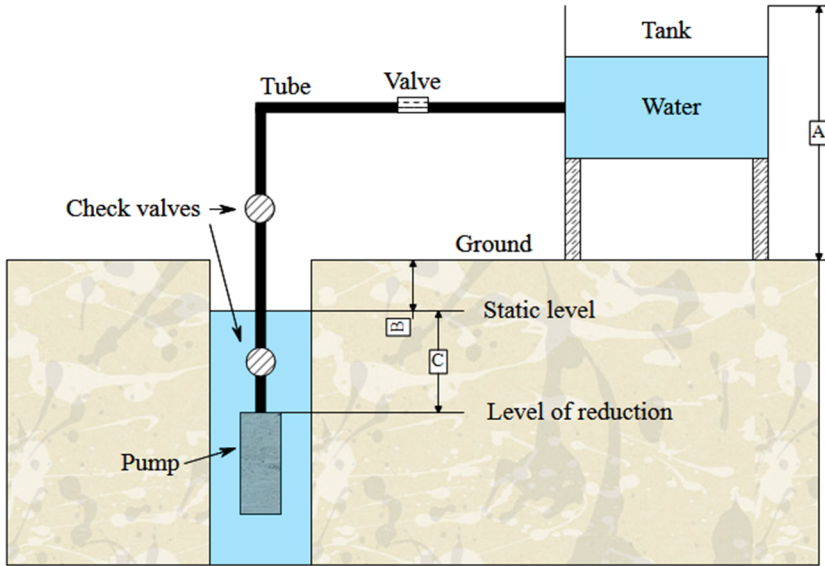


Fig. 1. Configuration of a water pumping system.

2.2 Determination of the Power Pumping Height

Figure 1 shows the configuration of a water pumping system.

During pumping, the water level inside the well tends to drop, so pumping is possible again when the regeneration of well balances the amount of water drawn (Kazem et al. 2013). The fall of the water level inside the well depends on some elements such as the kind of soil's permeability and thickness of water bearing.

The total pumping height (h) is the sum between static (h_s) and dynamic (h_d) heights:

$$h = h_s + h_d \quad (1)$$

For a well that have important variations of water level according to the flow, a corrective term is added and Eq. 1 is rewritten as follows (Hadj Arab et al. 2005):

$$h = h_s + \left(\frac{h_d + h_s}{Q_p} \right) Q_A \quad (2)$$

Q_P (m^3/h) and Q_A (m^3/h) are the flow of test and apparent flow respectively. The dynamic height is the distance between the water level in the well and the highest point from which the water is pumped. It can be calculated from Darcy-Welsbach formula (Ayop et al. 2018):

$$h_d = f \frac{L}{D} \frac{v^2}{2g} \quad (3)$$

f is the coefficient of friction, it depends on the Reynolds number and the relative roughness that characterizes the surface of the pipe, v (ms^{-1}) is the average speed of the

fluid, $D(m)$ and $L(m)$ are the diameter and length of piping respectively, $g(m/s^2)$ is the acceleration of gravity. The diameter D of piping is determined from Eq. 3 above.

The most materials used for the hydraulic canalization are metals (steel, copper) and polymers (PVC). In this paper we choose PVC because it is available with low cost and causes fewer losses. If the piping system have other kind of accessories (gate, angle, T-square, junction), losses of charge in each additional element can be calculated from Eq. 4:

$$h_d = k_{ac} \frac{v^2}{2g} \quad (4)$$

Where K_{ac} is a coefficient which depends on kind of accessory. K_{ac} , for different accessories, is calculated from Benyoucef and Hamidat et al. (2009).

During pumping, water level falls and induces a hydraulic resistance, R_h , through the pipe. This hydraulic resistance creates losses of charge j in the piping. Therefore, the total pumping height or the total manometric height (TMH) is obtained from the following equation:

$$TMH = h + A + C + j \quad (5)$$

A and C correspond to the height of the tank and the level of water reduction, respectively. In our study, we do not take into account the support of the tank and the shutoff valve.

We measured the static level, reduction level, height of tank and losses of charge. Results are shown in Table 2.

Table 2. Results of the measurements of the static level, reduction level, dynamic level, height of tank and losses of charge.

Statistic level	Reduction level	Dynamic level	Height of tank	Losses	HMT
12 m	24 m	36 m	5 m	10	45.1 m

2.3 Sunniness Level in Ngoundiane Site

Due to the non-availability of meteorological data in Ngoundiane site, irradiation and temperature data from Ndem village, Bambey, in the Diourbel region are used. The annual variation of the monthly daily irradiation average in Bambey zone is given in Fig. 2.

Annual average of daily solar irradiation of the zone of Bambey is of 5.85 kWh/m²/day. Maximal value of irradiation is obtained at month of April with a value of 7.05 kWh/m²/day while minimal value is recorded at month of December with a value of 4.88 kWh/m²/day. The average temperature of this site varies between 25–30 °C.

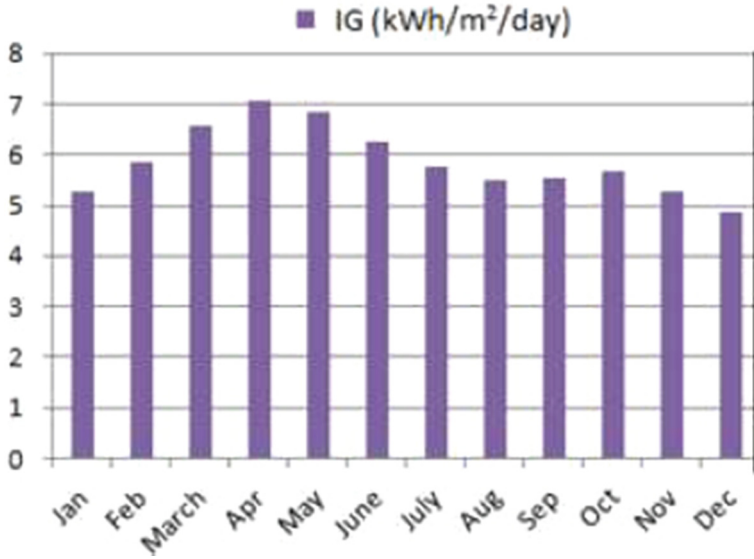


Fig. 2. Annual variation of monthly solar irradiation average of Bambezy zone (Sadio et al. 2017).

2.4 Methods

In this section, the different stages of proposed sizing methods are presented. First, the hydraulic and energy consumption are estimated using Eqs 6 to 9. They express the required hydraulic (E_h) and electrical (E_e) energies and the hydraulic (P_h) and electrical (P_e) power to satisfy the load requirements respectively:

$$E_h = C_h \cdot V_e \cdot TMH \quad (6)$$

$$E_e = \frac{E_h}{\eta_{MP}} \quad (7)$$

$$P_h = \rho \cdot g \cdot Q \cdot TMH \quad (8)$$

$$P_e = \frac{P_h}{\eta_{MP}} \quad (9)$$

V_e (m³) is the water quantity, C_h (kg.S.h/m²) is the hydraulic constant and its expression is given by Eq. 10:

$$C_h = \frac{\rho \cdot g}{3600} \quad (10)$$

$\rho = 1000$ kg/m³ is the density of water, η_{MP} is the efficiency of motor-pump couple and Q corresponds to the maximal pumping flow.

Process of Intuitive Sizing Method. Total PV module (P_{PV}) in W_C and useful battery (C_u) in Ah capacities are calculated from Eqs. 11 and 12 respectively:

$$P_{PV} = \frac{E_e}{k \cdot E_I} \quad (11)$$

and

$$C_u = \frac{N_j \cdot E_e}{DOD \cdot U_s \cdot \eta_{bat}} \quad (12)$$

k is the global efficiency of the system, it is estimated to 0.6, E_I represents the average solar irradiation of the site, N_j is the number of autonomy days, DOD and η_{bat} are the Depth of Discharge and efficiency of the battery, respectively and U_s is the voltage of the system. Residual (C_r) and total (C_{batl}) capacities are deducted from Eqs. 13 and 14, respectively:

$$C_r = DOD \cdot C_u \quad (13)$$

and

$$C_{bat} = C_u + C_r \quad (14)$$

The number of PV module (N_{PVs}) in series and the number of string parallel (N_{PVp}) are determined, respectively, as follows:

$$N_{PVs} = \frac{U_s}{U_{PVu}} \quad (15)$$

and

$$N_{PVp} = \frac{P_{PV}}{P_{PVu}} \quad (16)$$

U_{PVu} and P_{PVu} are the individual voltage and capacity of a PV module respectively. The number of batteries in series and parallel are given by Eqs. 17 and 18 respectively:

$$N_{bats} = \frac{U_s}{U_{batu}} \quad (17)$$

$$N_{batp} = \frac{C_{batTot}}{C_{batu}} \quad (18)$$

U_{batu} and C_{batu} are the unitary voltage and capacity of a battery.

Sizing of Other Components

Sizing of the Pump. The choice of the pump depends on the flow and the total manometric height (TMH). The pump flow is obtained by the following formula:

$$Q = \frac{3.6 \cdot P_h}{g \cdot MTH} \quad (19)$$

Equation 19 can be rewritten as:

$$Q = \frac{3.6 \cdot P_e \cdot \eta_{MP}}{g \cdot MTH} \quad (20)$$

Sizing of the Charge Controller. The power of charge controller must be higher than the total PV power, its voltage must be identical to the PV array voltage. It must support an upper intensity to maximal current of PV array and load demand when they simultaneous operate.

The number, the total input and output current of charge controller are calculated from Eqs. 21, 22, and 23, respectively:

$$N_{Ch} = \frac{P_{PV}}{P_{Ch}} \quad (21)$$

$$I_{Che} = \frac{P_{Ch} \cdot N_{Ch}}{U_S} \quad (22)$$

$$I_{Chs} = N_{ch} \cdot I \quad (23)$$

N_{ch} is the number of charge controller, P_{ch} is the nominal power of one charge controller, I_{Che} and I_{Chs} are the input and the output currents of a charge controller respectively and I is the operating current of the charge controller.

Sizing of Inverter. The nominal power of the inverter (P_{inv}) in VA is calculated from Eq. 24:

$$P_{inv} = \frac{1.2 \cdot P_e}{\cos \phi} \quad (24)$$

1.2 is the factor of oversizing and $\cos \phi$ is the power factor equal to 0.87.

Sizing of the Conductor's Sections. In this study, we use copper conductors that are sized to handle the intensity going through them. The section (S) of the wires between the different components is calculated as follows:

$$S = \frac{2 \cdot \rho \cdot L}{\Delta U} I_{\max} \quad (25)$$

ΔU is the drop of voltage, ρ is the resistance for copper, I_{\max} and L are the maximal current and length of the wires between two components respectively.

Sizing of Water Tank. For a best evaluation of water demand, we apply standard method. In this method, the storage capacity of tank is included between 25% and 50% with an average of drink peak estimated to 33%. This volume is divided in three reserve: distribution reserve (DR), safety reserve (SR) which depends on the service level and fire reserve:

$$V_{res} = N_j \cdot C_d \quad (26)$$

2.5 Proposed Numerical Sizing Method

The new sizing approach based on numerical methods, in particular, the determinist approach proposed in this paper is detailed in this part. Average data of irradiation and temperature in Bambey zone are handled. Empirical simple models are utilized to model the different components. From hourly equations, which relate different components of the system, a simple algorithm is elaborated and adapted to the data nature of our site. The daily average energy E_{PVav} produced by PV array, in kWh, is calculated from following mathematical expression (Sadio et al. 2018):

$$E_{PVav} = A_{PV} \cdot I_G \cdot \eta_{inv} \cdot \eta_{wire} \cdot \eta_r \left[1 - \beta \left(T_{amb} + \frac{G}{800} (T_{NOCT} - 20) - T_{ref} \right) \right] \quad (27)$$

A_{PV} is the section of PV array, η_{inv} , η_{wire} and η_r represent the inverter, wires and reference efficiencies, respectively, β is the temperature coefficient, T_{amb} is the ambient temperature, T_{NOCT} is the cell temperature in nominal conditions, which is measured under 800 W/m^2 of solar radiation, $20 \text{ }^\circ\text{C}$ of ambient temperature and 1 m/s of wind speed, T_{ref} is the reference temperature and G is the solar irradiance. The section of the PV array is given by Eq. 28:

$$A_{PV} = A_{PVu} \frac{P_{PV}}{P_{PVu}} \quad (28)$$

A_{PV} is the unitary section of a module. The difference between average energy produced by PV array and daily load demand is given by Eq. 29:

$$\Delta E = E_{PVav} - \frac{E_e}{\eta_{inv}} \quad (29)$$

If ΔE is lower than zero, the average energy stored in the battery system is calculated as follows:

$$E_{batav} = E_{bat \min} + \left(\frac{E_e}{\eta_{inv}} - E_{PVav} \right) \eta_{batc} \quad (30)$$

If ΔE is higher than zero, the average energy stored in the battery system is given by:

$$E_{batav} = E_{bat \min} + \left(E_{PVav} - \frac{E_e}{\eta_{inv}} \right) \quad (31)$$

With $E_{bat \min}$ is the minimum level of energy allowed in batteries. The discharge efficiency is considered to be equal to 1.

In order to protect batteries against damage and drastic reduction of their lifetime, the average energy stored in batteries is subject to the following restriction

$$E_{bat \min} \leq E_{batav} \leq E_{bat \max} \quad (32)$$

$E_{bat \max}$ is the maximum level of energy allowed in storage system.

If the average energy generated by PV array is lower than load demand, and average energy stored in battery reaches the allowed minimum, it occurs an energy deficiency, called Average Loss of Power Supply (ALPS). It represents the missing energy to satisfy the load demand and is mathematically expressed by Eq. 33:

$$ALPS = E_e - (E_{PVav} + E_{batav} + E_{bat\ min})\eta_{inv} \quad (33)$$

The Loss of power supply probability is the ratio between ALPS and load demand. It is expressed by:

$$ALPSP = \frac{ALPS}{E_e} \quad (34)$$

It varies between 0 and 1. If ALPSP is equal to 0, the system will always be able to satisfy load demand. If ALPSP is equal to 1, the system will never meet requirements load.

From all these considerations, we elaborated a simple algorithm, which aims to calculate the storage capacity corresponding to each value of the PV capacity considering the different operating conditions of system. The different stages of the algorithm are shown in Fig. 3. This algorithm is run by using input data defined in our previous work (Sadio et al. 2018) and technical and economic parameters given in Table 3.

Table 3. Technical and economic parameters of the components.

Designation	Characteristic	Unitary cost (Euros)
Module	250 W _C /48 V	362.95
Pump system	Lorentz PS2-1800	1307.12
Battery	190 Ah/2 V	151.00
Charge Controller	MPPT 150 V/60 A	510
Inverter	1000 VA, 48 V DC	207.4

The different stage of proposed numerical method are shown in Fig. 3. The algorithm of numerical sizing has been run using MATLAB software.

3 Results and Discussion

Figure 4 represents the variation of ALPSP in relation to PV capacity. It shows that the ALPSP decreases when PV capacity increases. Indeed, most large PV capacity allows to generate a great quantity of energy and reduce the energy deficiency.

Figure 5 shows different combinations of PV and battery capacities for various values of ALPSP called iso-reliability curves. The ALPSP varies between 0.3 and 0.9. The different combinations, which satisfy reliability levels of 0.9 and 0.3, are shown in Figs. 6 and 7, respectively. We remarked that the increase of ALPSP involves the one of

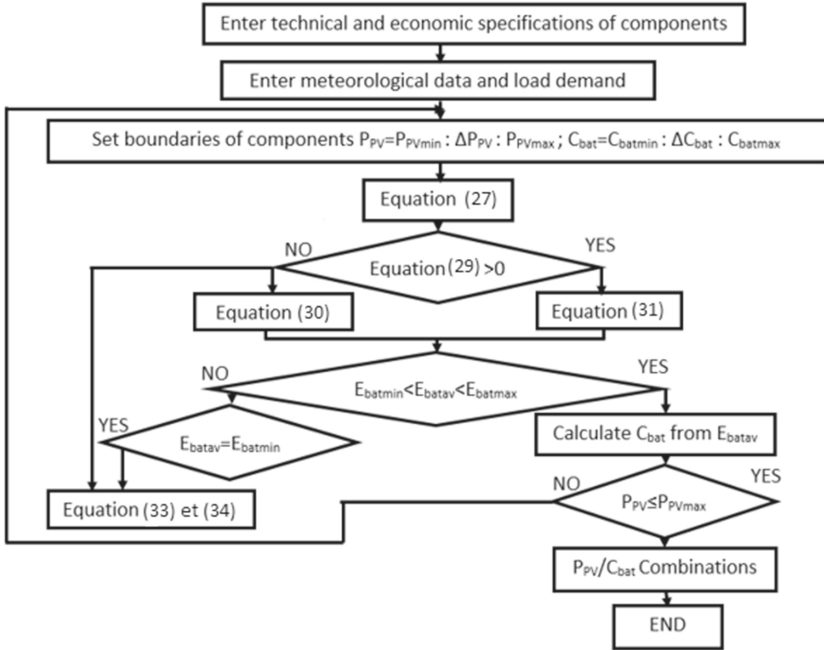


Fig. 3. Stage of proposed numerical sizing method.

components size. Indeed, to obtain small values of ALPSP and improve the reliability of system, PV and battery capacities must be important.

The smaller value of ALPSP provided by the model is 0.3 considered as great when referring in literature. This can be justified by the data nature because the use of average data reduces the accuracy of results. In addition, load water and TMH have been underestimated in sizing process.

In Fig. 7 we remarked that a PV capacity value of 8250 W_P corresponds to a storage capacity of 820 Ah (Table 4).

We obtained a combination of 8250 W_P/1638 Ah and 8250 W_P/820 Ah for intuitive and numerical methods, respectively. The numerical method allows to reduce the storage capacity to 50%. Indeed, the different state of the battery has been calculated from the energy generated by the PV array; that is not possible in intuitive method where the capacities are computed separately and result in oversizing. However, we noticed a high value of ALPSP 0.3, which is due to the use of average data in sizing process and an underestimation of the input parameters.

In order to show the importance of the results in this paper, the proposed model is compared with some results of the literature (Khatib et al. 2016; Kazem et al. 2013; Hadj Arab et al. 2005).

In Khatib et al. (2016), we noticed the same variation for the iso-reliability curves with the proposed model, but the values are weaker. We explained this difference by the models used to model the different components in the system, which are more robust in Khatib et al. 2016. Indeed, we have not access to meteorological hourly (or smaller) data

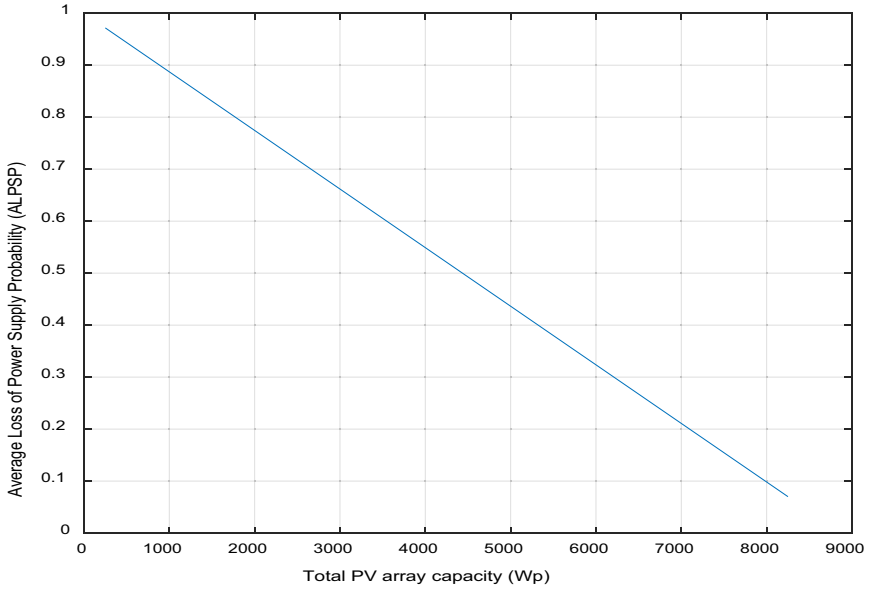


Fig. 4. Variation of ALPSP according to the total PV capacity.

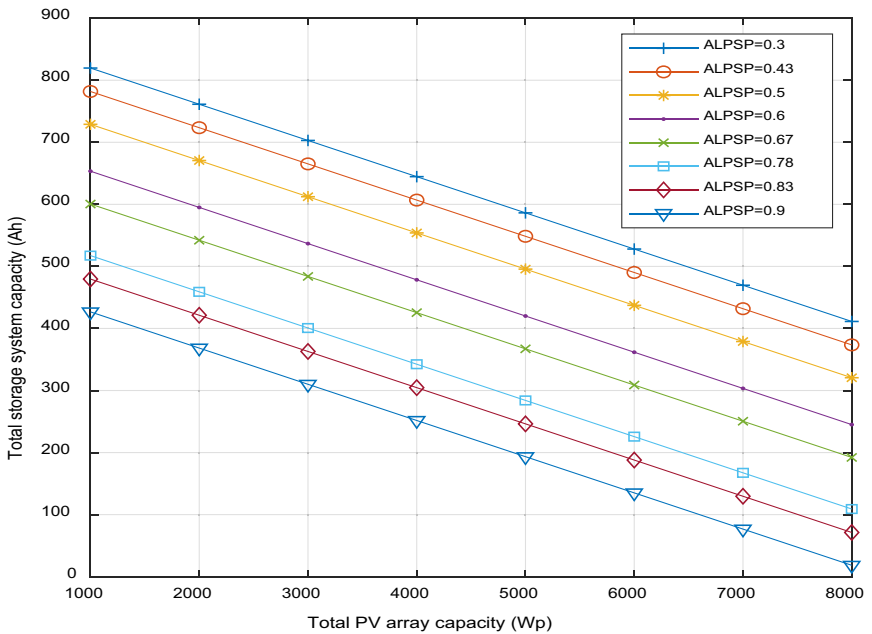


Fig. 5. Different combinations between PV and batteries capacities for various ALPSP.

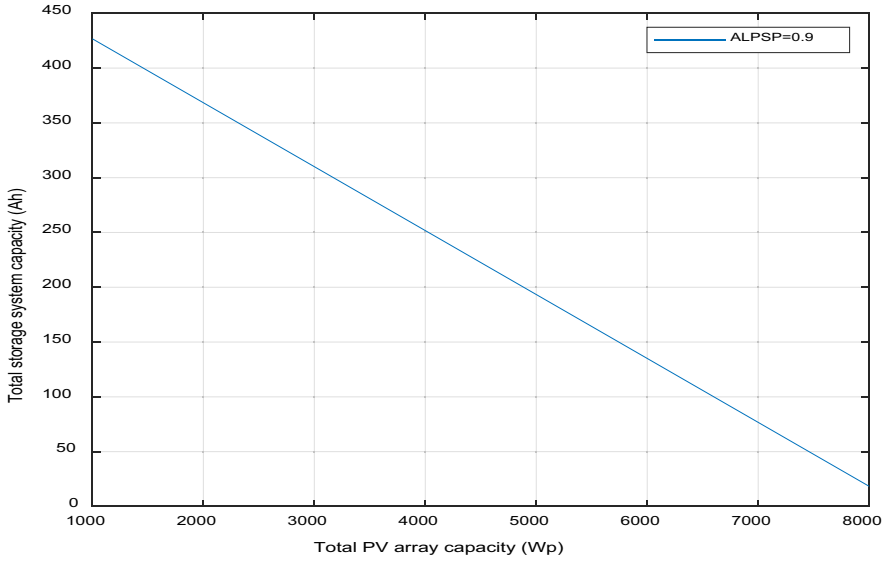


Fig. 6. Different combinations between PV and batteries capacities for 0.9 reliability level.

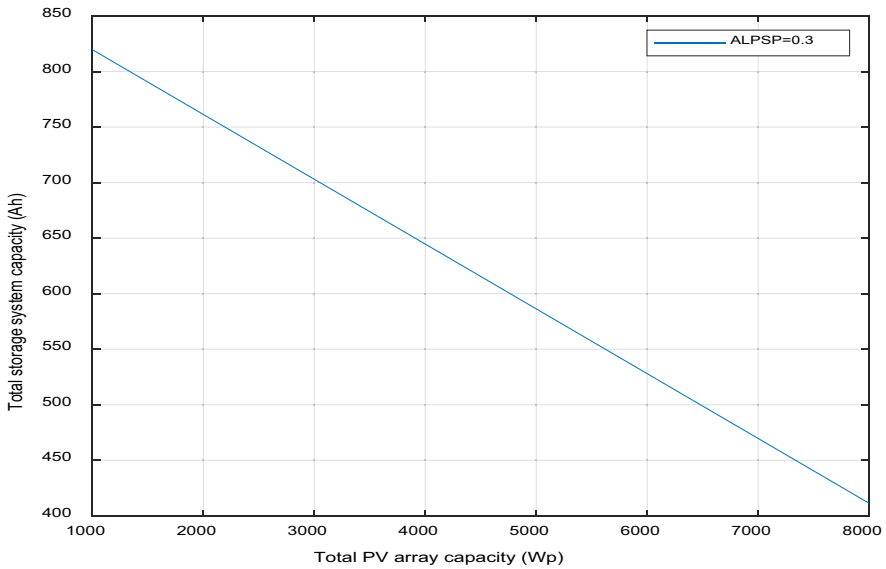


Fig. 7. Different combinations between PV and batteries capacities for 0.3 reliability level.

in Ngoundiane site for using such of models. We are constrained to use meteorological daily average, which not consider the uncertainty nature of these data and affect the accuracy of the results.

Table 4. Results of intuitive and numerical sizing methods.

Designation	Intuitive method	Numerical method
Hydraulic energy (Wh/day)	15669	15669
Electric energy (Wh/day)	26115	26115
Hydraulic power	2243.77	2243.77
Electric power (W)	3740	3740
Pump flow (m ³)	250	250
Piping diameter (mm)	19	19
Total capacity of PV array (W _p)	8250	8250
Total number of PV array	33	33
Total capacity of storage system (Ah)	1638	820
Total number of battery	216	120
Total number of charge controller	4	4
Total number of Inverter	6	6
Volume of tank (m ³)	250	250

In Kazem et al. (2013), we have small difference in the values of ALPSP. However, the battery capacity increases with the PV capacity in this paper. Contrary to our study where the PV and battery capacities are inversely proportional. What allows to find out a compromise between technical and economic criterion. In addition, with monthly data, a reliability of 0.3 is obtained, then by using machine learning to predict meteorological hourly data, the reliability can be increased and results can be strongly improved.

4 Conclusion

The optimal sizing of a photovoltaic water pumping system of a well implanted in Ngoundiane's village has been investigated in this paper. We have used the ALPSP to evaluate the technical performance of system. First, an intuitive method is applied by separately determining the capacity of components. Afterwards, a numerical sizing method is developed. The different components of the PV system have been modeled by using empirical simple model more adapted to the input parameters of Ngoundiane site. From these models a simple algorithm has been elaborated to find PV and battery combinations for various levels of reliability. ALPSP concept is used to evaluate the technical performance of system. After implementing this model in MATLAB, obtained results showed that the numerical sizing method allows to decrease the storage capacity to 50% when compared to the intuitive method. Nevertheless, the ALPSP values are seem high compared to the ones found in literature. This is due to an undervaluation of input parameters and the use of average data of meteorological variables in the model. These results can be improved by using hourly input data. It is also important to define an accurate input profile and to include all variables, which can affect the optimal operating

of the system. In the future works, an accurate model to predict and generate hourly data of solar radiation will be performed by using machine learning. From this data, the dynamic behavior of components of PV system can be studied with precision and many parameters would be taken into account in the sizing model.

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