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Study and sizing of photovoltaic pumping station intended for the irrigation of an isolated agricultural farm

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Title : Study and sizing of photovoltaic pumping station intended for irrigation of an isolated agricultural farm.

Abstract

This thesis delves into the study and sizing of a photovoltaic pumping station tailored for the irrigation needs of an isolated agricultural farm. The investigation begins with an analysis of energy requirements for irrigation and the potential advantages of harnessing solar energy for water pumping. Various components of the photovoltaic pumping system, including solar panels, inverters, and pumps, are scrutinized and selected based on their efficiency and suitability for the agricultural setting.

In addition, the study highlights the integration of Arduino Mega, powered by photovoltaic energy, into the system to regulate and control the pumping operations efficiently. This innovative approach enhances the automation and optimization of the irrigation process, contributing to improved water management and energy utilization on the farm.

Furthermore, a comprehensive sizing methodology is developed to determine the optimal configuration of the photovoltaic pumping station, taking into account factors such as water demand, solar irradiation, pump characteristics, and system losses. Practical considerations such as installation, maintenance, and monitoring of the system are also addressed, along with potential challenges and solutions during implementation.

Overall, this thesis offers valuable insights into the study and sizing of photovoltaic pumping stations for agricultural applications, showcasing the integration of innovative technologies like Arduino Mega powered by photovoltaic energy to create efficient and sustainable irrigation systems for isolated agricultural farms.

Titre : étude et dimensionnement d’une station de pompage photovoltaïque destinée à l’irrigation d’une exploitation agricole isolée.

Résumé

Cette thèse explore l'étude et le dimensionnement d'une station de pompage photovoltaïque adaptée aux besoins en irrigation d'une exploitation agricole isolée. L'étude commence par une analyse des besoins énergétiques pour l'irrigation et les avantages potentiels de l'utilisation de l'énergie solaire pour le pompage de l'eau. Divers composants du système de pompage photovoltaïque, tels que les panneaux solaires, les onduleurs et les pompes, sont examinés et sélectionnés en fonction de leur efficacité et de leur adéquation au contexte agricole.

De plus, l'étude met en avant l'intégration d'ArduinoMega, alimenté par énergie photovoltaïque, dans le système pour réguler et contrôler efficacement les opérations de pompage. Cette approche innovante améliore l'automatisation et l'optimisation du processus d'irrigation, contribuant à une meilleure gestion de l'eau et de l'énergie sur l'exploitation agricole.

De même, une méthodologie de dimensionnement complète est développée pour déterminer la configuration optimale de la station de pompage photovoltaïque, en tenant compte de facteurs tels que la demande en eau, l'irradiation solaire, les caractéristiques des pompes et les pertes du système. Les considérations pratiques telles que l'installation, la maintenance et la surveillance du système sont également abordées, ainsi que les défis potentiels et les solutions lors de la mise en œuvre.

En résumé, cette thèse offre des perspectives précieuses sur l'étude et le dimensionnement de stations de pompage photovoltaïque pour des applications agricoles, mettant en valeur l'intégration de technologies innovantes comme ArduinoMega alimenté par énergie photovoltaïque pour créer des systèmes d'irrigation efficaces et durables pour les exploitations agricoles isolées.

عنوان: دراسة وتصميم محطة ضخ فوتوفولتائية مخصصة لري مزرعة معزولة.

الملخص:

تتناول هذه الرسالة دراسة وتصميم محطة ضخ فوتوفولتائية ملائمة لاحتياجات الري في مزرعة زراعية معزولة. تبدأ الدراسة بتحليل احتياجات الطاقة اللازمة للري والفوائد المحتملة لاستخدام الطاقة الشمسية في ضخ المياه. يتم فحص واختيار مختلف مكونات نظام الضخ الفوتوفولتائي، مثل الألواح الشمسية والمحولات والمضخات، بناءً على كفاءتها وملاءمتها للسياق الزراعي

بالإضافة إلى ذلك، تسلط الدراسة الضوء على دمج أردوينو ميجا، المشغَّل بالطاقة الفوتوفولتائية، في النظام لضبط ومراقبة عمليات الضخ بكفاءة. تعزز هذه النهج الابتكاري التأتيم والتحسين في عملية الري، مما يساهم في إدارة أفضل للمياه والطاقة على المزرعة الزراعية بالمثل، يتم تطوير منهجية شاملة للتصميم لتحديد التكوين الأمثل لمحطة الضخ الفوتوفولتائية، مع مراعاة عوامل مثل الطلب على المياه، والإشعاع الشمسي، وخصائص المضخات، والخسائر في النظام. كما يتم مناقشة الاعتبارات العملية مثل التركيب والصيانة ومراقبة النظام، بالإضافة إلى التحديات المحتملة والحلول أثناء التنفيذ في الختام، تقدم هذه الرسالة آفاقًا قيمة حول دراسة وتصميم محطات الضخ الفوتوفولتائية لتطبيقات الزراعة، مع التركيز على دمج التقنيات المبتكرة مثل أردوينو ميجا المشغَّل بالطاقة الفوتوفولتائية لإنشاء أنظمة ري فعالة ومستدامة للمزارع الزراعية المعزولة

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General introduction

General introduction

In the realm of agricultural development, ensuring access to reliable water resources for irrigation purposes is paramount. However, for isolated agricultural farms situated in remote areas with limited infrastructure, securing a dependable water supply can pose significant challenges. Traditional irrigation methods reliant on diesel-powered pumps or grid-connected systems may be impractical or economically unfeasible in such contexts. In light of these constraints, the integration of photovoltaic (PV) technology in irrigation systems offers a promising solution to address the water needs of isolated agricultural communities.

This study embarks on a comprehensive exploration of the design and sizing considerations for a photovoltaic pumping station tailored specifically for the irrigation requirements of isolated agricultural farms. By leveraging the abundant solar energy available in remote regions, PV pumping systems present a sustainable and economically viable alternative to conventional pumping methods. Moreover, they contribute to mitigating environmental impacts associated with greenhouse gas emissions and dependence on finite fossil fuel resources.

The primary objective of this study is to conduct an in-depth analysis of the irrigation water requirements of isolated agricultural farms and to devise optimized PV pumping solutions that align with the unique needs and challenges of these settings. Through meticulous evaluation of site-specific conditions, including solar irradiance levels, water source availability, and crop water demand, this study aims to formulate tailored recommendations for the design and implementation of PV pumping systems.

Furthermore, this study endeavors to assess the economic feasibility and environmental implications of adopting solar-powered irrigation solutions compared to conventional alternatives. By conducting cost-benefit analyses and environmental impact assessments, the study seeks to elucidate the potential benefits in terms of cost savings, energy efficiency, and environmental sustainability associated with the deployment of PV pumping stations for agricultural irrigation.This study aims to offer insights and guidance for stakeholders in agricultural development, rural electrification, and renewable energy. By harnessing solar energy for the irrigation in isolated farms , it seeks to advance sustainable farming practices . **[1]**

Chapter I State of the art of renewable energy

Introduction

Today, electricity is a fundamental requirement for economic development worldwide. Its significance increases alongside technological advancements, industrialization, and the pursuit of modern comforts. Enhanced production correlates with improved quality of life and wealth generation. However, the current reliance on fossil fuels for the majority of electricity production is met with challenges such as resource depletion, environmental concerns, and escalating energy demands. Consequently, many countries prioritize the exploration of new energy sources. Renewable energies emerge as an ecological alternative to fossil fuels. Their deployment promises widespread access to electricity, particularly in remote areas, while circumventing the need for extensive power infrastructure. To underscore the importance of renewable energies, particularly solar energy, this chapter offers an overview of the world's primary energy consumption forms. We specifically delve into the production of electricity from solar energy, as it aligns with our research focus. Additionally, we delineate the key milestones of an ambitious renewable energy development initiative in Algeria.

Global electricity production is experiencing a steep rise, driven particularly by the demands of emerging nations. Presently, a significant portion of the world's electricity is generated through the combustion of fossil fuels (such as oil, coal, or natural gas) or nuclear power. However, this paradigm is undergoing a shift, with renewable energy sources gradually supplanting fossil fuels due to their exhaustibility and environmental impact. **[2]**

I. Different Renewable Energies in Algeria

Algeria, a country endowed with diverse natural resources, has been actively exploring various renewable energy sources to diversify its energy mix, reduce dependency on fossil fuels, and mitigate environmental impacts. This section provides an overview of the different renewable energies in Algeria, highlighting their potential, challenges, and contributions to the country's sustainable development agenda.

I.1. Solar Potential

Considering its geographical location, Algeria has one of the highest solar resources in the world. The duration of sunshine throughout the vast majority of the national territory exceeds 2000 hours annually and can reach 3900 hours (high plateaus and Sahara).

The solar energy received annually on a horizontal surface of 1m² in Algeria demonstrates significant variation based on geographical location. In the northern regions, such as the coastal areas, the average solar energy reception is close to 3 kWh/m² per year. In contrast, the southern parts of Algeria, particularly in the Sahara Desert and the far south, receive more intense solar radiation, exceeding 5.6 kWh/m² annually. This abundance of solar irradiance underscores Algeria's vast potential for solar energy generation, offering ample opportunities for sustainable energy development and utilization across the country. **[3]**

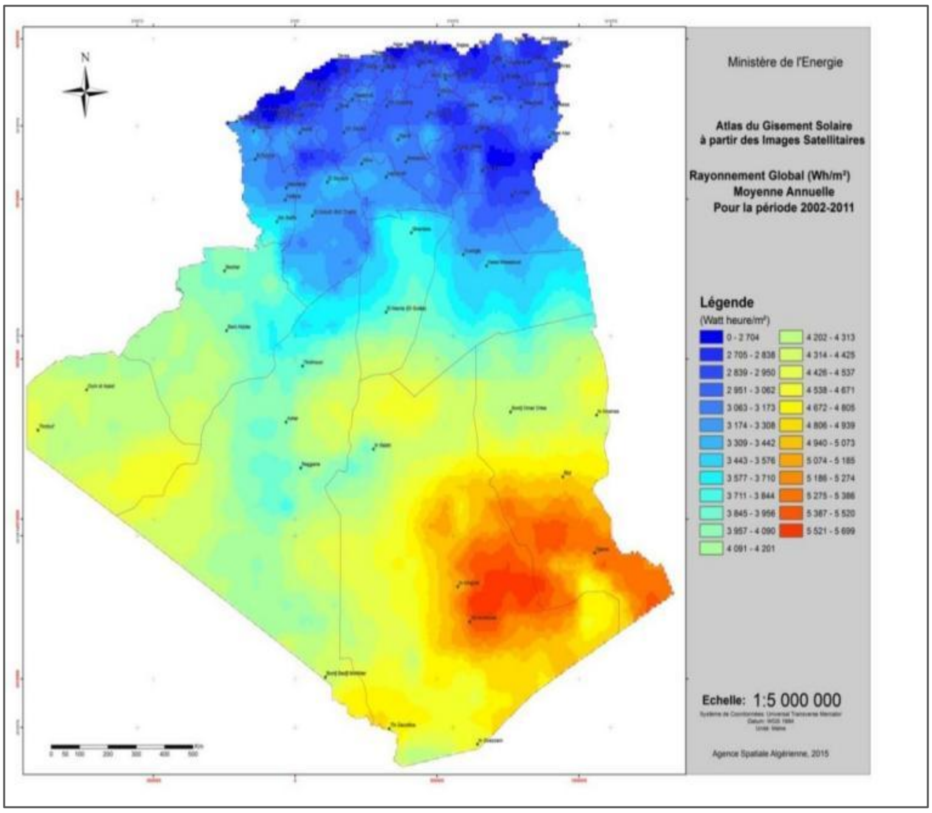


Figure 1.1 : Map of Average Annual Direct Global Irradiation.

I.2. Wind Potential

The wind resource in Algeria varies greatly from one location to another. This is mainly due to a diverse topography and climate. Indeed, our vast country is divided into two distinct geographical zones. The Mediterranean North is characterized by a coastline of 1200 km and a mountainous relief, represented by the two chains of the Tell Atlas and the Saharan Atlas.

In between, there are plains and high plateaus with a continental climate. The South, on the other hand, is characterized by a Saharan climate.

The map below (Figure 1.2) shows that the South is characterized by higher speeds than the North, especially in the Southeast, with speeds exceeding 7 m/s and reaching over 8 m/s in the Tamanrasset region (In Amguel).

Regarding the North, it is generally observed that the average speed is relatively low. However, there are microclimates along the coastal sites of Oran, Bejaïa, and Annaba, on the high plateaus of Tébessa, Biskra, M'sila, and El Bayadh (6 to 7 m/s), and in the Far South (>8m/s).

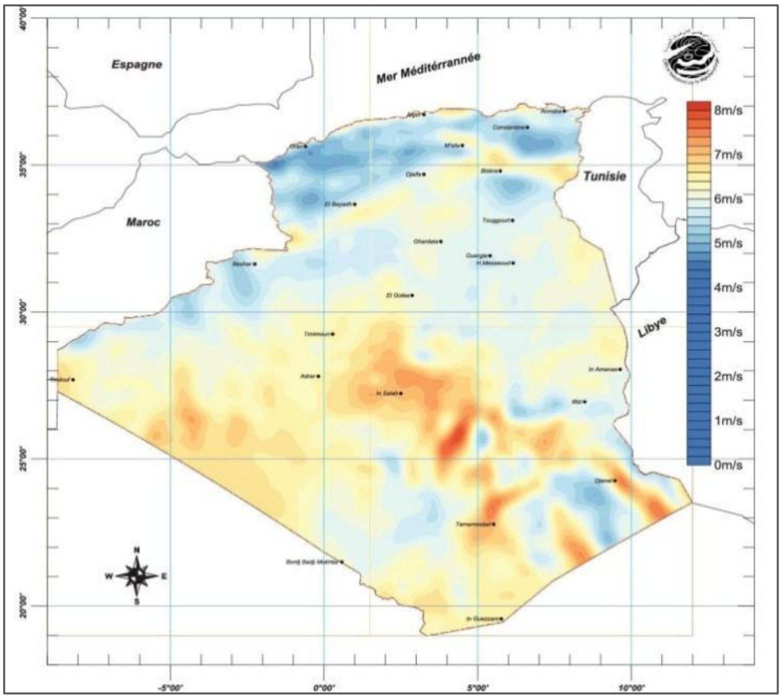


Figure 1.2 : Map of Average Annual Wind at 50m.

I.3. Geothermal Energy Potential

The compilation of geological, geochemical, and geophysical data has identified over two hundred (200) hot springs that have been inventoried in the northern part of the country. Approximately one-third (33%) of them have temperatures exceeding 45°C. There are high-temperature sources reaching up to 118°C in Biskra.

Studies on the thermal gradient have identified three zones where the gradient exceeds 5°C/100m :

- Relizane and Mascara Zone

- AïneBoucif and SidiAïssa Zone

- Guelma and Djebel El Onk Zone

I.4. Hydraulic Potential

The total quantities falling on Algerian territory are significant, estimated at 65 billion cubic meters, but ultimately benefit the country little: a reduced number of precipitation days, concentration in limited areas, high evaporation, and rapid runoff to the sea. **[4]**

In general terms, surface resources decrease from north to south. Currently, useful and renewable resources are estimated to be around 25 billion cubic meters, with approximately 2/3 coming from surface resources.103 dam sites have been identified, with over 50 dams currently in operation.

II. Development of Renewable Energies In Algeria

Table 1.1 : Phases of the Algerian RenewableEnergy Program 2015-2030.

	1st phase 2015-2020 [MW]	2nd phase 2021-2030 [MW]	TOTAL [MW]
Photovoltaic	3000	10575	13575
Wind	1010	4000	5010
CSP	-	2000	2000
Cogeneration	150	250	400
Biomass	360	640	1000
Geothermal	05	10	15
TOTAL	4525	17475	22000

Algeria is steadfast in its commitment to renewable energies, aiming to offer global and sustainable solutions to environmental challenges while addressing the preservation of fossil energy resources. This commitment is exemplified through the initiation of an ambitious program for the development of renewable energies. The government first embraced renewable energy in February 2011, with subsequent revisions in May 2015. Algeria is now embarking on a new era of sustainable energy. The updated Renewable Energy Program sets a target to install approximately 22,000 MW of renewable power by 2030 for domestic consumption, with the strategic objective of potential exportation contingent upon market conditions.

III. Solar energy in Algeria

Solar energy is crucial for Algeria's sustainable development and energy security. The country has implemented strong policies and incentives to promote solar power, including the National Renewable Energy Development Plan. Technological advancements have enhanced solar efficiency, leading to a proliferation of utility-scale and rooftop installations. Despite progress, challenges like financing and grid integration remain. However, Algeria's commitment to renewables and innovation signals a promising future for solar energy, contributing to global sustainability goals. **[6]**

III.1. Solar Thermal Energy

Electricity production through thermodynamic processes involves heating a fluid to generate steam. To achieve sufficient temperature levels, solar radiation must be concentrated. The steam thus produced is converted into electrical energy through a steam turbine. There are several types of concentrators, including two main principles: those that concentrate solar rays onto a point and those that concentrate them onto a line.

III.1.1. Cylindrical-parabolic concentrators

Concentration occurs on long tubes located at the focal line of cylindrical-parabolic collectors. These collectors are equipped with sun tracking systems along at least one axis. The heat transfer fluid circulating inside these tubes is heated to high temperatures to produce high-temperature steam through a conventional heat exchanger.

Figure 1.3 : Cylindrical parabloic concentrator.

III.1.2. Tower concentrator

Concentration is focused on a central receiver. In this system, a large number of mirrors (heliostats) are positioned around a central tower. These mirrors are adjustable along two axes (zenith and azimuth) so that solar radiation is reflected towards a single point throughout the day. Solar radiation is converted into high temperature by an absorber to heat the heat transfer fluid to produce high-temperature steam. **[7]**

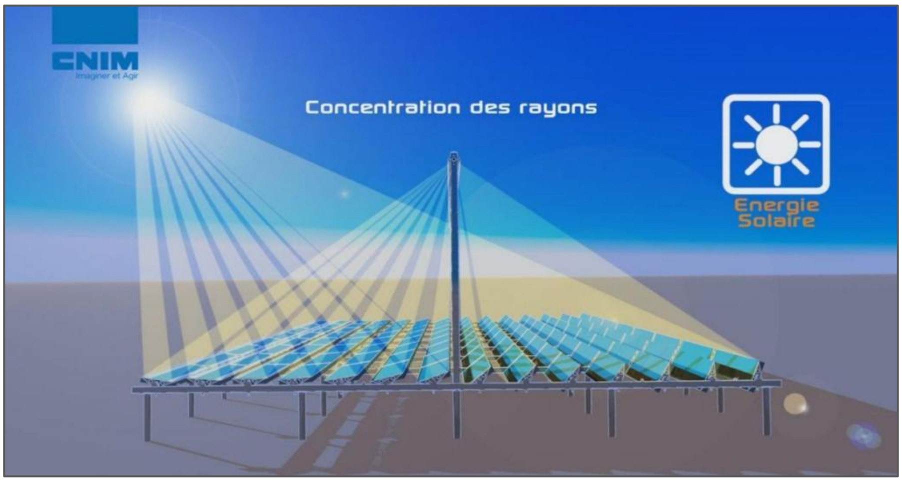


Figure 1.4 : Linear fresnel lens collector.

III.2. Photovoltaic Solar Energy

It involves directly producing electric energy in direct current from light energy using photovoltaic panels (the principle of the photovoltaic effect will be explained later). It is a clean and silent energy source with a lifespan of photovoltaic modules approaching 20 years.

IV. Solar Potential in Algeria

Algeria boasts an exceptional solar resource with an average of 3,000 hours of sunshine per year and an annual global direct irradiation of 2,000 kWh/m². This potential is unevenly distributed across the territory, with southern regions receiving the most sunshine.

An assessment conducted by the German space agency revealed that Algeria has the largest solar potential in the entire Mediterranean basin. It is estimated at 169,440 terawatt-hours per year (TWh/year) for solar thermal energy and 713.9 TWh/year for photovoltaics. **[8]**

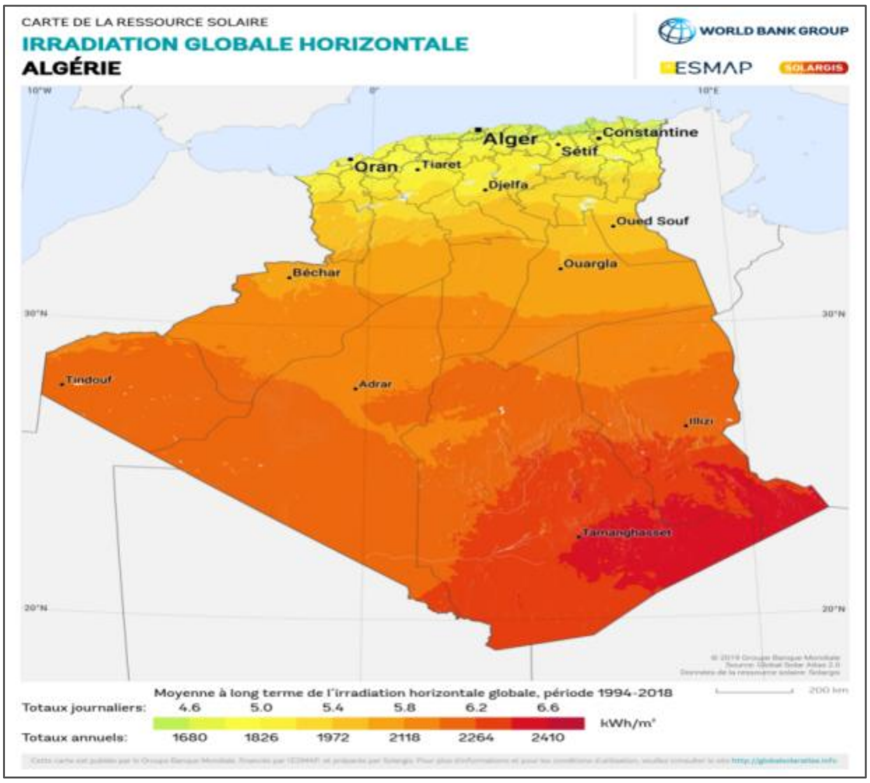


*Figure 1.5 :**Map of Irradiation.***

The Algerian government has implemented a national strategy for the development of renewable energies, aiming to achieve a solar energy production capacity of 4,000 MW by the year 2030.

V. The solar stations in Algeria

Algeria hosts several solar power plants in operation and in various stages of development. Among the most significant ones are:

- ❖ **150 MW Solar-Gas Hybrid Power Plant**

Figure 1.6 :10 MW Wind Farm.

Location: HassiR’mel (Laghouat)

Capacity: 150 MW

Technology:

ISCC System (Integrated Solar Combined Cycle), 120 MW Combined Cycle, 30 MW Solar Thermal (Parabolic CSP);

HTF System (Heat Transfer Fluid) 393°C;

Sun Tracking System (Tracker);

Commissioned: July 2011 **[7]**

- **Pilot Photovoltaic Power Plant of OuedN’Chou 1.1 MWp**

Figure 1.7 : OuedN'Chou Photovoltaic Pilot Plant 1.1 MWp.

Location: Oued N'chou (Ghardaïa), Capacity: 1,131,816 Wp, Technology: Eight subfields with Monocrystalline, Polycrystalline, Amorphous, and Thin Film CdTe technologies on fixed and motorized structures, Commissioned: June 2014. **[9]**

- **343 MWp Photovoltaic Power Plant Project**

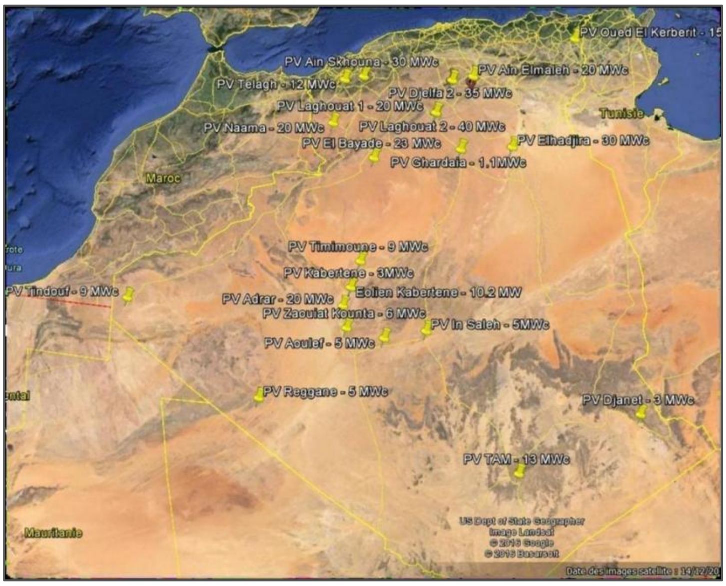


Figure 1.8 : Photovoltaic Power Plant Project.

Table 1.2 : Photovoltaic Power Plant Project

Wilaya	Locality	InstalledCapacity (MW)	Start-up
ILLIZI	Djanet	03	19/02/2015
ADRAR	Adrar	20	28/10/2015
ADRAR	Kabertene	03	13/10/2015
TAMANRASSET	Tamanrasset	13	03/11/2015
TINDOUF	Tindouf	09	14/12/2015
TAMANRASSET	In-Salah	05	11/02/2016
SOUK AHRAS	Oued El Kebrit	15	24/04/2016
OUARGLA	El-Hidjra	30	16/02/2017
BATNA	Oued El-Ma	02	16/01/2018

Conclusion

Algeria has an exceptional solar resource and significant potential for solar energy development. The country has made significant progress in this field in recent years, with the construction of several photovoltaic and thermodynamic solar power plants.

The development of the solar sector in Algeria is a national priority. The Algerian government has implemented a national strategy for renewable energies, aiming to achieve a solar energy production capacity of 4,000 MW by 2030.

Despite its significant potential, solar energy development in Algeria faces numerous challenges, including the high cost of installations, lack of skilled workforce, limited research and development, and regulatory instability.

To address these challenges, it is essential to implement incentive policies for investors, invest in research and development, and strengthen local capacities.

Solar energy has significant potential to contribute to the diversification of Algeria's energy mix and meet its growing energy demand. The development of the solar sector requires the implementation of incentive policies, investment in research and development, and capacity building at the local level.

Solar energy holds substantial promise in Algeria's energy diversification efforts and in addressing its increasing energy needs. Expanding the solar sector necessitates robust incentive policies, substantial investment in research and development, and targeted capacity building initiatives at the local level. These measures are crucial for enhancing the country's energy security, promoting sustainable development, and leveraging Algeria's abundant solar resources to achieve long-term energy sustainability goals. **[10]**

Chapter II Modeling of PV System

Introduction

In a photovoltaic system, the conversion of light energy into electrical energy occurs through semiconductor materials within photovoltaic (PV) cells. These cells, sensitive to visible wavelengths, act as sensors for capturing solar radiation. When multiple PV cells are interconnected in series or parallel configurations, they form a photovoltaic generator (PVG). It's important to note that the PVG's current-voltage (I-V) characteristic is nonlinear, influenced by factors like illumination levels, cell temperature, and equipment aging.

The operational state of the photovoltaic generator hinges upon the load it's connected to. This state varies, potentially deviating from the maximum power point (MPP), characterized by optimal current and voltage levels. To optimize the conversion efficiency of photovoltaic energy, employing a Maximum Power Point Tracking (MPPT) mechanism becomes imperative. This mechanism continuously adjusts the operation of the system to ensure it operates at or near the MPP, thus maximizing power output. Various MPPT techniques exist, ranging from traditional methods like Perturb and Observe to cutting-edge approaches utilizing artificial intelligence algorithms. These techniques play a vital role in harnessing the full potential of photovoltaic systems and enhancing their performance in real-world applications.

In addition to managing the operational state of the photovoltaic generator, MPPT techniques also play a crucial role in adapting to changing environmental conditions. Factors such as variations in solar radiation intensity, cloud cover, and shading can significantly impact the output of a photovoltaic system. By dynamically adjusting the operating parameters of the system, MPPT algorithms can effectively mitigate the effects of these fluctuations, ensuring optimal performance and energy yield.

Overall, the integration of MPPT techniques, including both traditional and AI-based methods, is essential for unlocking the full potential of photovoltaic systems. By continuously optimizing energy conversion processes and adapting to dynamic environmental conditions, MPPT algorithms contribute to the widespread adoption and effectiveness of solar energy as a clean and renewable power source. **[11]**

I. Photovoltaic (PV) systems

Photovoltaic (PV) systems, also referred to as solar power systems, have emerged as a versatile and sustainable solution for meeting energy needs across various sectors. They harness solar energy through photovoltaic cells, converting sunlight directly into electricity. These systems consist of a comprehensive array of components meticulously designed to maximize energy production efficiency.

Solar panels, the cornerstone of PV systems, are strategically positioned to absorb sunlight and initiate the electricity generation process. A crucial component, the solar inverter, facilitates the conversion of direct current (DC) electricity produced by the panels into alternating current (AC) electricity, compatible with standard electrical grids. Additionally, mounting structures, cabling, and electrical accessories ensure the seamless integration and operation of the system.

To further optimize performance, some PV systems incorporate solar tracking mechanisms, which dynamically adjust the orientation of the panels to follow the sun's path throughout the day. This tracking capability enhances energy capture and maximizes output, particularly in areas with variable sunlight angles.

Moreover, the integration of battery storage solutions enables PV systems to store excess energy generated during periods of peak sunlight for later use, providing resilience against grid outages and enabling greater energy independence.

From small-scale residential installations to large utility-scale solar farms, PV systems offer unparalleled scalability to suit diverse energy requirements and spatial constraints. This scalability, coupled with declining technology costs, has accelerated the adoption of solar power worldwide.

Beyond environmental benefits, such as reduced carbon emissions and mitigated reliance on finite fossil fuels, PV systems offer compelling economic advantages. They deliver long-term cost savings on electricity bills, often recouping initial investment costs within a relatively short period.

In essence, PV systems represent a transformative shift towards clean, renewable energy sources, fostering energy independence, economic prosperity, and environmental stewardship. As the global transition towards sustainable energy continues to gain momentum, PV systems stand at the forefront, driving positive change towards a greener and more sustainable future. **[12]**

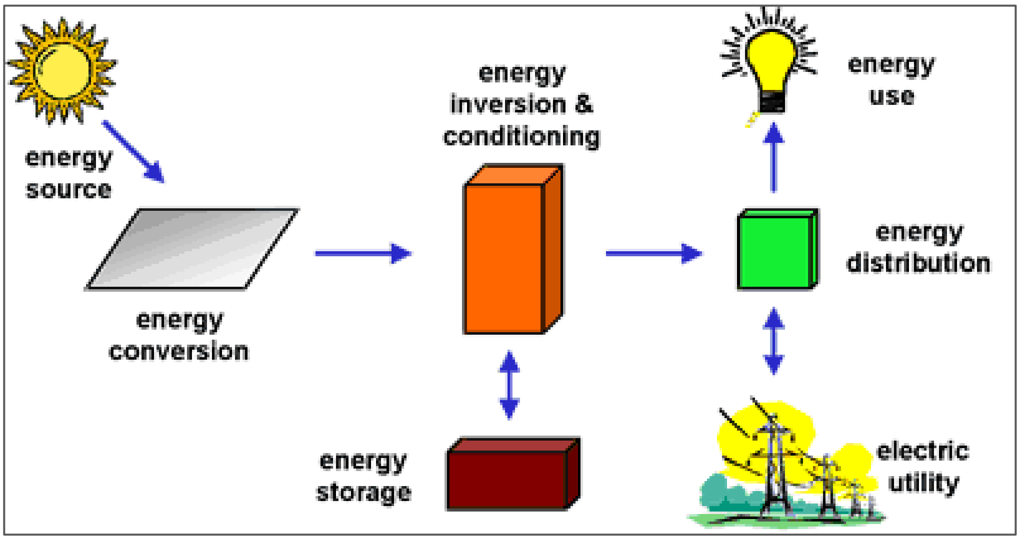


Figure 2.1 : Example of photovoltaic system.

A photovoltaic (PV) system harnesses sunlight to generate electricity through solar panels, which convert sunlight directly into usable electric power using semiconductor materials like silicon. These systems typically include solar panels that absorb sunlight, an inverter to convert the generated direct current (DC) into alternating current (AC), and mounting structures to position panels optimally for sunlight exposure. PV systems can be grid-tied, feeding excess electricity into the utility grid, or off-grid with battery storage for standalone applications. They are widely used in residential, commercial, and industrial settings for their sustainability, low operating costs, and contribution to energy independence and environmental conservation. PV technology exemplifies the practical application of renewable energy, offering a clean, reliable, and scalable solution to meet global energy demands while reducing carbon footprints.

II. Modeling the Photovoltaic Conversion Chain

The photovoltaic (PV) cell, commonly known as a solar cell, serves as the fundamental component in the process of photovoltaic conversion. Functioning as a semiconductor device, it transforms electrical energy into light energy utilizing the Sun's inexhaustible source of energy. Leveraging the properties of semiconductor materials widely used in the electronics industry, such as diodes, transistors, and integrated circuits, the PV cell operates within a p-n junction configuration.

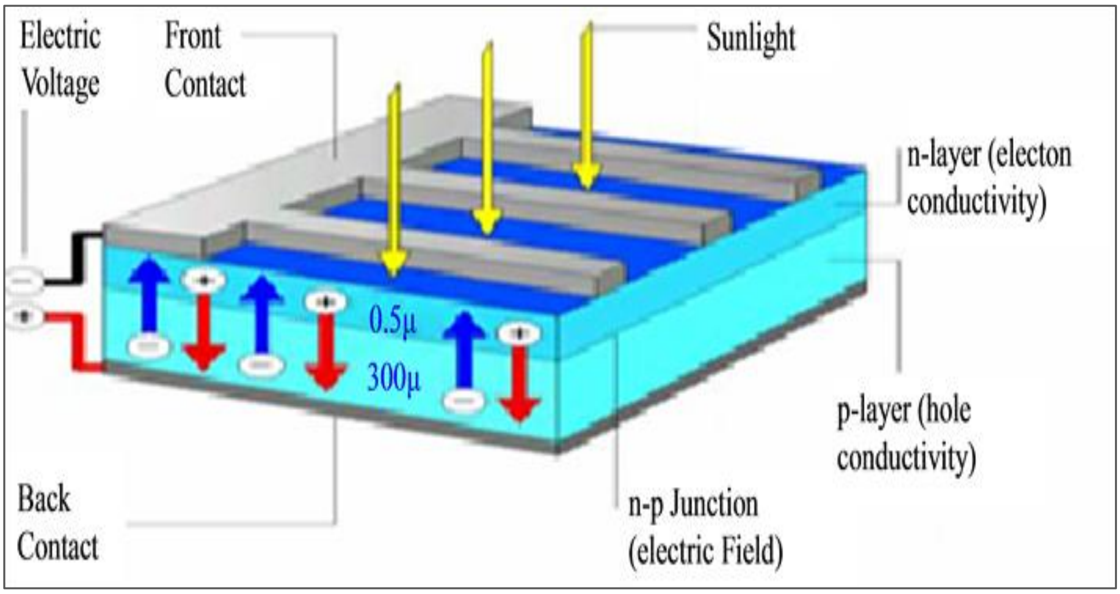


Figure 2.2 : Structure and solarprocess of solarcell.

Typically, a PV cell consists of layers composed of doped p (positive) and n (negative) semiconductor materials, forming the p-n junction. This structure creates a permanent electric field within the material, akin to a magnet with a consistent magnetic field. When a photon of light is absorbed by the semiconductor material, it imparts its energy to an electron, freeing it from its valence band and enabling it to move under the influence of the electric field. This movement results in the migration of electrons towards the top surface and the creation of holes that migrate in the opposite direction. **[13]**

Electrodes placed on the upper and lower surfaces of the cell facilitate the collection of electrons, enabling them to perform electrical work as they recombine with the holes at the front surface. The PV cell's equivalent circuit, comprises a current source, a diode, a series resistance, and a shunt resistance, representing its electrical characteristics.

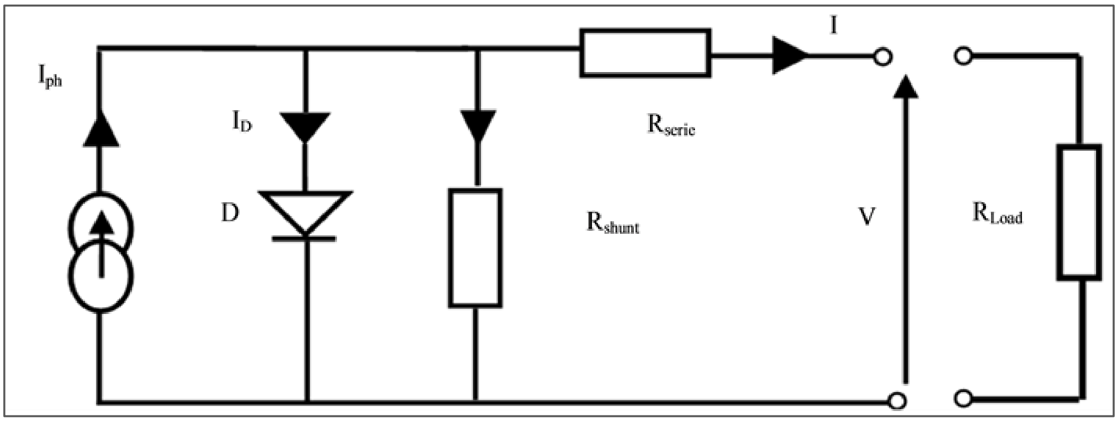


Figure 2.3 : Equivalent electricaldiagram of a photovoltaiccell.

Industrially, PV cells based on monocrystalline silicon achieve energy efficiency of 13% to 14%, while those based on polycrystalline silicon attain 11% to 12%, and amorphous silicon by thin films achieve 7% to 8%. This efficiency is a testament to the advancements in PV technology and its potential to harness solar energy effectively.

In summary, the PV cell's operation is governed by the photovoltaic effect, wherein incident photons interact with electrons in the semiconductor material, generating a flow of electricity. The electrical equivalent diagram serves as a valuable tool for modeling PV cells and understanding their behavior in photovoltaic systems.**[14]**

III. Photovoltaic Cells

A single photovoltaic (PV) cell comprises a thin semiconductor wafer typically crafted from highly purified silicon, although PV cells can be fashioned from various semiconductor materials. The most prevalent material used in PV cell production is crystalline silicon. The wafer consists of two layers, each doped with different materials—boron on one side and phosphorous on the other. This doping process creates an excess of electrons on one side and a deficit on the other.

When sunlight strikes the wafer, photons dislodge some of the surplus electrons, creating a voltage difference between the two layers as the excess electrons attempt to migrate towards the deficient side. In silicon, this voltage typically amounts to 5 volts. Metallic contacts are affixed to both sides of the semiconductor, allowing electrons to flow through an external circuit, effectively completing the electrical pathway.

It's important to note that a PV cell doesn't possess storage capacity; instead, it functions as an electron pump, facilitating the movement of electrons through the circuit. The amount of current generated depends on the number of electrons dislodged by solar photons. Larger cells, more efficient cells, or cells exposed to intense sunlight will produce a greater number of electrons, resulting in higher current output.

Photovoltaic cells, also known as solar cells, come in various types, each with its own characteristics and applications. Here are some of the most common types:

III.1. Monocrystalline Silicon Cells

These cells are made from single-crystal silicon, offering high efficiency and longevity. They are easily recognizable by their uniform dark color and rounded edges.

Monocrystalline cells are commonly used in rooftop installations and solar farms where space is limited. **[15]**

Figure 2.4 : Monocrystallinesiliconcell.

III.2. Polycrystalline Silicon Cells

Polycrystalline cells are composed of multiple silicon crystals, resulting in a less uniform appearance compared to monocrystalline cells. While they typically have lower efficiency than monocrystalline cells, they are more cost-effective to produce, making them a popular choice for large-scale solar projects.

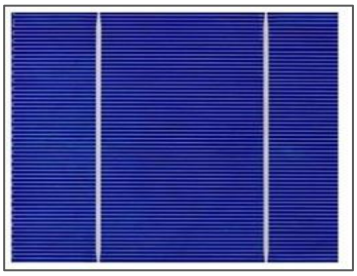


Figure 2.5 : Polycrystallinecells.

III.3. Amorphous silicon

Amorphous silicon (a-Si) is the non-crystalline form of silicon used for solar cells and thinfilm transistors in LCDs. Used as semiconductor material for a-Si solar cells, or thin-filmsilicon solar cells, it is deposited in thin films onto a variety of flexible substrates, such as glass, metal and plastic. They are considered one of the most environmentally friendly photovoltaic technologies, since they do not use any toxic heavy metals such as cadmium or

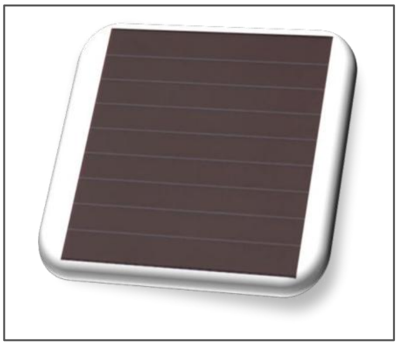


Figure 2.6 : Amorphoussiliconcell.

Each type of photovoltaic cell has its own advantages and limitations, making them suitable for different applications depending on factors such as cost, efficiency, and durability. Ongoing research and development efforts aim to further improve the performance and affordability of solar cells to drive the widespread adoption of solar energy. **[16]**

IV. Photovoltaic water-pumping technology

Photovoltaic water-pumping technology utilizes two distinct techniques for water pumping.

IV.1.Real-time Solar-Powered Pumping

In this technique, solar energy is utilized immediately for water pumping, often referred to as "pumping over the sun." This approach necessitates the presence of a water reservoir to store the pumped water for subsequent use, such as during the evening or periods of low sunlight. **[17]**

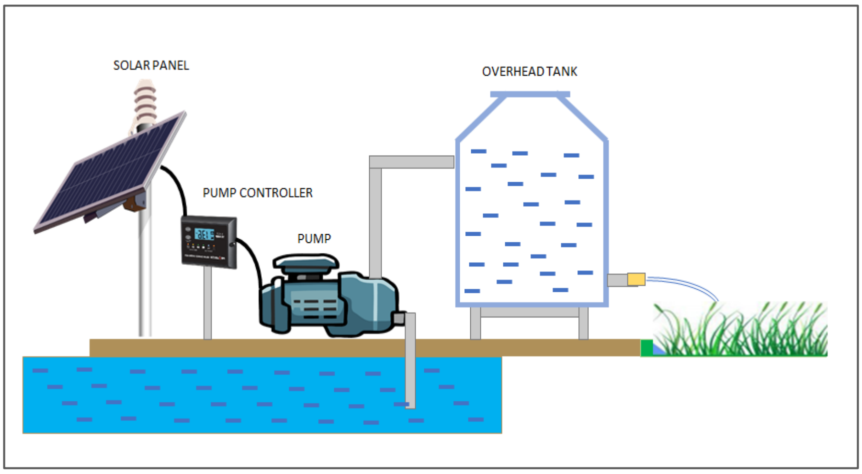


Figure 2.7 : Pumping over the sun illustration.

IV.2.Battery Energy Storage

Alternatively, energy storage via batteries can be employed. During daylight hours, solar energy is stored in batteries, allowing for the pumping of water at a later time when sunlight is unavailable or insufficient. This method provides greater flexibility in water pumping operations, independent of solar irradiance levels. **[18]**

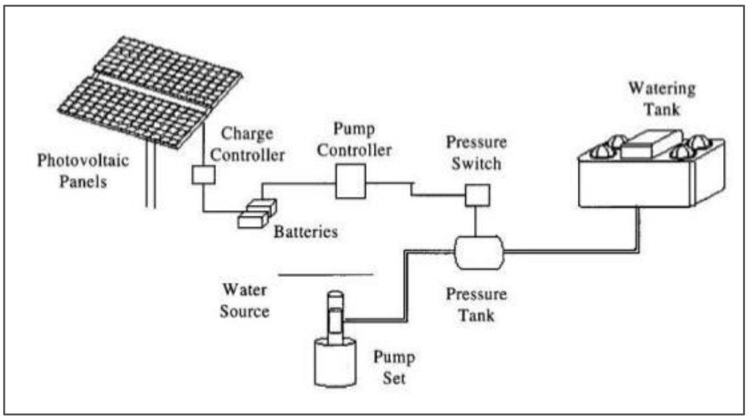


Figure 2.8 : Pumping via energystored in batteries illustration.

V. Sizing and dimensioning of a photovoltaic pumping system

The different steps for sizing a pumping system are :

1. Calculation of Water supply needed.

2. Calculation of the hydraulic energy needed.

3. Determination of available solar energy.

4. Size of photovoltaic generator.

5. Sizing of the pump.

V.1. Calculation of Water Supply Needed

Calculating the water needs of a specific population hinges on factors such as lifestyle, environment, and regional climate conditions. Similarly, irrigation water requirements are influenced by crop type, meteorological variables like temperature, humidity, wind speed, soil characteristics, and irrigation methods. Nonetheless, it's crucial to draw upon local practices and experiences. In tropical regions, water requirements can be approximated using the values provided in the table below.

Table2.1 Calculation of Water Supply Needed.

Humans
Per person 5 to 10 liters/day minimum Normal living conditions 30 liters/day
Animals
Sheep and goats 5 liters/day
Horse 40 liters/day
Donkey 20 liters/day
Camel 20 liters/day
Irrigation
Market farming 60m^3/hectare/day
Rice 100 m^3/hectare/day
Sugar cane 65 m^3/hectare/day
Cotton 55 m^3/hectare/day

The water requirements for crops are influenced by factors including crop type, local weather conditions (such as temperature, humidity, and wind speed), soil characteristics (like texture and moisture-holding capacity), and the irrigation methods employed (such as drip irrigation, sprinkler systems, or flood irrigation). Each of these variables impacts how much water is needed to ensure optimal crop growth and yield. It's essential to integrate local knowledge and practices when estimating water requirements. Local experiences provide valuable insights into how environmental factors interact with agricultural practices, influencing water needs. In tropical regions, for instance, where conditions may be characterized by high temperatures and significant rainfall variability, specific values from local data or regional tables are utilized to approximate irrigation water requirements accurately. By combining scientific data with local knowledge and experiences, stakeholders can develop robust strategies for managing water resources effectively. This approach ensures that water allocation meets the demands of both human populations and agricultural activities while considering sustainability and environmental stewardship in diverse climatic and geographical contexts.**[19]**

V.2. Calculation of the Hydraulic Energy Needed

After establishing the required water volume for each month and understanding the well's characteristics, we can compute the average daily and monthly hydraulic energy needed using the following relationship:

$$E_h = C_h . Q_a . THD$$

$$C_h = g . p_a / 3600$$

Where :

g : is acceleration of gravity [9.81 m.s^{-2}] ;

E_h : is the needed hydraulic energy [kwh/day] ;

THD : is the total dynamic head [m] ;

The tank capacity is detemined by the daily water needs and autonomy of the systemm.

[20]

V.3. Calculation of the Daily Electrical Energy Required

The energy needed to lift a certain amount of water over a certain height given for one day is calculated using the following equation:

$E_e = E_h / (n_{MP} . n_{ond})$

Where :

E_e :electrical energy [kwh/day] ;

n_{MP} : the effeciency of the pump

n_{ond} : : the effeciency of the inverter.

V.4. Size of photovoltaic generator

By the graphical method it is possible to size a photovoltaic pumping installation to satisfy the water needs of a well-defined consumption. **[21]**

These are graphical representations designed for easy numerical interpretation. They streamline the process of obtaining test system calculations results by offering visual clarity. Manufacturers develop these diagrams using calculated or measured data, providing potential pump configurations. For instance, next figure displays the performance characteristics of the SP14A-3 electric pump manufactured by GRANDFOS**. [22]**

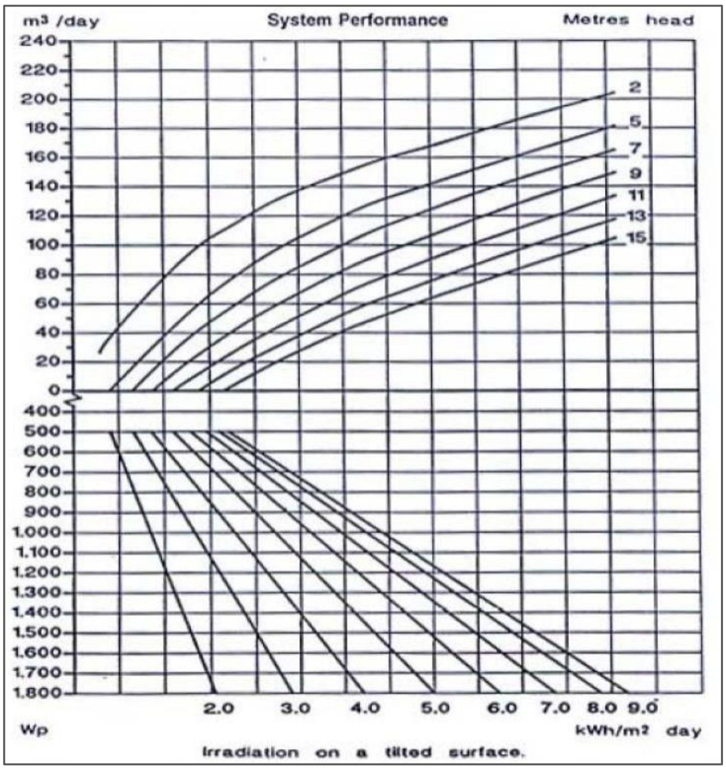


Figure 2.9 : Typical Curve of the Performance of a Pump under Conditions of Use.

V.5.Sizing of the Pump

The choice of pump is based on two factors:

Total Dynamic Head **TDH**

The hourly flow rate **Qh**

$$Q_h = \frac{Q[m^3/day]}{h}$$

h: is the maximum number of hours of sunshine at [1000 w/m2].

VI. Dimensioning and Sizing of Solar Pumping Stations

To define the power of used for the operation of the pump provided by the solar panels, the minimum data are:

-The geographical location to determine global solar irradiation.

-The flow rate to determine daily water requirements during the period of need.

-The total dynamic head to measure the static level, the height of the tank and the pressure drops due to the piping.

We proceed as follows:

1- Define the total monthly and daily irradiation in [wh/m2 /day] in relation to the latitude of the work area.

2- Select a pump based on flow rate and total dynamic head values.

3- Select the inverter suitable for the pump (voltage and power).

4- Determine the peak power necessary to operate the pump by the analytical or graphical method.

5- Choose the type of solar panel (defined by their nominal power).

6- Determine the number of PV panels.

7- Check the nominal voltage for the inverter to operate (according to the panels).

8- Determine the number of serial / parallel panels (the connection form). **[23]**

Conclusion

In this study, our primary focus was on determining the optimal size for a photovoltaic pumping system. We thoroughly examined the various components that make up this photovoltaic setup, exploring two distinct pumping techniques: direct solar-powered pumping and battery-assisted pumping. Throughout our analysis, we emphasized the benefits of direct solar-powered pumping over the alternative method.

Direct solar-powered pumping harnesses solar energy directly from sunlight to drive the pumping process, eliminating the need for additional energy storage devices such as batteries. This approach offers several advantages, including lower operating costs, reduced maintenance requirements, and increased reliability due to fewer components involved. Additionally, direct solar-powered pumping systems are environmentally friendly, as they produce no emissions during operation and rely solely on renewable energy sources.

By contrast, battery-assisted pumping systems incorporate energy storage solutions to provide a reliable water supply even during periods of low sunlight or at night. While these systems offer greater flexibility and reliability in certain scenarios, they typically incur higher upfront costs and require ongoing maintenance of the battery storage units.

Overall, our study highlights the efficiency and sustainability of direct solar-powered pumping as a viable solution for water pumping applications in various contexts. By leveraging the abundant and renewable energy resource provided by sunlight, direct solar-powered pumping systems offer a cost-effective and environmentally friendly approach to meeting water supply need. **[24]**

Chapetr III Conception and realization of pumping station

I. Introduction

In a photovoltaic pump station, energy is generated from sunlight using solar panels. These panels, strategically placed to capture sunlight, contain photovoltaic cells that convert sunlight into electricity. This electricity is then transformed from direct current (DC) to alternating current (AC) using an inverter, making it compatible with the operation of water pumps.

With this setup, farmers can irrigate their fields using solar power in a straightforward manner. The solar panels absorb sunlight throughout the day, continuously generating electricity. This electricity powers the water pump, which draws water from a source such as a well, river, or storage tank.

The pump then distributes the water to the fields through a network of pipes or drip lines, providing moisture to the crops' roots. The operation of the pump can be controlled automatically or manually, depending on the setup. Automatic control systems may adjust the pump's speed or activation based on factors like sunlight intensity, soil moisture levels, or predefined irrigation schedules.

By using solar energy to power the irrigation system, farmers can reduce their reliance on fossil fuels and grid electricity. This not only lowers operational costs but also reduces carbon emissions and environmental impact, contributing to a more sustainable farming practice. In essence, a photovoltaic pump station enables farmers to irrigate their fields efficiently and sustainably, using the power of the sun.

By integrating solar energy into irrigation systems, farmers can decrease dependence on fossil fuels and conventional electricity grids. This shift not only cuts operational expenses but also diminishes carbon footprints and environmental harm, fostering more sustainable agricultural practices. Essentially, photovoltaic pump stations empower farmers to irrigate fields effectively and sustainably, harnessing the sun's energy. This approach supports resilience against energy price fluctuations and enhances agricultural productivity, laying a foundation for long-term environmental stewardship and economic viability.**[25]**

II. System components

II.1. Solar panel

Figure 3.1 : TPS105-90W

The Monocrystalline Module TPS105-90W solar panel is a powerful and reliable device designed to capture sunlight and turn it into electricity. It's made with special monocrystalline cells that are really good at converting sunlight into power. These cells are tough and can handle different kinds of weather like rain and snow.

This solar panel is not only strong but also very efficient, meaning it can produce a lot of electricity. It's perfect for many different places like homes, businesses, or even on boats and RVs. You can install it on rooftops or on the ground—it's easy to set up wherever you need it.

Using this solar panel helps us use clean energy from the sun instead of relying on fossil fuels, which are harmful to the environment. It's a simple and effective way to power our homes and devices while helping to protect the planet.**[26]**

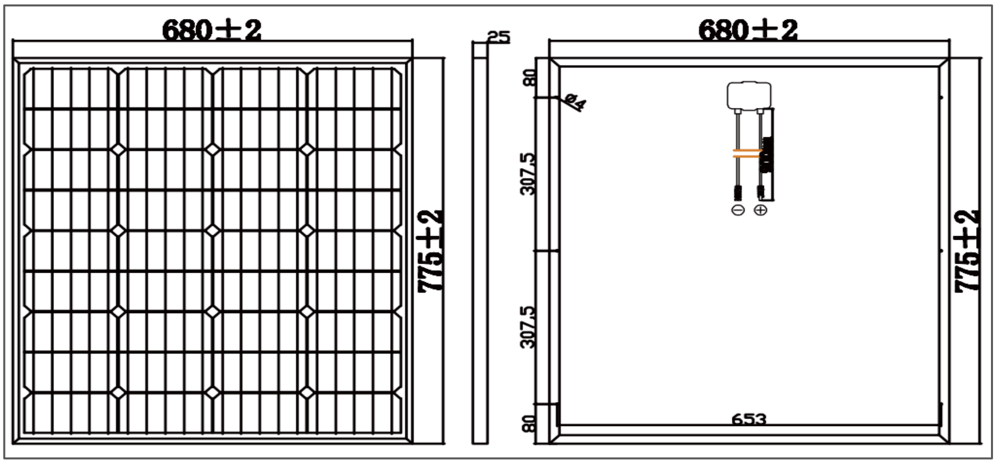


Figure 3.2 : Panel sizings.

For the mechanical specification :

Table 3.1 mechanical specification

MECHANICAL SPECIFICATION

Cell Type	MONO crystalline 158.75*158.75mm
Number of cells	36pcs
Dimensions	680x775x25mm
Front Glass	3.2mm Low iron tempered glass
Frame	Anodized aluminum alloy
Connector	MC4 PLUG
Output Cables	Length 0.9m

And for the performance at standar test condition and the absolute max limits :

Table 3.2 performance at standar test

PERFORMANCE AT STANDARD TEST CONDITION (STC:1000W/m²,25°C,AM1.5)

Module Series	TPS105S-90W-MONO
Maximum Power at STC(Pmax)	90W (+/-5%)
Short Circuit Current(Isc)	5.10A
Open Circuit Voltage(Voc)	22.68V
Maximum Power Current(Imp)	4.72A
Maximum Power Voltage(Vmp)	19.08V

Table 3.3 absolute max limits

ABSOLUTE MAXIMUM LIMITS

Parameters	Unit	Rating
Operation temperature	°C	-40 to +85
Strorage temperature	°C	-40 to +85

II.2. Arduino mega

➢ **Overview**:

The Arduino Mega is a versatile microcontroller board designed for a wide range of electronics projects. It features an expanded number of digital and analog pins, providing ample connectivity options for sensors, actuators, and other components. With its powerful microprocessor and extensive feature set, the Arduino Mega is suitable for both beginners and advanced users alike.

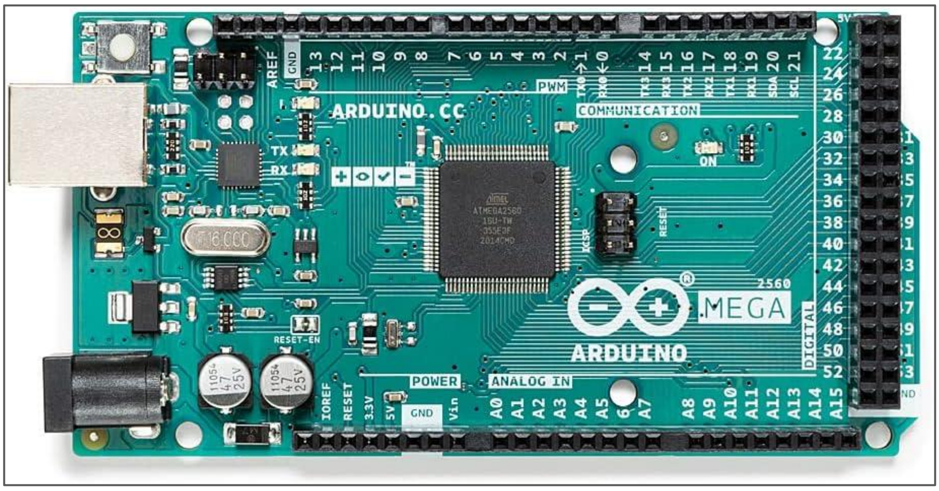


Figure 3.3 : Arduino-Mega.

➢ **Key Specifications**

- Microcontroller: ATmega2560
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limit): 6-20V
- Digital I/O Pins: 54 (of which 15 provide PWM output)
- Analog Input Pins: 16
- DC Current per I/O Pin: 40mA

- DC Current for 3.3V Pin: 50mA
- Flash Memory: 256 KB (8 KB used for bootloader)
- SRAM: 8 KB
- EEPROM: 4 KB
- Clock Speed: 16 MHz
- Dimensions : 101.52mm x 53.3mm

❖ **Features**

- Wide operating voltage range allows flexibility in power supply options.
- Large number of digital and analog pins for versatile connectivity.
- Built-in voltage regulator ensures stable operation within recommended voltage range.
- Compatible with a wide range of sensors, shields, and expansion modules.
- Can be programmed using the Arduino IDE, making it accessible to beginners.

❖ **Applications**

- Robotics and automation projects
- Sensor monitoring and data logging systems
- Home automation and IoT applications
- Educational projects for teaching programming and electronics

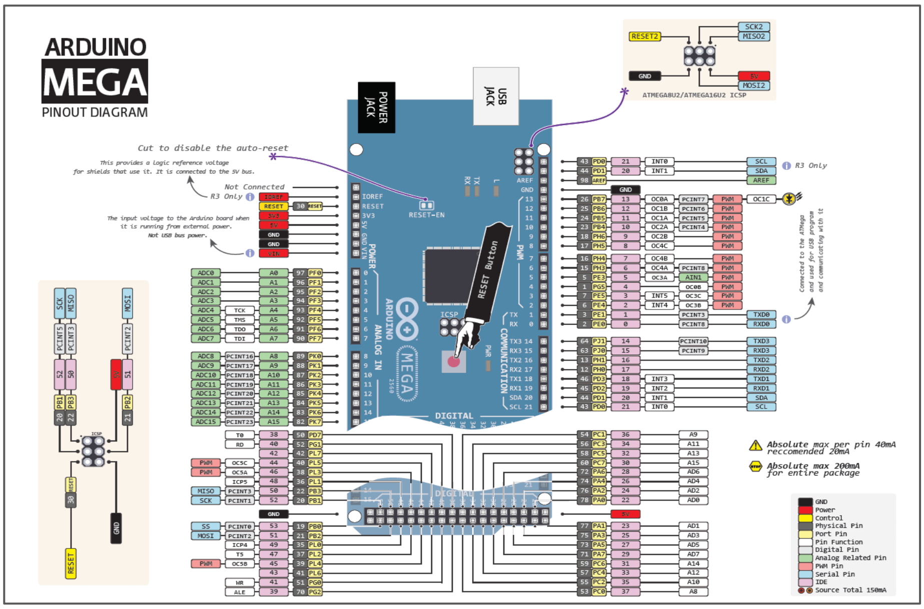


Figure 3.4 : Arduino connections diagram.

The Arduino Mega offers unparalleled versatility and performance, making it an ideal choice for a wide range of electronics projects. Whether you're a hobbyist, student, or professional, the Arduino Mega provides the tools you need to bring your ideas to life.

II.3. Relay

❖ **Overview:**

A relay is an electromechanical switch used to control high-power circuits with low-power signals. It serves as a crucial component in various electronic systems, providing isolation and protection while enabling remote control of devices.

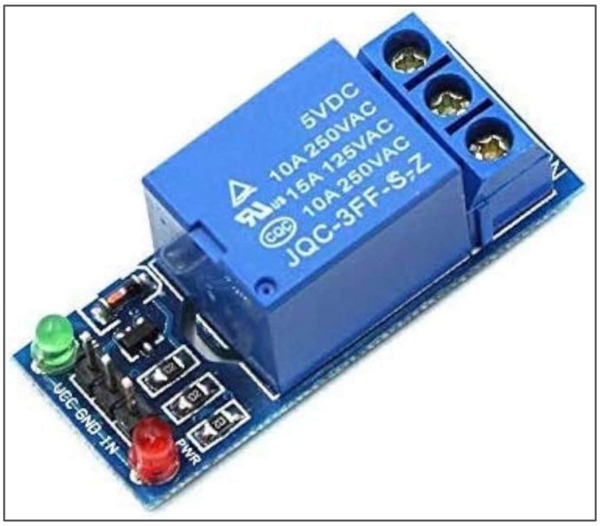


Figure 3.5 : Relay 5v

❖ **Key Specifications**

- Input Voltage: 5V DC
- Contact Configuration: Single Pole Single Throw (SPST), Single Pole Double Throw (SPDT), Double Pole Double Throw (DPDT)
- Contact Rating: Typically ranges from a few milliamps to several amps, depending on the relay model
- Coil Resistance: Varies depending on the relay model and configuration
- Coil Power Consumption: Calculated by multiplying the coil voltage by the coil current

❖ **Features**

- Provides isolation between the control circuit and the load circuit, protecting sensitive components from high voltages or currents.

- Offers various contact configurations to accommodate different switching requirements, such as normally open (NO), normally closed (NC), and common (COM) terminals.
- Can be controlled by low-power signals, such as those from microcontrollers, sensors, or switches.
- Suitable for a wide range of applications, including home automation, automotive electronics, industrial control systems, and more.
- Available in different form factors, including PCB-mounted relays, plug-in relays, and solid-state relays, to meet specific installation requirements.
- Offers reliable switching performance and long-term durability, ensuring stable operation in demanding environments.

❖ **Applications**

- Control of lighting systems, fans, and motors in home automation projects
- Remote operation of appliances and devices in automotive applications
- Implementation of safety interlocks and emergency stop circuits in industrial machinery
- Integration into alarm systems and security systems for monitoring and control purposes
- Use in relay modules and breakout boards for prototyping and development purposes

The relay's versatility, reliability, and ease of use make it an indispensable component in electronic circuits requiring switching of high-power loads. Whether in DIY projects or commercial applications, the relay provides a simple and effective solution for controlling electrical devices with low-power signals.

II.4.Vela YTX7A-BS Battery

❖ **Overview**

The VELA PUISSANCE Moto Humide Rechargeable Battery YTX7A-BS is a versatile and reliable power source designed for motorcycles and various small engine vehicles. With its maintenance-free design and sealed construction, it offers hassle-free operation and long service life. This battery provides high starting power, making it suitable for cold weather conditions and demanding applications. Its compatibility extends to motorcycles, scooters, ATVs, and other recreational vehicles, ensuring dependable performance across a range of activities. Built-in safety features protect against overcharging and short circuits, while its environmentally friendly design adheres to sustainability standards. Whether on the road, off-road, or on the water, the VELA PUISSANCE YTX7A-BS battery delivers the energy needed to power your adventures with confidence and reliability..

Figure 3.6 : Vela YTX7A-BS Battery.

❖ **Key Specifications:**

Key specifications for the VELA PUISSANCE Moto Humide Rechargeable Battery YTX7A-BS:

- **Model**: YTX7A-BS
- **Chemistry**: Lead-acid (wet cell or flooded)
- **Voltage:** 12 volts (nominal)
- **Capacity**: Typically between 6 to 8 ampere-hours (Ah)
- **Dimensions**: Vary based on manufacturer, typically standardized to fit specific motorcycle models
- **Terminals**: Standardized terminals for easy connection to the motorcycle's electrical system
- **Maintenance**: Maintenance-free design, sealed construction
- **Performance:** Cold-cranking amps (CCA), reserve capacity (RC), and cycle life may vary depending on manufacturer and specific battery model

❖ **Applications**

The VELA PUISSANCE Moto Humide Rechargeable Battery YTX7A-BS is suitable for various applications where reliable starting power and stable electrical supply are essential. Some common applications include :

- **Motorcycles:** Ideal for powering the electrical systems of motorcycles of various makes and models, providing the necessary energy to start the engine and operate lights, ignition, and other accessories.
- **Scooters:** Compatible with scooters and mopeds, offering dependable performance for starting the engine and powering onboard electronics.
- **ATVs (All-Terrain Vehicles):** Suitable for use in ATVs for recreational or utility purposes, delivering the power needed to start the engine and operate headlights, winches, and other accessories.
- **Dirt Bikes**: Designed to meet the demands of off-road riding, providing reliable starting power for dirt bikes and ensuring consistent performance in rugged terrain.
- **Utility Vehicles:** Used in various utility vehicles such as golf carts, garden tractors, and small utility trucks, providing reliable electrical power for starting and operating essential functions.
- **Personal Watercraft:** Compatible with some personal watercraft models, powering the electrical systems and engine start-up in jet skis and other recreational watercraft.
- **Power Sports Equipment:** Used in a variety of power sports equipment such as go-karts, mini bikes, and off-road vehicles, providing the energy required for engine start-up and operation.

II.5. Pump

❖ **Overview**

The windshield washer pump, or "pompe lave glace," delivers cleaning fluid onto surfaces. It's powered by electricity and pressurizes the fluid, spraying it through a nozzle. It's used in automotive vehicles, industrial equipment, agricultural machinery, boats, and household appliances for cleaning tasks. In industries, it's part of cleaning systems for machinery, while in agriculture, it keeps windows and mirrors clean for clear visibility. In marine environments, it cleans surfaces exposed to seawater, and in households, it's repurposed for outdoor cleaning tasks. Overall, it's a versatile tool for applying cleaning fluid in various settings, enhancing visibility, cleanliness, and maintenance.

Figure 3.7 : Washer pump.

❖ **Key Specifications**

Key specifications for a windshield washer pump, typically include:

- Power Source: Electrically powered.
- Fluid Delivery Method: Sprays fluid onto surfaces.
- Pressure: Pressurizes the fluid for efficient spraying.
- Nozzle Type: Directs the fluid onto the surface being cleaned.
- Application: Used in automotive vehicles, industrial equipment, agricultural machinery, boats, and household appliances.
- Versatility: Can be adapted for various cleaning tasks in different environments.
- Compatibility: Designed to fit different systems and machinery for cleaning purposes.
- Durability: Constructed to withstand the rigors of different applications and environments.
- Maintenance: May require occasional cleaning and inspection for optimal performance.
- Safety Features: Built-in safeguards to prevent malfunction and ensure safe operation.

❖ **Applications**

Applications of a windshield washer pump include:

- Automotive Vehicles: Used in cars, trucks, buses, and other vehicles to clean windshields and headlights for improved visibility.
- Industrial Equipment: Integrated into cleaning systems for machinery and equipment in manufacturing plants, factories, and industrial facilities.
- Agricultural Machinery: Installed on tractors, combine harvesters, and other agricultural equipment to keep windows and mirrors clean during farming operations.

- Marine Vehicles: Employed on boats, ships, and other marine vessels to clean windows, windshields, and other surfaces exposed to seawater and debris.
- Household Appliances: Repurposed for tasks such as cleaning outdoor furniture, decks, and windows in residential settings.
- Recreational Vehicles: Used in RVs, campers, and trailers to clean windows and exterior surfaces for improved visibility and aesthetics.
- Commercial Vehicles: Installed on delivery trucks, vans, and other commercial vehicles to maintain clear visibility while driving.
- Construction Equipment: Utilized on construction vehicles and machinery to clean windows and mirrors for safety and visibility on job sites.
- Aviation: Adapted for use in aircraft to clean cockpit windows and exterior surfaces for enhanced visibility during flight.
- Public Transportation: Installed on buses, trains, and other public transportation vehicles to ensure clear visibility for drivers and passengers.

These applications demonstrate the versatility and importance of the windshield washer pump across various industries and sectors, contributing to safety, efficiency, and cleanliness in different environments.

II.6. BRUDUS 60A MPPT Solar Charge Controller

The BRUDUS 60A MPPT Solar Charge Controller is a key component in solar power systems, particularly those with larger capacities or demanding energy requirements. An overview of its features and functions:

- ❖ **MPPT Technology**: This controller utilizes MPPT (Maximum Power Point Tracking) technology, which is highly efficient in extracting maximum power from solar panels by continuously adjusting the operating point of the panels.
- ❖ **High Charging Capacity:** With a maximum charging current of 60A, this controller is suitable for handling larger solar arrays and battery banks, making it ideal for medium to large-scale solar installations.
- ❖ **Dual Voltage Compatibility:** It typically supports both 12V and 24V battery systems, providing flexibility in system design and compatibility with various battery configurations.

- **LCD Display**: Many models come equipped with an LCD display that provides real-time monitoring of key system parameters such as battery voltage, charging current, solar panel voltage, and charging status.
- **Multiple Protection Mechanisms**: The controller is equipped with comprehensive protection features including overcharge, over-discharge, overload, short-circuit, and reverse polarity protection, ensuring the safety and longevity of your batteries and system components.
- **Temperature Compensation**: Some models incorporate temperature compensation functionality, which adjusts charging parameters based on ambient temperature changes, ensuring optimal charging performance in different environmental conditions.
- **User-Friendly Design**: The controller is designed for ease of use and installation, with intuitive interfaces and terminals for connecting solar panels, batteries, and loads.
- **Durable Construction:** Constructed with high-quality materials and built to withstand harsh environmental conditions, the controller is designed for long-term reliability and durability.

Overall, the BRUDUS 60A MPPT Solar Charge Controller offers advanced features and robust performance, making it a popular choice for medium to large-scale solar power systems where efficient energy management is crucial.

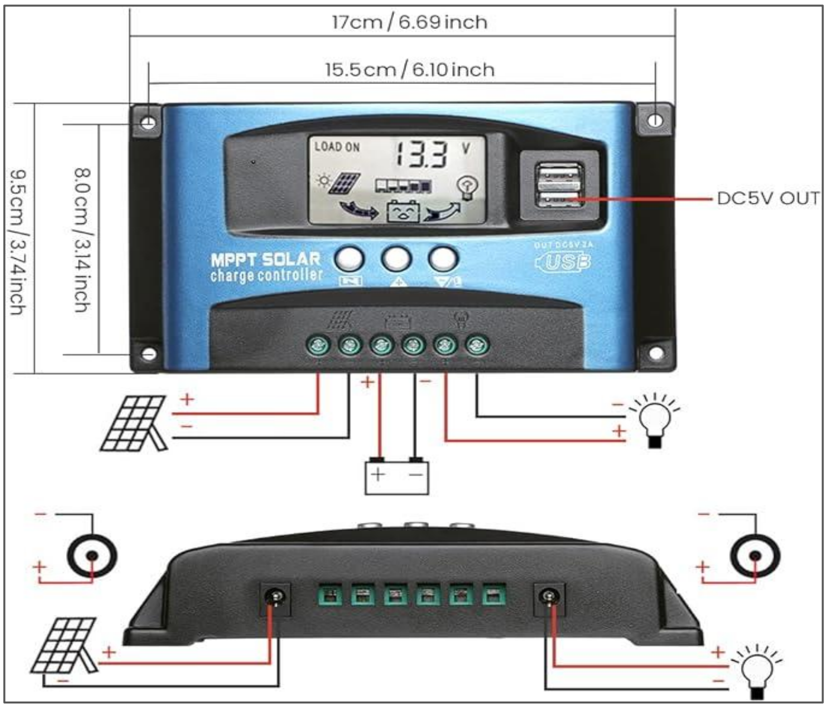


Figure 3.8 : Brududs 60A MPPT Solar Charge Controller.

II.7. Ultrasonic sensor

The ultrasonic sensor typically operates at around 5V, which matches the Arduino Mega's voltage levels. It has a detection range of several meters, providing a digital output signal (HIGH or LOW) to indicate object presence within the range. Some sensors may offer an analog output representing distance. The accuracy is specified in millimeters or centimeters. The operating frequency is typically in the ultrasonic range (above 20 kHz). The sensor emits an ultrasonic beam with a specific angle, influencing the detection area. It operates effectively within a specified temperature range. The sensor connects to the Arduino Mega via digital pins or a dedicated communication protocol like I2C or UART. **[27]**

Figure 3.9 : Ultrasonic sensor.

❖ **HC-SR04 specifications and dimensions**

- Working Voltage: DC 5V
- WorkingCurrent: 15mA
- WorkingFrequency: 40Hz
- Max Range: 4m
- Min Range: 2cm
- Measuring Angle: 15 degree

- Trigger Input Signal: 10µS TTL pulse
- Echo Output Signal Input TTL lever signal and the range in proportion
- Dimensions: 45 * 20 * 15mm

III.Program

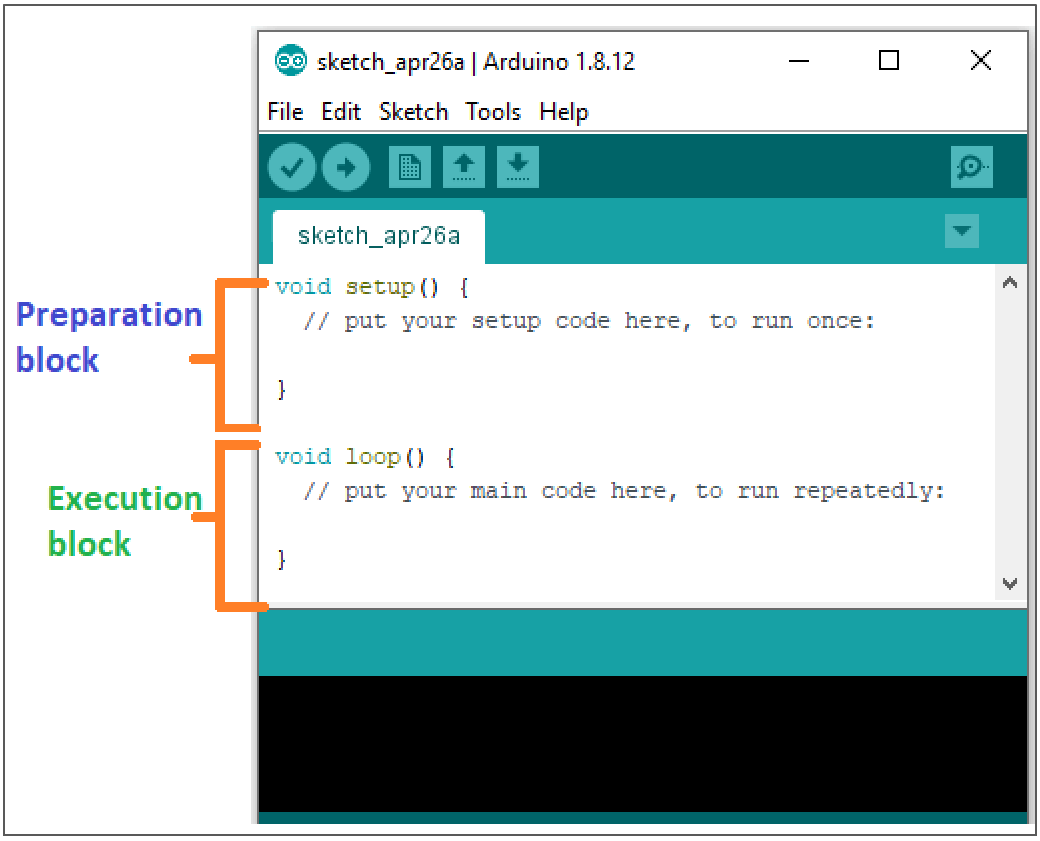


Figure 3.10 : Arduino code explanation.

Arduino code is like a recipe for your electronics project. Writing instructions (code) using simple commands in a language similar to English. These instructions tell the Arduino board what to do, like turning on a light when a button is pressed or reading data from a sensor. Using pins on the Arduino to connect to different parts of projects, like sensors or motors. Also adding pre-made code parts called libraries to make things easier. Once the code is ready, we upload it to the Arduino board, and it follows the instructions to make the project work.

The Arduino code continuously monitors sunlight levels and battery charge. Additionally, it uses an ultrasonic sensor to measure the water level in the well. When there's enough sunlight to power it and the battery has sufficient charge, the pump is activated. If the water level in the well is low, indicating a need for more water in the irrigation tank, the pump increases its pumping rate. The code communicates with the solar panel charge controller to optimize charging settings and manages power usage to conserve energy when sunlight is low. Error handling is included to address any issues, such as sensor failures or communication problems.

❖ **CODE**

```
// Pin Definitions

constinttrigPin = 9;    // Ultrasonic sensor trig pin

constintechoPin = 10;   // Ultrasonic sensor echo pin

constintpumpPin = 7;    // Pump control pin

constintbuttonPin = 2;  // Button pin

// Thresholds

constintliquidThreshold = 3; // Liquid level threshold in centimeters

void setup() {

  // Serial communication initialization

Serial.begin(9600);

  // Pin mode initialization

pinMode(trigPin, OUTPUT);     // Trig pin as output

pinMode(echoPin, INPUT);      // Echo pin as input

pinMode(pumpPin, OUTPUT);     // Pump pin as output

pinMode(buttonPin, INPUT);    // Button pin as input with internal pull-up resistor

}

void loop() {

  // Variables declaration
```

```
long duration, distance;

boolbuttonClosed;

  // Read button state

buttonClosed = digitalRead(buttonPin) == HIGH; // LOW when button is pressed

  // Clear the trigPin

digitalWrite(trigPin, LOW);

delayMicroseconds(2);

  // Send a pulse to trigger the ultrasonic sensor

digitalWrite(trigPin, HIGH);

delayMicroseconds(10);

digitalWrite(trigPin, LOW);

  // Measure the duration of the pulse on the echoPin

duration = pulseIn(echoPin, HIGH);

  // Calculate distance in centimeters

distance = duration * 0.034 / 2;

  // Print distance to serial monitor

Serial.print("Distance: ");

Serial.print(distance);

Serial.println(" cm");

  // If the liquid level is below the threshold and the button is closed, start the pump

if (distance <liquidThreshold&&buttonClosed) {
```

```
Serial.println("Starting pump...");

digitalWrite(pumpPin, HIGH); // Turn on the pump

  } else {

Serial.println("Stopping pump...");

digitalWrite(pumpPin, LOW); // Turn off the pump

  }

  // Delay for stability

delay(1000);

}
```

❖ **Installation**

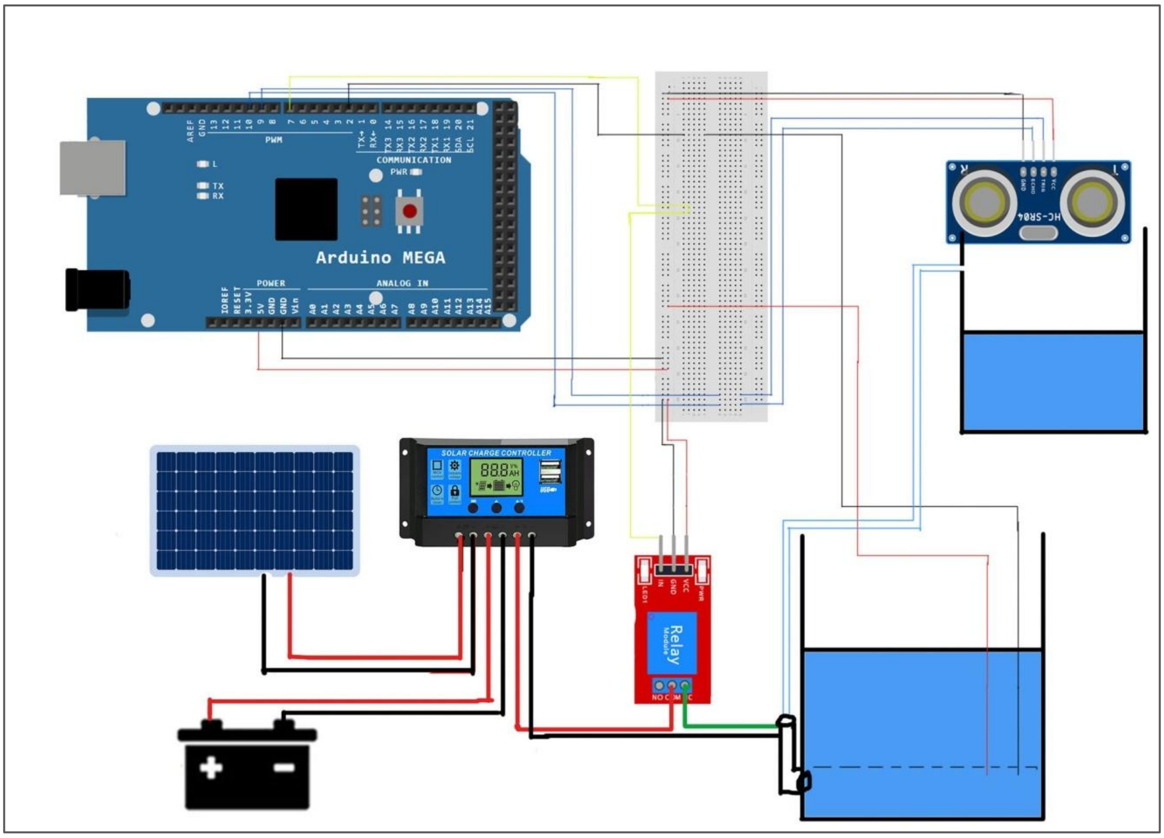
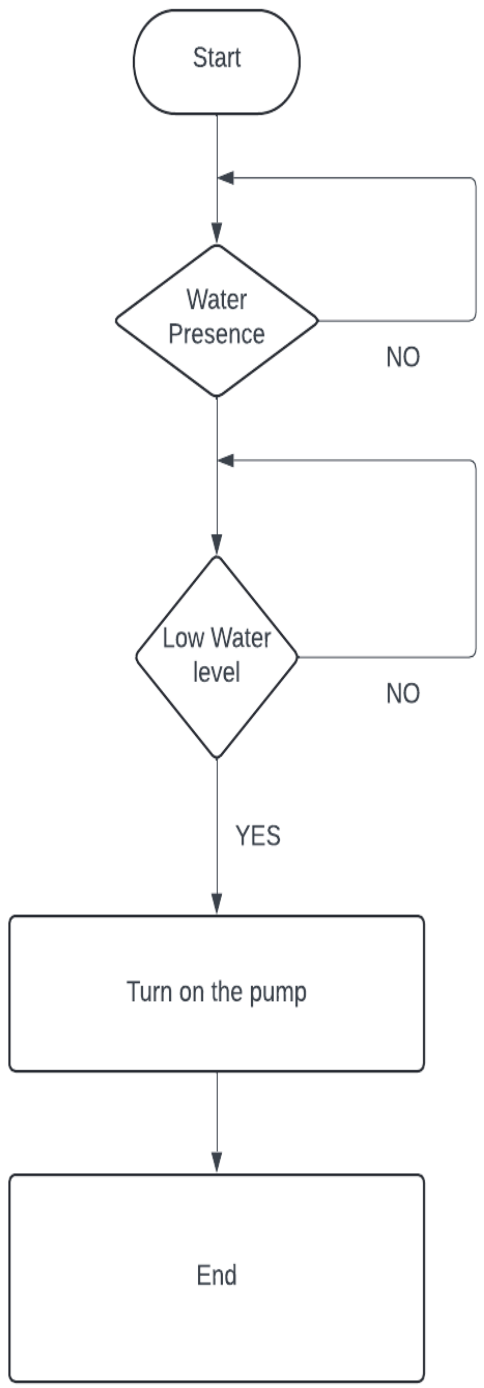


Figure 3.11 : Electrical installation.

IV.Organizational chart



Conclusion

In concluding this chapter, we have not onlydelved into the intricacies of the components comprising our electrical installation but have also shed light on the pivotalroleplayed by Arduino programming in its operation. Throughmeticulouscoding and calibration, we have programmedArduino to orchestrate the seamless interaction betweenvarious components, ensuring optimal functionality and efficiency. Fromsensorreadings to pump control, Arduino serves as the central nervous system, coordinating the intricate dance of signals and actions thatbringourelectrical installation to life. As wenavigate the complexities of implementation, the integration of Arduinoprogramming stands as a testament to the fusion of technology and innovation drivingourprojectforward.

General conclusion

General conclusion

In conclusion, the study and sizing of a photovoltaicpumping station for the irrigation of an isolated agricultural farmrepresent a significantstridetowardssustainablefarming practices in remote areas. Throughmeticulousanalysis and optimization, we'veshowcased the effectiveness of integratingadvanced technologies like the ArduinoMegamicrocontroller and solar panels to meet agricultural water requirementswhilereducingreliance on traditionalenergy sources.

The ArduinoMegamicrocontroller has played a pivotalrole in enhancing control and monitoring capabilitieswithin the photovoltaicpumping station. Itsversatility and processing power enablepreciseregulation of pumpoperations, optimizingenergyutilization and seamlesslyintegratingwith irrigation systems. Coupledwithsolar panels, whichofferabundant and sustainableenergy, this system significantlyreducesdependency on fossil fuels whileminimizingenvironmental impact.

Moreover, the integration of adaptive stages has contributed to maximizingenergy extraction fromsolar radiation, leading to enhanced system performance and operationalefficiencies. Theseadvancements not onlyincrease the reliability and effectiveness of the photovoltaicpumping station but alsoimprove agricultural productivity and resilience in remotefarmingcommunities.

Lookingahead, continuedresearch and investment in solar-powered irrigation technologies are crucial. By harnessingrenewableenergy sources and leveraginginnovative technologies like the ArduinoMegamicrocontroller, wecanfurtheradvancesustainablefarming practices and mitigate the impacts of climate change on global foodsecurity. Through collaborative efforts and ongoing innovation, wecancreate a more resilient and sustainable future for agriculture in remoteregionsworldwide.

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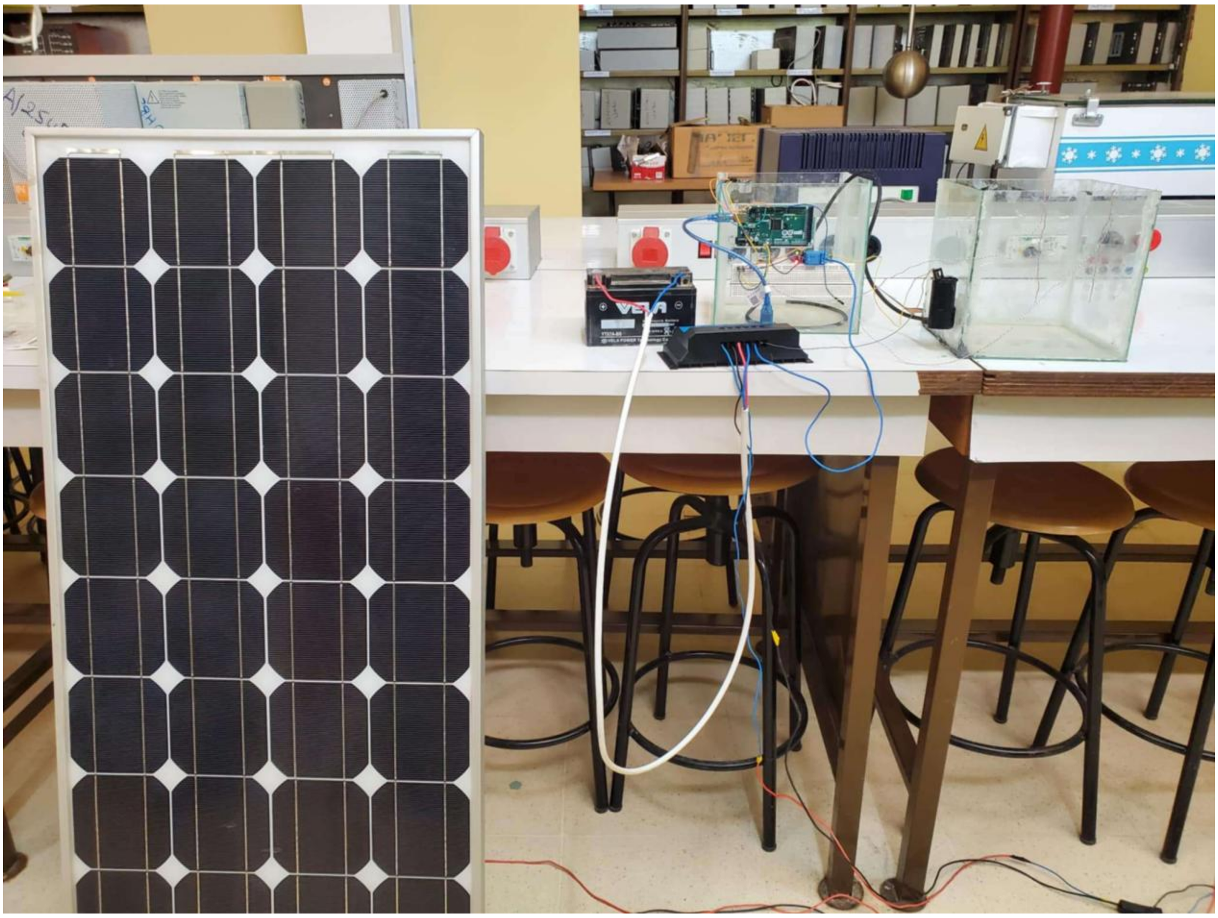
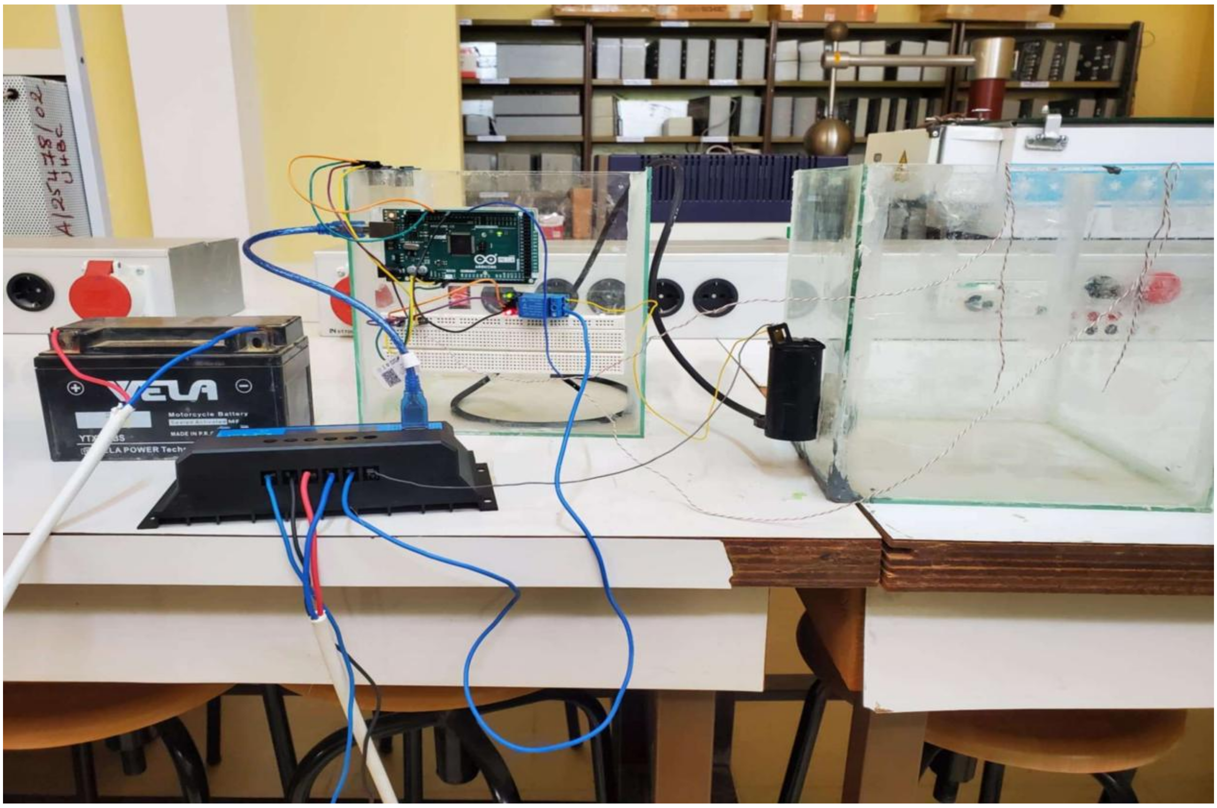
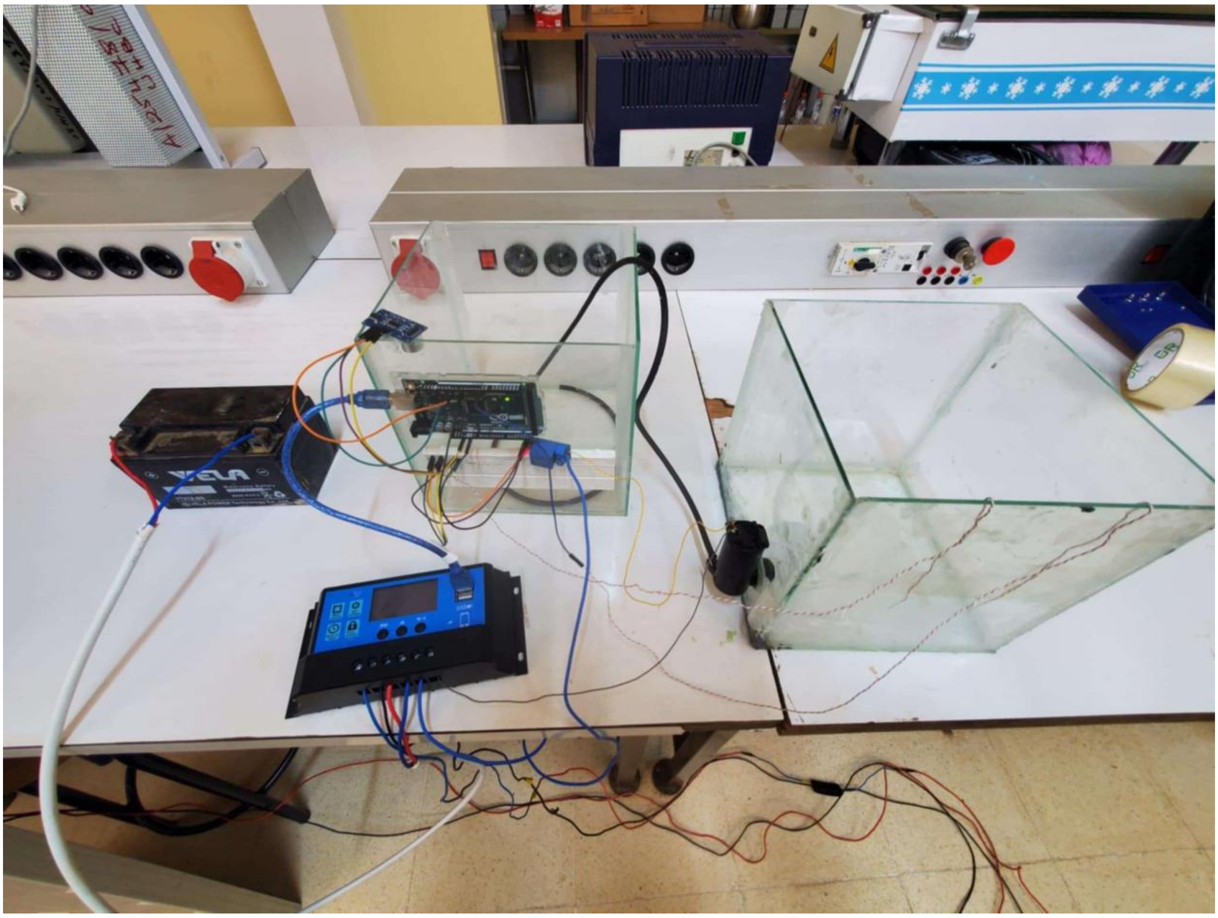



VELA
Motorcycle Battery

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