Renewable and Sustainable Energy Solar Energy and Electrical System Design

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***Abstract*—In some parts of the world, our dependence on fossil fuels has lasted much longer than it should have. The transformation and sustainability of the energy sector can therefore be seen as one of the most important challenges we face today. The International Energy Agency (IEA) has published that the final consumption of electricity increases by 25% from 2020 to 2030 according to the Net Zero Emissions (NZE), of which the building sector accounts for nearly 32% of electrical energy. Thus, the orientation towards new energy sources remains the only way to meet our daily needs and to keep a sustainable autonomy. This article proposes a solution to the problem of ensuring a sustainable power supply for a building, and to do this it is necessary to rely on a methodology that consists first of making a collection of data for the various electrical equipment of the building, [1] then taking advantage of them for the calculation of energy needs. Finally, and after this assessment the sizing of electrical devices for sustainability and energy optimization.**

***Index Terms*—Optimization, sustainability , Energy, New energy sources.**

I. Introduction

Renewable energy is an energy source that does not run out and can be used in a sustainable way. It is produced from natural resources that are continuously regenerated, such as the sun, wind, water, biomass and geothermal energy. The use of renewable energy has many benefits, including protecting the environment and combating climate change. It can also contribute to energy security by reducing dependence on non-renewable energy sources, which are limited and often located in unstable regions of the world [2].

The sustainability of electric power depends on how it is produced and used. If it is produced from renewable energy sources and used efficiently, electrical energy can be sustainable. If it is produced from non-renewable energy sources, such as coal, natural gas or oil, it can have a negative impact on the environment and contribute to climate change [3].

There are several ways to make electrical energy more sustainable. For example, by using renewable energy generation technologies, such as solar or wind power, improving the energy efficiency of buildings and electrical appliances, using smart grids to optimize electricity distribution, and implementing policies and programs to encourage the adoption of sustainable technologies.

The sustainability of the electricity system also depends on three other dimensions: First, the proportion of renewables linked to intermittent sources like solar or wind. Producing from these sources presents a particular constraint depending on the weather or the time of day. Electricity production must be stable and reactive to meet demand. Not all sources of electricity production are equally efficient on these criteria. On the other hand, the quality and size of the transmission network is also an element of sustainability: The advantage of electrical energy is that it can be transported instantaneously over long distances. It travels across borders, if the networks are well designed and the commercial contracts are well established...; We must also take into account the development of isolated sites whose cost of connection to the network would be too high. In developing countries, it is estimated that half of the demand, currently unsatisfied, could be supplied by local sources with new renewable energies. Finally, the challenge of storage: currently it is difficult or expensive to store electricity. [4] Of course, we have batteries for our cell phones, computers and for backup networks. But the proven storage for renewable electricity is the water reservoir: mountain lake or artificial reservoir.

This paper is organized as follows: Section 2 presents a review of the research literature contributing to the development of energy sustainability with renewable sources. Section 3 describes the study methodology, Need Production, sizing and storage. Section 4 represents a real case study. Finally, section 5 concludes the paper. [5]

II. LITERATURE REVIEW

The use of solar energy as clean energy, as well as the variety of production of different types of energy used in the building sector, such as electricity, heating, cooling and fresh water, have made the use of integrated energy systems (IES) in the building sector more attractive. In IESs, in addition to the variety of energy production, such as electricity and heat, there is the possibility of energy storage, which can play an important role in meeting building demands during peak or sunless hours. Although much research has been done in recent years on the efficiency of these systems using various analyses, such as energy, exergy, economic and environmental [6].

Solar energy can be harnessed through three primary methods: photovoltaics, solar heating & cooling, and concentrating solar power. Photovoltaics convert sunlight directly into electricity through an electronic process, serving a range of applications from small devices like calculators and road signs to residential homes and large-scale commercial enterprises. Meanwhile, solar heating & cooling (SHC) and concentrating solar power (CSP) utilize the sun's heat to offer space or water heating through SHC systems, or to operate conventional electricity-generating turbines within CSP power plants.

Today, wind power is a mature renewable energy source that has great potential to become an important primary energy source in the future. Over the past decade, wind power has developed by leaps and bounds. During this period, global wind power capacity has increased rapidly, with an average annual growth rate of 29%. By mid-2010, total installed capacity had increased to more than 175 GW, and is estimated to reach 260 GW in 2012 and 425 GW in 2015. However, energy policies largely determine whether or not wind power development can maintain this pace and reach the target in the future. Although most wind turbines are built on land, offshore wind is a relatively new sector of wind energy that has attracted public attention because of its many advantages over onshore wind [7], [8].

Society has been using wind energy to generate electricity for a relatively short time. Since wind speed increases with altitude, [9] it makes sense to use the upper layers of the atmosphere, where wind strength is higher. Therefore, various technologies have recently been developed to capture wind energy at high altitude. When these airborne wind systems, also known as high-altitude wind systems, become a reality, the result will be a new form of renewable electricity generation, which can contribute to cleaner production in industry. [10] However, a single dominant design for airborne wind systems has yet to emerge, hindering progress in this new renewable energy sector.

When only one renewable energy source is used, the biggest associated problem is variable energy production due to constantly changing weather resources [11]. The problem of energy variability is reduced by combining renewable sources in a hybrid energy system. Renewable sources complement each other in the hybrid energy system, i.e., the strength of one source can be used to reduce the weakness of the other, thus improving the efficiency and reliability of the system [12]. Due to the complementary nature of the sources, the need for batteries and diesel power systems is reduced compared to a single source system.

III. METHODOLOGY

The objective is to produce electrical energy autonomously from solar energy using photovoltaic systems. It will contribute to the protection of the environment.

The specific objectives are to:

- Identify and choose the loads for which we want to produce electrical energy from the energy by PV systems.
- Study the technical feasibility of the photovoltaic mini-power plant.

First we will start from the power balance and the global energy balance of the structure, to define the electrical loads to be taken into account by the technical feasibility study, then, we will make the dimensioning of the necessary mini-power station.

The sizing method consists of first determining the peak power of a photovoltaic panel that provides the required electrical energy during the day [13].

It consists in determining the period of need for electricity, and the consumption required. This step involves few calculations, but requires relatively a lot of thought because a mistake at this stage can make the photovoltaic installation obsolete.

The method consists of the following steps:

A. Need Production

A well adapted system requires the evaluation of the electrical power of the applications to be powered. The required energy is expressed by :

$$E_c = P \times t \tag{1}$$

E_c : Energy consumed
P : operating power of the device
t :time of use

Indeed, as a photovoltaic system has to supply its energy during a whole day, it is natural to take the 24-hour period as a unit of time. it is natural to take the 24-hour period as the unit of time.

The energy E, is therefore the electrical energy consumed in 24 hours by the application and is expressed in Watt-hours per day (Wh/d). It is also called daily consumption [14], [15].

To calculate the total consumption of an installation, we first calculate the electrical energy consumed in 24 hours by each piece of equipment or each electrical function and then and then we add them up.

$$E_t = \sum P_i \times T_i \tag{2}$$

P_i : Electrical power of an appliance "i" expressed in Watt .
T_i : Duration of use of this device " i " in hours per day (h/d).

When all appliances are operated at the same voltage, the daily consumption can also be expressed in consumption can also be measured in Ampere - hour per day (Ah/d), which is a convenient unit for all battery systems linked to a battery.

B. Optimal tilt and orientation of the photovoltaic collectors

The energy supplied by photovoltaic collectors is directly proportional to the amount of sunlight. In order to optimize the solar installation, it is necessary to take into account this factor, which in turn depends on the location of the installation, the orientation and the inclination of these collectors.

Ideally, they should face due south in the northern hemisphere and due north in the southern hemisphere, away from shady areas, and tilted at an angle that allows the optimization of the energy recovered. An inclined plane is characterized by its inclination β (with respect to the horizontal), and its orientation or azimuth χ with respect to the south.

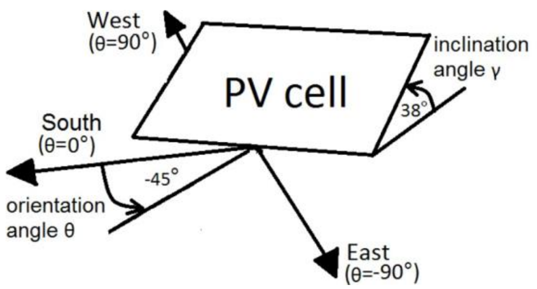

Fig. 1. Definition of angles for an inclined plane: inclination γ and the angle of incidence θ

The closer the rays are to the perpendicular to the plane of the panels ($\cos\vartheta = 1$), the more amount of energy available is important.

- On average, over the year, the optimal tilt to maximize the annual energy produced is equal to the latitude of the location.
- A tilt greater than the latitude can increase the energy recovered in winter (the path of the sun being low in the sky), at the expense of that recovered in summer.The opposite is true for a tilt lower than the latitude.

These considerations are taken into account when sizing a photovoltaic system [16].

The design of photovoltaic systems requires the knowledge of the useful solar radiation on the installation site. This knowledge is one of the essential parameters of the preliminary study. For a given electrical need, the more solar energy received, the less solar panels to install and vice versa. When crossing the atmosphere, the solar radiation is absorbed and diffused on the ground. The influence of the atmosphere causes the scattering and absorption of part of the incident radiation. The modification of the solar radiation by the atmosphere follows quite complex and mostly random phenomena.

The quantity of light energy received at the Earth's surface at any given moment is influenced by a myriad of factors. These encompass elements such as the composition of atmospheric gases, cloud cover, the reflectivity of the ground (referred to as albedo), ambient temperature, wind patterns, relative humidity, and more. However, it's important to note that these variables are contingent upon specific geographical locations, the time of year, the time of day, and the current weather conditions.

Consequently, the accumulation of reliable data is of paramount importance. This data is typically collected over an extended period, thanks to the utilization of a specialized instrument known as a heliograph. Meteorological stations employ the data collected by the heliograph to generate statistics regarding integrated solar radiation, often measured in units like kilowatt-hours per square meter per joule (KWh/m² . J). These statistics, aggregated over a day, primarily serve the purpose of dimensioning and optimizing photovoltaic systems for efficient energy generation.

C. Sizing of the photovoltaic generator

This step consists in calculating the quantity of photovoltaic modules that we will need to to cover the electricity needs.

Peak power of a photovoltaic generator

The peak power of the panels to be installed depends on the irradiation of the place of installation. It is calculated by applying the following formula: [17]

$$P_{ch} = \frac{E_c}{I_r} . K \qquad (3)$$

P_{ch} : Peak power of photovoltaic fields in Watt peak (Wp)
E_c :Energy consumed per day (Wh/day)
I_r : Average daily sunshine time (h/day)
K : Correction coefficient

K is between 0.55 and 0.75. The value often used in the calculations of the system with battery is k=0,65.

D. Storage

To carry out the sizing of the batteries, we proceed as follows: [18]

- We calculate the energy consumed (Ec) by the various receivers.
- The number of days of autonomy required is determined.
- We determine the acceptable depth of discharge for the type of battery used

$$C_{ch} = \frac{E_c \times N}{D \times U} \qquad (4)$$

C_{ch} : capacity of the battery field in amperes. Hour (Ah)
E_c : energy consumed per day (Wh/d)
N :number of days of autonomy
D :Maximum allowable discharge (0.5 for lead-acid batteries)
U : battery voltage (V)

The lifespan of a battery declines rapidly as the depth of discharge increases. Typically, we aim to restrict the depth of discharge to 50%, using only half of the battery's capacity.

A Battery Energy Storage System (BESS) is a sophisticated solution that employs rechargeable batteries to store energy for later use.

Rechargeable batteries have the capability to store excess energy generated by intermittent renewable sources. This stored energy can then be distributed based on user demand.

Energy consumption varies throughout the day and across seasons, resulting in peak and off-peak hours. A BESS enables users to transition between these timeframes, adapting energy usage and cutting down on electricity expenses.

One of the prominent applications of a BESS in load management is peak shaving. This involves reducing energy consumption during peak demand periods. Similarly, consumers can curtail their costs, much like in energy arbitrage.

A BESS plays a significant role in facilitating swift recovery for power plants and grids following a blackout. Instead of relying on a diesel generator, consumers have the option to utilize a battery storage system - a more economical and environmentally friendly standalone power solution. Operating autonomously from the power grid's transmission line, a BESS can supply power for a specific duration, ranging from minutes to hours.

A BESS can furnish power to residences, enterprises, and other establishments, ensuring their uninterrupted operation. This is especially crucial for healthcare facilities and other entities that deliver services related to human health and safety. Depending on its storage capacity, a BESS can furnish backup power for as long as necessary, even in the case of a severe power grid breakdown. [19], [20].

E. Charge controller

The regulator is designed according to the following parameters: voltage, input current and output current.
The nominal voltage must be the voltage of the photovoltaic field and the input current is the maximum load current that the modules can deliver. To estimate this current, it is best to take 1.5 times the maximum current. Then the output current must be greater than the maximum value that the receivers can draw simultaneously.

F. Sizing of inverters

Inverter allows to convert the direct electricity produced by the photovoltaic panels into alternating electricity, in order to to power appliances operating in alternating current.
The sizing of the inverter is based on the sum of the maximum power of different equipment operating in AC and also depends on :

- Input voltage: it is equal to that of the battery or regulator.
- Output voltage: Generally 220 VAC, 50 HZ.
- Nominal power: this power is defined according to the needs energy needs.

Our stand-alone system consists of individual modules with a nominal power of 100 Wp each and is intended to supply our electrical appliances which consume constant electrical energy on a daily basis throughout the year.

IV. CASE STUDY

A photovoltaic system is an electricity production system designed to fulfill a specific task. In other words, it is used to cover the energy needs of isolated sites, in our case those of a building. This system consists of several elements: mainly the PV modules that represent the field of collection of solar rays, the batteries where the energy produced by the modules is stored, the regulator that protects the battery against overloads and thus regulates the value of the nominal voltage, the inverter that ensures the conversion of direct current into alternating current needed by users, and the wiring that connects the various components of the system together.
In order to achieve a successful stand-alone photovoltaic installation, we conducted a detailed study regarding the sizing method of the photovoltaic system taking into account its estimated consumption from the electrical appliances available in the building.
It turns out that the energy produced depends directly on the permanent fluctuations of the weather conditions of our site of use and the load imposed by the user as well as the number of days of autonomy.

Appliance	Quantity	Watts	Hours On per Day	Watt Hours per Day
CFL Bulb - 60 Watt Equivalent	10	18	6	1080
Coffee Machine	1	1000	0.2	200
Fridge - 20 cu. ft. (AC)	1	353	4	1412
Microwave	1	1000	0.3	300
Toaster Oven	1	1200	0.2	240
TV - LCD	1	150	3	450
Freezer - Chest - 15 cu. ft.	1	270	4	1080
Vacuum	1	1000	1	1000
Laptop	1	100	4	400
Router	1	7	24	168
Modem	1	7	24	168
Smart Phone-Recharge	1	6	3	18
Coffee Machine	1	1000	0.2	200
Espresso Machine	1	800	1	800
Central Air Conditioner - 24,000 BTU NA	1	3800	1	3800
Well Pump - 1/3 1HP	1	1000	1	1000

Fig. 2. estimated consumption from the electrical appliances

To figure out the Peak power, we use the equation 3 :

$$P = \frac{12.2Kwh}{6.1h} \times 1.15 = 2.5Kw$$

Our autonomous system is made up of individual modules with a nominal power of 100 Wp each and is intended for the supply of our electrical appliances we have opted for the use of 26 modules combined with each other. And to calculate the capacity of the used batteries, we need to know the number of days of autonomy provided by the batteries 4.

$$C_{ch} = \frac{12.2 \times 3}{(1 - 0.5) \times 48} \times 1000$$
$$C_{ch} = 153.7Ah$$

Therefore, we have chosen 04 batteries whose characteristics are too powerful. In order to guarantee the protection and functioning of the storage park, we opt for the use of a regulator in our installation to use 01 regulators in our installation. The inverter used is with a power of 8 KW and a 230 V input.

V. Conclusion

At the end of this paper, the conjugation of the energy problem with the objectives of sustainable development gave birth to the development of renewable energies. In this sense, we were able to demonstrate, first of all, that these energies are considered as an urgent necessity, and not a choice, in spite of all the constraints which hinder their development on a large scale currently. Since we suffer from a scarcity of fossil energy resources on the one hand and the weight of the energy bill, on the other hand, we have enormous potential for the development of renewable energy.

Through this work, we have presented an example of a real solar system that has ensured the sustainability of energy autonomy of a building. Based on the approaches cited in this paper: Need Production, sizing and storage.

we could conclude that renewable energies have a promising future for our country promising future, given their dual importance in contributing to sustainable development.

NOTATION

- **IEA :**International Energy Agency
- **NZE:** Net Zero Emissions
- **IES:** integrated energy systems
- **CSP:**concentrating solar power
- **PV :** photovoltaic
- E_c : Energy consumed
- P : operating power of the device
- t :time of use
- P_i : Electrical power of an appliance "i" expressed in Watt
- T_i : Duration of use of this device " i " in hours per day (h/d).
- P_{ch} : Peak power of photovoltaic fields in Watt peak (Wp)
- E_c :Energy consumed per day (Wh/day)
- I_r : Average daily sunshine time (h/day)
- K : Correction coefficient
- C_{ch} : capacity of the battery field in amperes. Hour (Ah)
- E_c : energy consumed per day (Wh/d)
- N :number of days of autonomy
- D :Maximum allowable discharge (0.8 for lead-acid batteries)
- U : battery voltage (V)

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