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Thesis

In pursuit of obtaining the Master's degree

Field: Petrochemical Industries

Specialization: Automation in the petrochemical industry

Hybrid Nitrogen and Oxygen Generator – Solar Powered

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First and foremost, we thank ALLAH for His endless mercy and guidance throughout this work. Without His help, none of this would have been possible.

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Finally, we wish to express our deepest gratitude to everyone who has supported us, whether near or far, through their unwavering kindness, encouragement, and invaluable contributions, your presence and assistance have made a profound impact.

It is with great pleasure that I dedicate this modest work:

- To the dearest person in my life, my mother.
- To the one who made me a man, my father.
- To my brother and my sister.
- To my partner, Badrou.
- To all my friends.
- To all the members of my family.

I dedicate this work to all those who have contributed to my success.

"Laouacheria Nidal"

I dedicate this thesis

- To my dear family, for their love, patience, and constant support throughout my journey.
- To my friends, for their presence, encouragement, and advice.

And to all those who, in one way or another, helped me reach this goal.

"Bouabdellah Badreddine"

الملخص

يُشكّل النيتروجين والأكسجين النسبة الأكبر من مكونات الغلاف الجوي، حيث يمثل النيتروجين حوالي 78% بينما يمثل الأكسجين نسبة تقدر بحوالي 20%. تلعب هذه المواد دورًا حيويًا في العديد من المجالات الصناعية والطبية، خاصة في ظل الأزمات الصحية مثل جائحة كورونا، التي كشفت عن الحاجة الملحة للأكسجين الطبي. ومع ذلك، تعتمد الطرق التقليدية لإنتاج هذه المواد على وحدات ضخمة مركزية، مما يجعلها مكلفة وصعبة التوزيع. لذلك، نقترح حلاً مبتكرًا يتمثل في تصميم مولد صغير الحجم يعمل بالطاقة الشمسية وتتميز هذه المولدات بقدرتها على الإنتاج التلقائي حسب الحاجة بشكل ذكي لتوفير الكمية المطلوبة من الأكسجين أو النيتروجين مما لا يقلل من الهدر فحسب، بل يضمن أيضًا توفير الإمدادات بشكل مستمر وفعّال، مما يسد الفجوة في البنية التحتية الحالية ويوفر توريد سريع وفعّال في حالات الطوارئ.

الكلمات المفتاحية: النيتروجين، الأكسجين، الإنتاج، مولد، الطاقة الشمسية.

Résumé

L'azote et l'oxygène constituent la plus grande proportion de la composition de l’atmosphère, l'azote représentant environ 78 % et l'oxygène environ 20 %. Ces substances jouent un rôle vital dans de nombreux domaines industriels et médicaux, notamment en période de crises sanitaires comme la pandémie de COVID-19, qui a révélé le besoin urgent en oxygène médical. Cependant, les méthodes traditionnelles de production de ces substances reposent sur de grandes unités centralisées, ce qui les rend coûteuses et difficiles à distribuer. C'est pourquoi nous proposons une solution innovante consistant en la conception d'un générateur compact fonctionnant à l'énergie solaire. Ces générateurs se distinguent par leur capacité à produire automatiquement, de manière intelligente la quantité nécessaire d'oxygène ou d'azote selon la demande. Cela permet non seulement de réduire le gaspillage, mais aussi d'assurer un approvisionnement continu et efficace, comblant ainsi les lacunes de l'infrastructure actuelle et fournissant une ressource rapide et efficiente en cas d'urgence.

Mots clés : L’azote, l'oxygène, production, générateur, l'énergie solaire.

Abstract

Nitrogen and oxygen make up the largest proportion of the atmosphere, with nitrogen accounting for about 78% and oxygen accounting for about 20%. These substances play a vital role in many industrial and medical fields, especially during health crises such as the COVID-19 pandemic, which highlighted the urgent need for medical oxygen. However, traditional methods of producing these substances rely on large centralized units, making them costly and difficult to distribute. Therefore, we propose an innovative solution in the form of a generator powered by solar energy. These generators feature smart automatic production capabilities, supplying the required amount of oxygen or nitrogen as needed. This not only reduces waste but also ensures a continuous and efficient supply, Bridging the gap in the current infrastructure and providing a fast and efficient resource in emergency situations.

Keywords: Nitrogen, oxygen, production, generator, solar energy.

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Abbreviation

GEN: generator

TS: TechSki

PSA: Pressure Swing Adsorption

Wt: weight adsorption

VSC: Variable speed compressor

VFD: Variable frequency drive

AC: Alternating current

DC: Direct current

General Introduction

General Introduction

Air is a mixture of gases that surrounds the planet and it is composed of a wide variety of substances, they are:

- 78% nitrogen (N_2);
- 21% oxygen (O_2);
- 0.97% argon (Ar);
- 0.03% carbon dioxide (CO_2);
- rare gases (helium, neon, krypton, radon);
- water vapor;
- hydrogen;
- solid and liquid
- articles in suspension (liquid or solid water, fine dust, salt crystals, pollen);
- methane;

and other atmospheric elements but the main elements are nitrogen (N_2) and oxygen (O_2), Accordingly we conducted research aimed at identifying their potential uses, and found that they offer benefits in various applications.

Subsequently, we needed to determine the technologies specifically designed for extracting these gases Also to select the ones that align with our objectives in terms of environmental impact, cost, and gas purity.

However, Numerous companies offer different processes for generating nitrogen and oxygen, we opted for our approach especially because we want to implement the generator in solar-powered and humid environments, motivated by A few key factors:

- Solar power represents a free source of energy
- Significant advancements are being made in battery development technology currently
- Significant financial assets and strong investment potential present in humid regions of countries like Qatar and Saudi Arabia make them ideal for implementing such technologies

The foundation of our work will be the three-dimensional (3D) modeling a solar-powered hybrid generator capable of producing both nitrogen and oxygen, using the SolidWorks software.

Thus, our study is separated into four chapters:

- Overview of Nitrogen and Oxygen
- Gas Separation Technologies
- Generator Description and Data Sheet
- Innovative Aspects

Chapter I

Overview of Nitrogen and Oxygen

I.1.Introduction

Nitrogen and Oxygen are both crucial for human being life and together make the majority of earth atmosphere, these gases are indispensable offering benefits across healthcare, manufacturing, agriculture, and environmental protection.

I.2. General information about Nitrogen

I.2.1. Definition

Is a chemical element with the symbol N and atomic number 7 hat exists primarily as a diatomic gas (N_2) in Earth's atmosphere, where it constitutes about 78% of the air, it plays a crucial role in many fields and is utilized in both its gaseous (N_2) and liquid (LN_2) forms, depending on the application.

I.2.2. The position of nitrogen in the periodic table

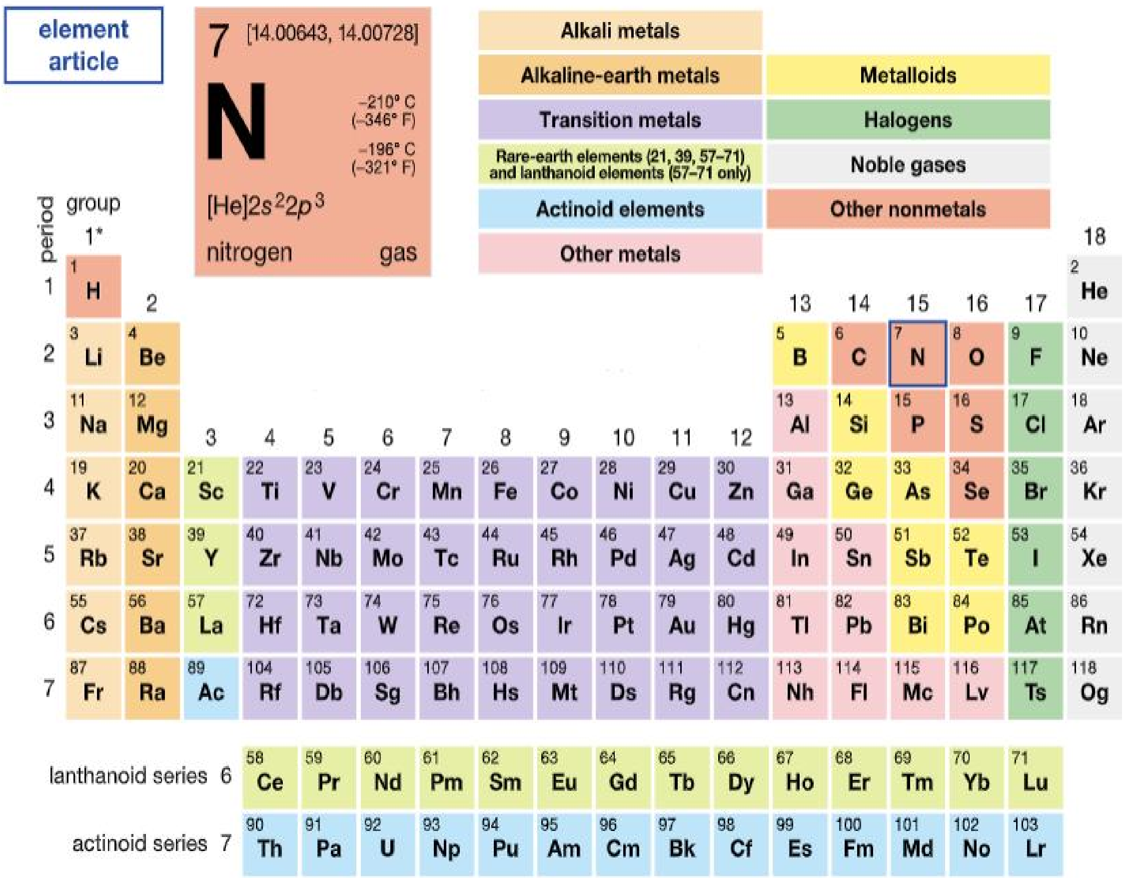


Figure I.1: Nitrogen’s Placement in the periodic table

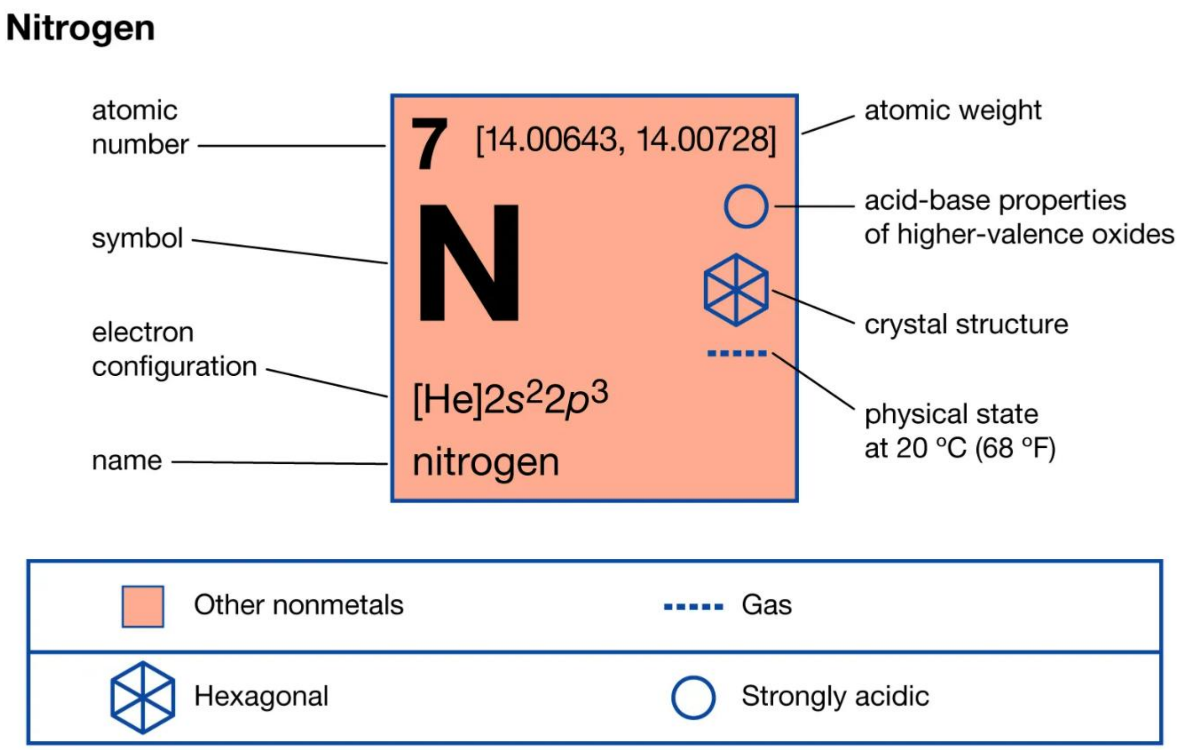


Figure I.3: Figure showing the properties of nitrogen

I.2.3. The applications of nitrogen

Nitrogen is a versatile element with a wide range of applications across various industries due to its inert nature and unique properties.

I.2.3.1. Gaseous Nitrogen (N_2 - Gas Form)

a) Preservation and food industry

When nitrogen is introduced into a package, it drives out oxygen and any moisture present. By modifying the atmosphere inside the package, food packaging with nitrogen preserves quality, slows down spoilage and extends the products' shelf life it also provides a protective cushion around the food, helping prevent damage during transport. [1]

For example,

the continuous flushing of N_2 gas through the head space of bottles that contained pasteurized milks stored at 6 °C or 8 °C, showed high inhibitory effects on total bacterial counts in all experiments. When comparing retail pasteurized milks and milks pasteurized at the pilot plant scale, the treatments were most efficient when N_2 was applied shortly after the pasteurization stage. Moreover, the efficiency of the treatments at the level of pasteurized milk seemed to depend on the initial raw milk quality.

The analyses of the partial sequences of the 16S rRNA and rpoB genes revealed that the Bacillus species is common in milk under N_2 treatment after prolonged cold storage. Irrespective of the conditions, whether C or N, Bacillus weihenstephanensis was present in all samples, indeed, the results obtained here indicate that N_2 gas-based treatment of pasteurized milk constitutes an interesting approach to improve the quality of pasteurized milk and to extend the shelf life of pasteurized milk, although present data suggest that the treatments are temperature- and milk-age- (i.e., “quality of raw milk”) -dependent. To the best of our knowledge, no study thus far has considered the use of N_2 gas to treat pasteurized milks [2].

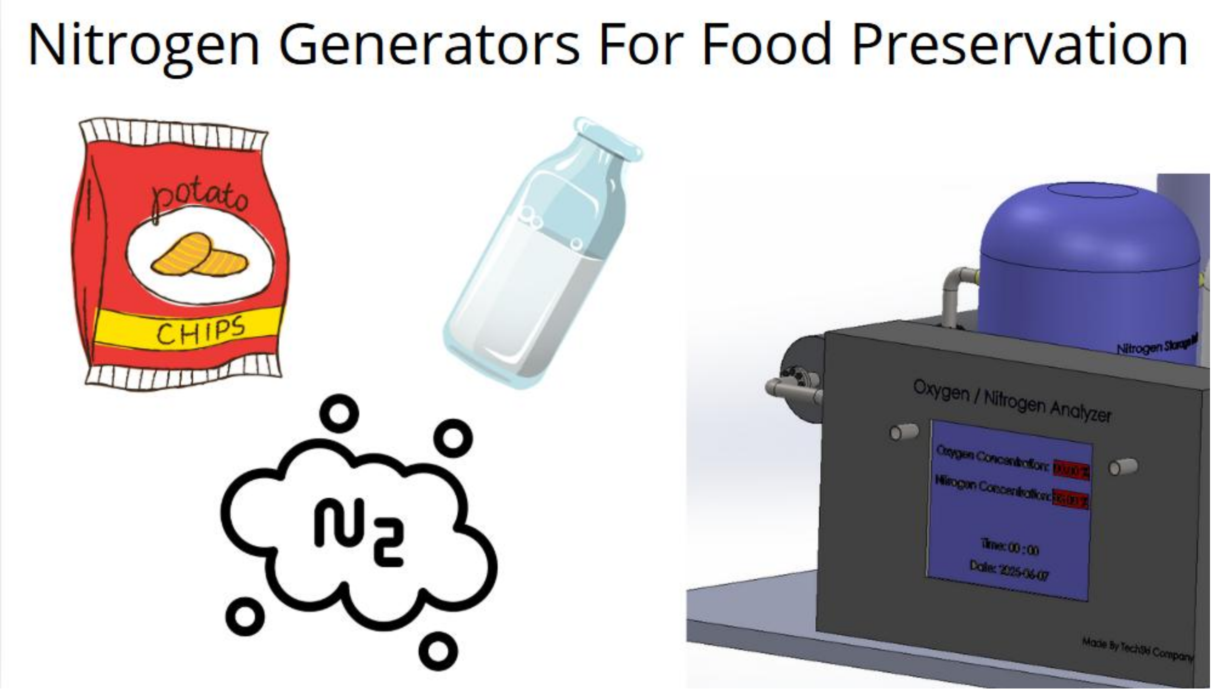


Figure I.4: Marketing Image Showing Nitrogen Generator in Milk and Chips Packaging

However, numerous studies have supported the role of nitrogen gas in food preservation for example experiments conducted by the Royal Society of Chemistry on potato crisps have shown that nitrogen gas flushing improves shelf-life stability by reducing lipid oxidation and preserving flavor.

Moreover, studies published by the National Center for Biotechnology Information (NCBI), USA on fresh-cut vegetables demonstrate that N_2 packaging helps maintain appearance and delays degradation by creating a low-oxygen, high-CO_2 environment.

b) Light Bulb Production:

In incandescent light bulbs, nitrogen gas is often used as a cheaper alternative to argon.

Nitrogen gas is added to the bulb to create an inert environment, which helps prevent the filament from oxidizing and reduces its rate of evaporation, this process significantly prolongs the lifespan of the bulb.

c) Electronics Manufacturing:

Due to its ease of manipulation and its natural properties, Nitrogen is used in the production of semiconductors and circuit boards to create an oxygen-free environment ensuring better solder joints and higher product quality.

d) Tire Inflation:

It is preferable to use the Nitrogen Gas instead of air to inflate car or airplane tires in order to maintain stable tire pressure.as is known Nitrogen is dry and free of moisture and oxygen, which are the main causes of rust and corrosion.

Figure I.5: Picture showing tire inflation using nitrogen

e) Medical and Pharmaceuticals sectors:

Like the same principle applied in food packaging, Nitrogen gas is used also in pharmaceutical packaging to displace oxygen in vials, ampoules, and medicine containers, avoiding unwanted reactions., also in medical instruments it is employed for sterilization to prevent contamination, and as a driving force in surgical tools by providing pneumatic power to operate drills, saws, and other precision equipment.

Additionally, nitrous oxide (N_2O), a nitrogen-based compound is used as an anesthetic in medical procedures.

f) Stainless Steel Fabrication:

By preventing the oxidation during the welding operation and boosts various mechanical properties, including toughness and resistance to stress corrosion cracking, nitrogen gas improves stainless steel Manufacturing.

Figure I.6: A picture of welding with Nitrogen

g) other applications:

There are several sectors where we can work with Nitrogen gas including chemical plants, Mining, pollution control and even scientific research.

I.2.3.2. Liquid Nitrogen (LN_2 - Cryogenic Form)

Nitrogen in a liquid state is a colorless, odorless, and tasteless substance with a temperature of around -195.8°C (-320.4°F) near to its boiling point at standard atmospheric pressure (1 atm). making it ideal for freezing and cooling some aspects including [3] [4] [5]:

- biological materials
- food items (e.g. fruits, vegetables, seafood, or ice cream)
- tools and materials during cutting or grinding processes
- electronic components
- Abnormal tissues and medical equipment in healthcare industry
- Catalysts and Reactors

Regardless of its cryogenic properties liquid Nitrogen has various applications such as:

- Inert Liquid Medium by Preventing combustion/oxidation in chemical reactors
- Propellant or Pressurization Commonly used in aerospace by pushing fuel through rocket systems
- Shielding or Displacement for example its can be introduced into a system to flood an area and displace oxygen or other reactive gases.

I.3. General information about Oxygen

I.3.1. Definition

Oxygen, discovered by Joseph Priestley in 1774 and named by Antoine Lavoisier, Oxygen is a highly reactive chemical element with the symbol O and atomic number 8 which is at standard temperature and pressure, oxygen is a colorless, odorless gas that makes up about 21% of the Earth's atmosphere by volume [6].

I.3.2. The position of oxygen in the periodic table

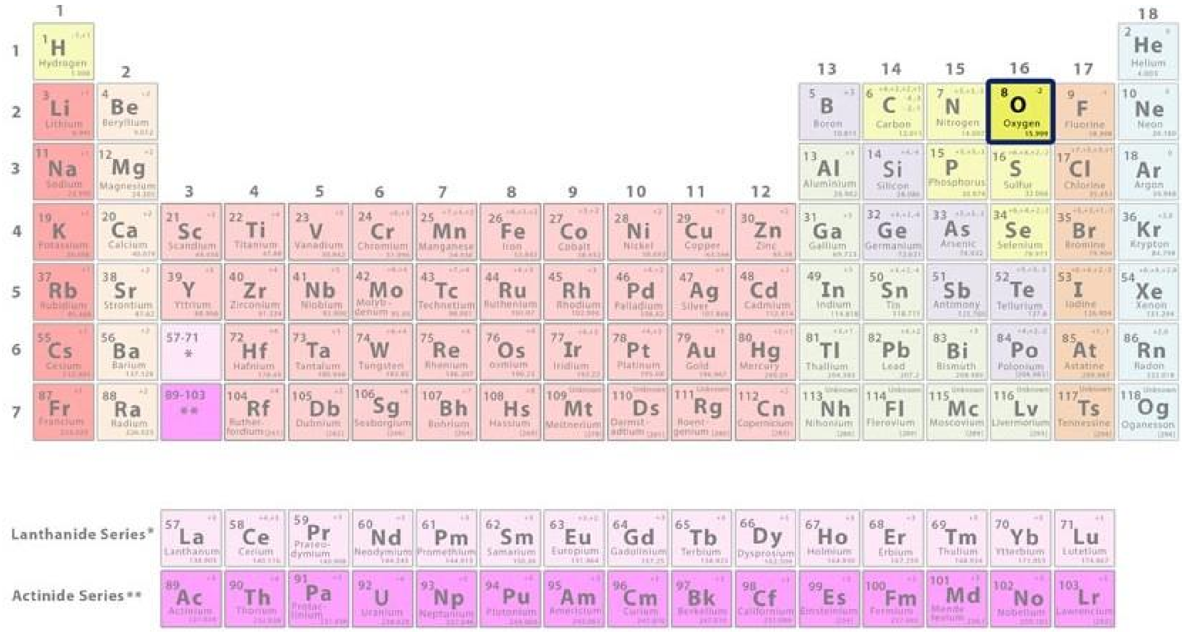


Figure I.7: Oxygen’s placement in the periodic table

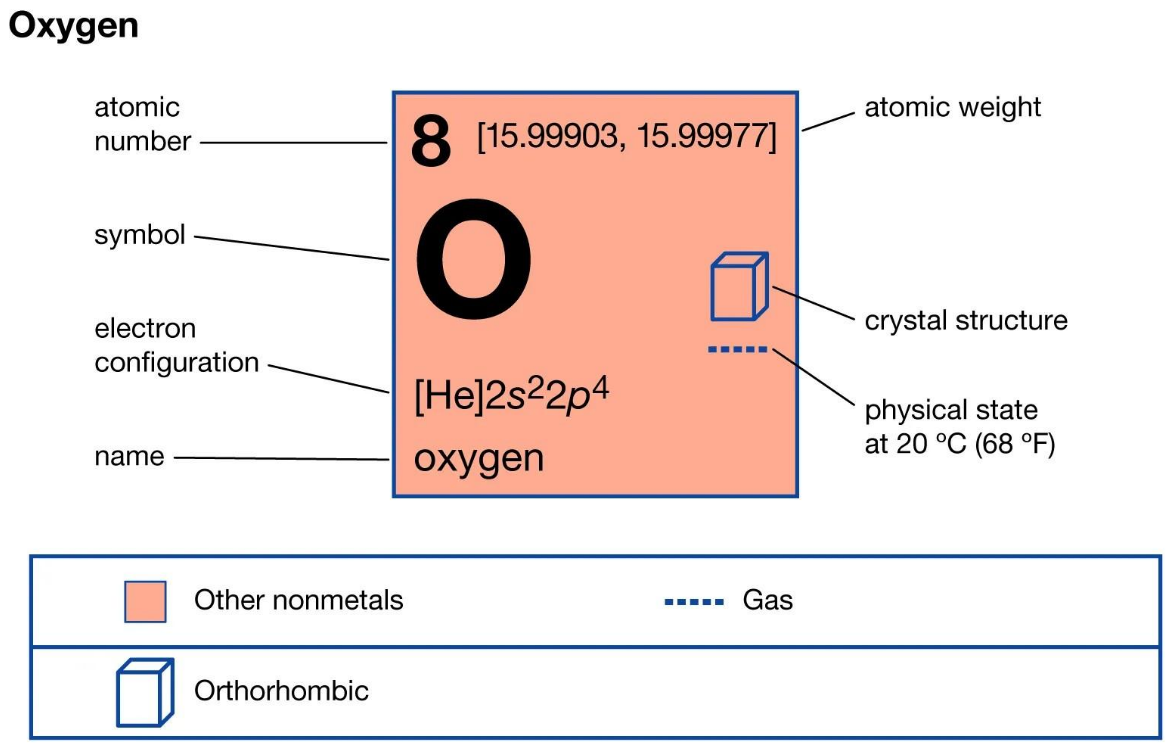


Figure I.8: Figure showing the properties of oxygen

I.3.3. The applications of oxygen

I.3.3.1. Medical and Healthcare

a) Respiratory Support:

By delivering the oxygen via masks or ventilators to maintain adequate blood oxygen levels for patients with breathing difficulties.

b) Hyperbaric oxygen therapy (HBOT):

Is a medical treatment that involves breathing pure oxygen in a pressurized room or chamber. This therapy increases the amount of oxygen in the blood, which can help promote healing, reduce inflammation, to treat conditions like decompression sickness, carbon monoxide poisoning, chronic wounds and improve overall health. [7]

c) Anesthesia:

Oxygen is Mixed with other gases to ensure patient safety during surgeries [8].

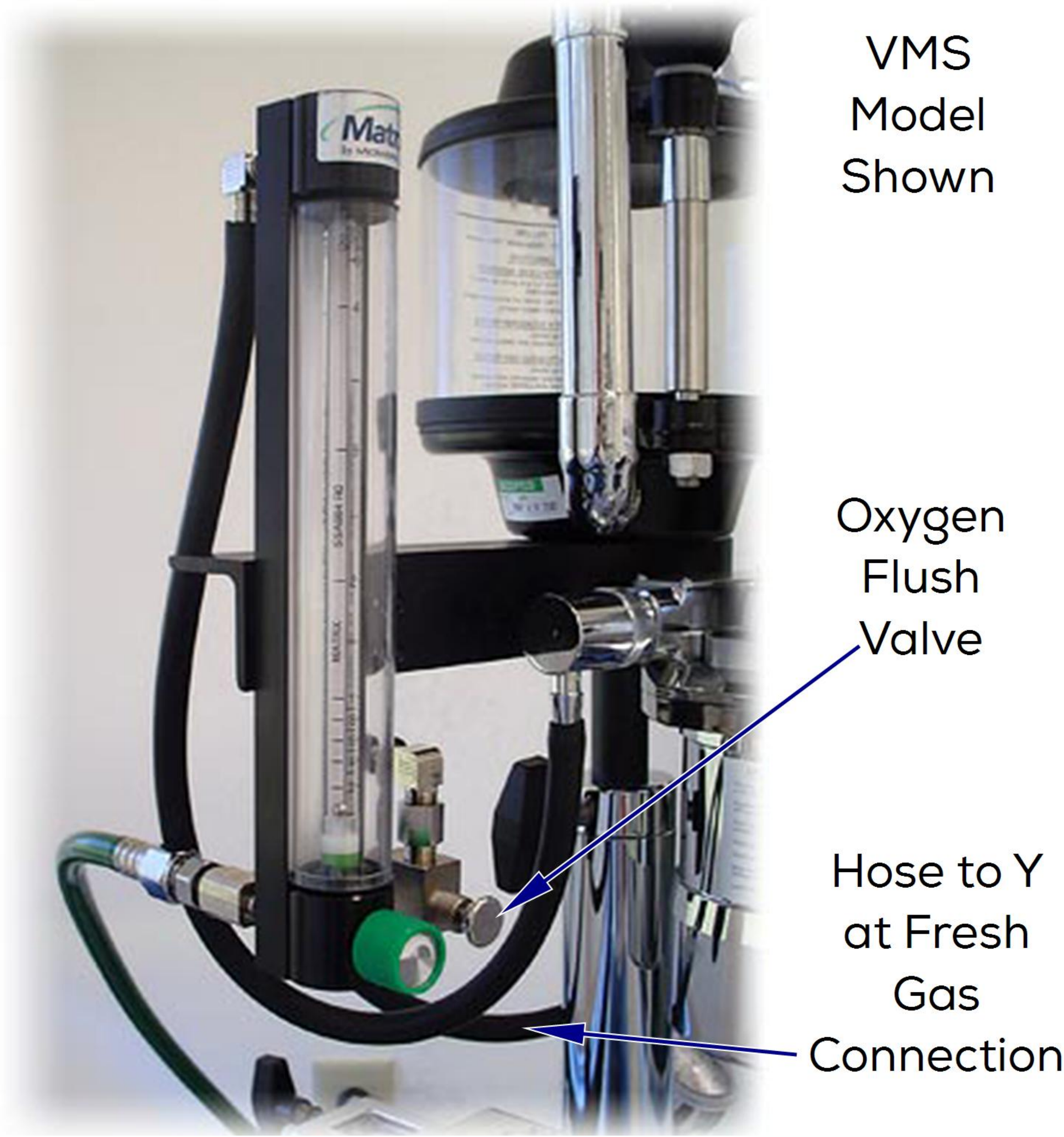


Figure I.9: Oxygen flush valve on an anesthesia machine

d) Pharmaceutical Manufacturing:

Molecular oxygen is considered the greenest reagent in organic chemistry and is widely used in pharmaceutical and fine chemical manufacturing, particularly in aerobic oxidation reactions. To address safety concerns when using flammable solvents, a diluted form of oxygen (less than 10% O_2 in N_2) is typically used in batch processes. However, recent studies show that pure oxygen, when used in continuous-flow reactors, can be safely handled at scale, offering faster reaction rates, improved product quality, and higher process efficiency. The oxygen produced by our generator provides a clean, efficient, and cost-effective on-site solution for these applications, making it an ideal choice for modern pharmaceutical manufacturing [9].

I.3.3.2. Water Treatment

a) Seawater pretreatment:

Oxygen (O_2) is used to oxidize dissolved contaminants, converting them into insoluble forms that can be removed through filtration or sedimentation

b) Aeration (Oxygenation of Water):

By injecting air or pure oxygen into the water to increase the dissolved oxygen (DO) level into water achieving crystal clear water and a balanced ecosystem. Effective aeration promotes healthy fish and plant life, more efficient filtration, and helps maintain stable water conditions during colder months.

c) Advanced Oxidation Processes (AOP):

By degrading organic and inorganic pollutants using oxidizing agents to break down contaminants into carbon dioxide (CO_2), water (H_2O), and harmless byproducts which Oxygen (O_2) plays a crucial role by generating hydroxyl radicals (·OH) and other reactive oxygen species (ROS), Optimizing O_2 delivery improves efficiency of this process [10].

I.3.3.3. Manufacturing Sector

I.3.3.3.1. Introduction

Due to its chemical properties as a reactive gas that supports combustion and oxidation, oxygen (O_2) plays a crucial role in various manufacturing processes. We listed some of them below:

a) Chemical & Petrochemical Industry:

Oxygen used as a reactant or as a supporting agent in various chemical processes such as:

- Ethylene Oxide (EO) Production which is produced through the catalytic oxidation of ethylene with oxygen
- Acids Production
- Vinyl Acetate Monomer (VAM) Production where we can see clearly that is the oxygen is involved directly in this process under the chemical reaction:

$$C2 \quad H4 \quad + CH3 \quad COOH + \frac{2}{1} \quad O2 \quad \rightarrow CH3 \quad COOCH = CH2 \quad + H2 \quad O \qquad (I.1)$$

- Syngas Production
- Polymerization

b) Metal Manufacturing :

A key technology in steel production is Basic Oxygen Furnace "BOF", where the primary function of oxygen is decarburization also pure oxygen reacts with the impurities in the steel like carbon, sulfur, and phosphorus to create a slag that is removed from the furnace, this process efficiently refines iron into high-quality steel [11].

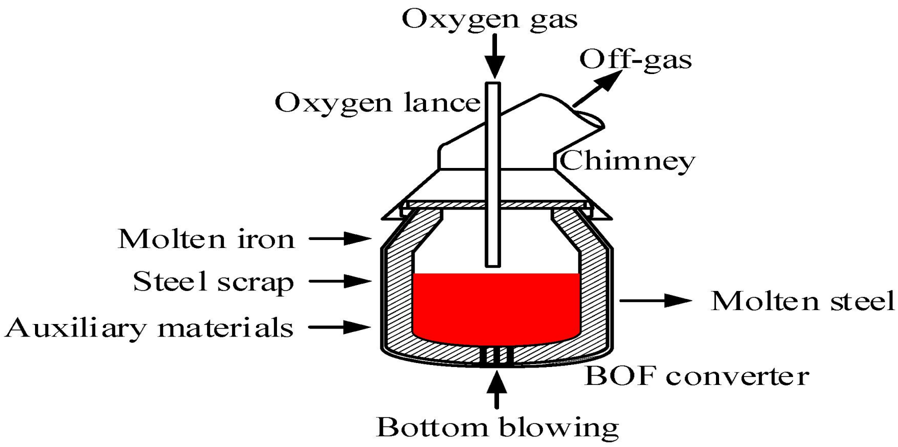


Figure I.10: The schematic representation of BOF steelmaking

c) Glass & Ceramics Sector:

The main role of oxygen in this sector is to generate higher temperatures, which improve the quality of the final product, along with other roles such as:

- Supporting chemical reactions that remove carbon.
- Oxygen Plasma Treatment to clean or modify glass or ceramic surfaces

d) Pulp and Paper Industry:

The use of oxygen in this sector is also crucial for improving pulp brightness and strength in several operations, including:

- Oxygen Delignification by removing the remaining lignin from wood pulp after cooking.
- Oxygen Bleaching by replacing or reducing harmful chemicals like chlorine dioxide.
- Lime Kiln Enrichment where increasing oxygen improves combustion efficiency.
- Oxidation of Sulfur Compounds which minimizes bad odors and air pollution Within the mill.

I.3.3.3.2. Conclusion

We can conclude that oxygen is well known for its applications in the medical field. However, as highlighted above, it is also indispensable in the manufacturing sector just like nitrogen.

I.3.3.4. Energy Sector

Oxygen significantly contributes in enhancing efficiency, reducing emissions, and enabling advanced energy technologies, The following notes are its primary uses in the energy industry:

- Oxygen-Fuel Combustion: instead of air containing just 21 % oxygen injecting higher proportion leads to Higher flame temperatures which improves efficiency, reduces NO_x emissions, and facilitates easier CO_2 capture.
- Gasification by helping to convert carbon-based materials into syngas ($CO + H_2$) which enable clean fuel production, hydrogen generation and better carbon capture.

- Production of clean Hydrogen by helping in autothermal reforming (ATR)

I.3.3.4. Scientific Research

Oxygen is indispensable in scientific research from laboratories to universities we listed below the major Practices of this substance:

- Respiratory, Biological and Medical Research.
- Chemical Reactions and material synthesis.
- Environmental Research.
- Aerospace Research.

I.4.Concultion

The development and implementation of advanced technologies are essential to effectively extract, purify, and utilize nitrogen and oxygen for their Roles and that is exactly what scientists have done.

Chapter II

Gas Separation Technologies

II.1. Introduction

It is well understood that air is composed of multiple gases, and their separation relies on advanced technological processes. we systematically explored and analyzed these technologies one by one.

II.2. Definition of Gas separation technology

The process of isolating specific gases from a mixture, in our case the air, is called gas separation which involves various methods including:

II.2.1. Cryogenic Distillation

A separation process that cools a gas mixture, such as air or natural gas, based on differences in its components' boiling points in order to separate them by liquefying in extremely low temperatures.

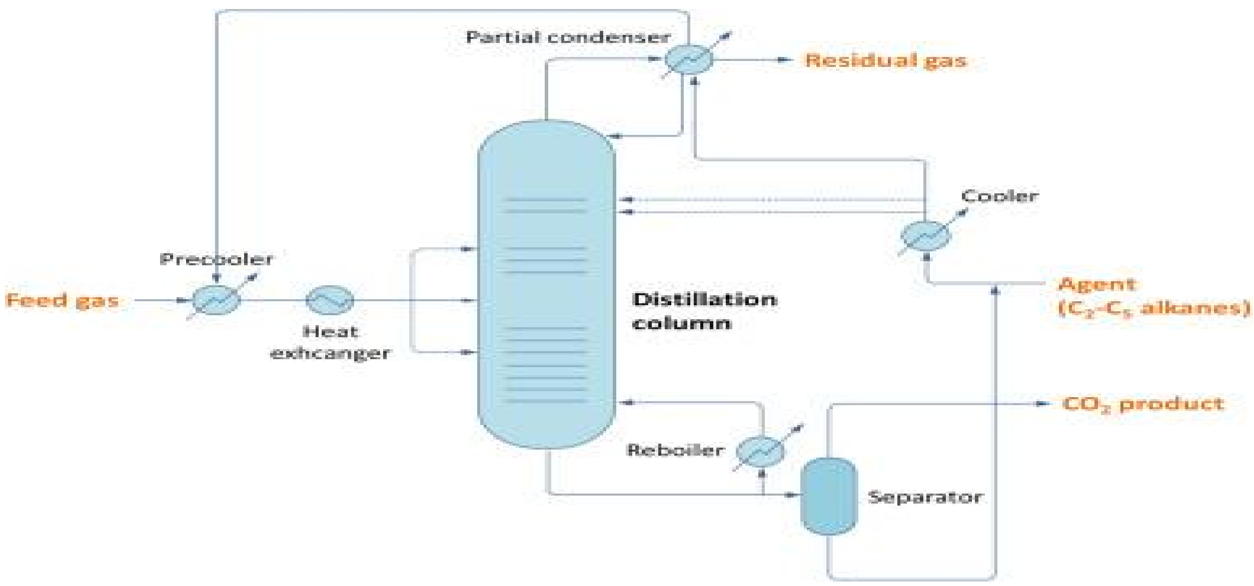


Figure II.1: The schematic flow diagram of Ryan Holmes process

II.2.2. Membrane Separation

Membrane technology refers to a range of engineering processes that use semi-permeable membranes to separate substances, typically in gas or liquid streams based on differences in molecular size, solubility, and chemical Interactions, and it operates based on the principle of selective permeability, where certain gas molecules pass through the membrane faster than others due to molecular properties, pressure gradients, and the membrane's material composition.
The types of membranes used in gas separation [12]:

II.2.2.1. Mixed Matrix Membrane

These combine a continuous polymeric matrix with dispersed inorganic or organic filler materials, such as zeolites, metal-organic frameworks (MOFs), carbon nanotubes, or nanoparticles.

II.2.2.2. Polymeric Membranes

Typically composed of synthetic polymers like polyimide, polysulfone, cellulose acetate, or polydimethylsiloxane (PDMS), which are chosen for their flexibility, processability, and tunable separation characteristics.

II.2.2.3. Isotropic Membranes

They have a uniform structure and composition throughout their thickness, meaning their properties (e.g., porosity, density, or permeability) do not vary from one side to the other or across their cross-section.

II.2.2.4. Anisotropic Membranes

Membranes with a non-uniform structure, featuring a thin, selective layer on top of a thicker, porous support, designed to enhance separation efficiency by combining high selectivity with good flow rates.

II.2.2.5. Supported Liquid Membranes

Membranes where a liquid phase, containing a selective carrier or solvent, is held within the pores of a solid support, typically a porous polymer or ceramic material allowing specific gases or molecules to dissolve into the liquid, move across it, and exit on the other side, driven by concentration or pressure differences, while the solid support provides structural stability.

II.2.2.6. Ceramic and Metal Membranes

Made from materials like ceramics (e.g. alumina, silica, or zirconia) or metals (e.g. palladium or stainless steel), offering high durability and resistance to extreme conditions.

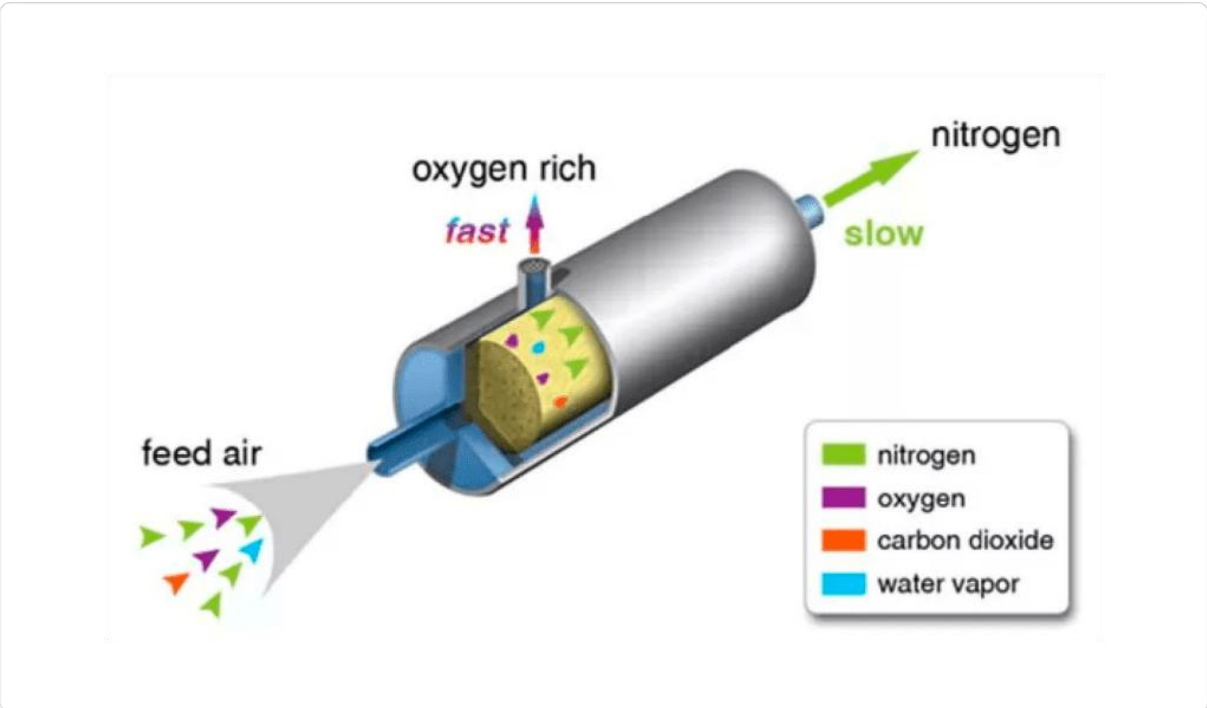


Figure II.2: Membrane Technology

II.2.3. Pressure Swing Adsorption (PSA)

A gas mixture is passed through an adsorbent material, such as zeolites or activated carbon, which selectively adsorbs specific gas components at high pressure. Upon reducing the pressure, the adsorbed gases are desorbed, allowing for their collection and purification.

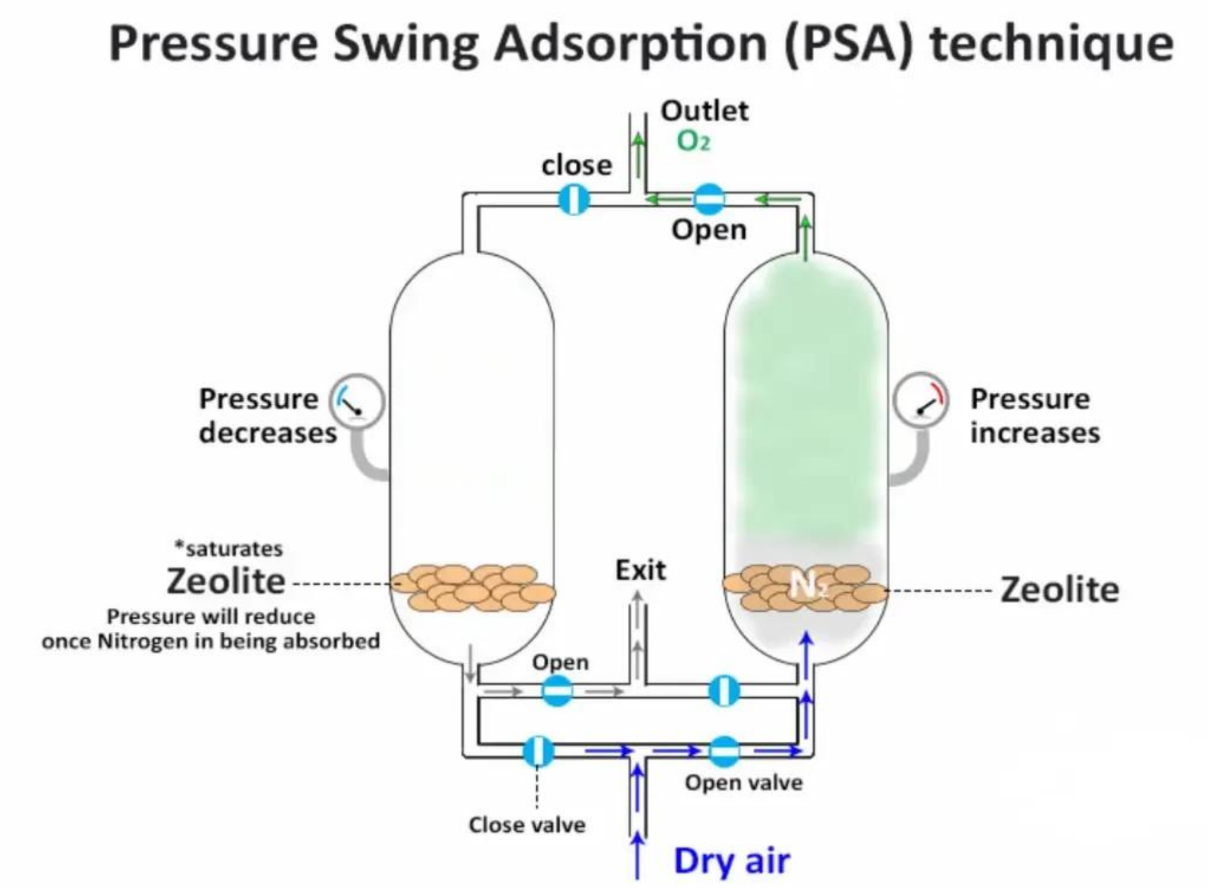


Figure II.3: Pressure Swing Adsorption Technology

II.2.4. Vacuum Swing Adsorption (VSA)

A non-cryogenic gas separation technique where a gas mixture, often air, is passed through special solids, or adsorbents material like zeolites at near-atmospheric pressure, selectively capturing specific components such as nitrogen. A vacuum is then applied to reduce the pressure below atmospheric levels, desorbing the trapped gases and regenerating the adsorbent for reuse, commonly employed to produce high-purity oxygen.

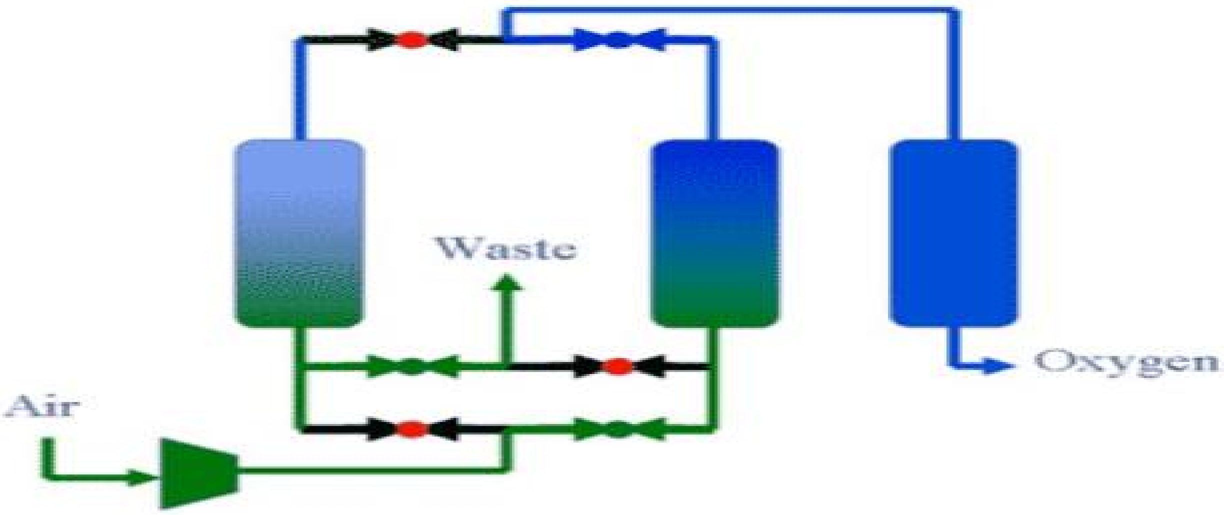


Figure II.4: Vacuum Swing Adsorption (VSA)

II.4. Conclusion

The results demonstrate that from our research that the choice of any technology to implement in any gas separation system depends on the constructors and their system specifications, such as purity, energy consumption, and production capacity.

Chapter III

Generator Description and Data Sheet

III.1. Technology Selection

III.1.1. Gas Separation

We, based on the analyses conducted by our team in the figure below [13] [14] [15]:

Table III. 1: Technology Selection table for gas separation

Technology	Oxygen Purity	Nitrogen Purity	Energy Consumption	Initial Cost	Maintenance
Cryogenic Distillation	99.5% %	99.999%	High	High	High
Membrane Separation	90–93%	95–99%	Low	Medium	Low
Pressure Swing Adsorption (PSA)	90–95%	95–99.999%	Medium	Medium	Medium
Vacuum Swing Adsorption (VSA)	90–93%	95–99.5%	Lower than PSA	Medium	Medium

After fixing our standards:

- Prioritizing sustainability (solar power).
- Dual output (N2 and O2).
- Moderate scale (10-50 Nm³/h).
- Flexible purity (95-99.9% N2, 90–95% O2).
- Scalability: Can be adapted for different industries.
- Cost-effectiveness over time.
- Real-time adjustment of flow, purity and power use based on demand signals which automate the generator.

We have chosen a hybrid system "PSA unit using zeolite adsorbent to produce oxygen and polyimide Membrane to produce Nitrogen Separation "powered by solar energy.

III.1.2. Process Flow Summary

Air enters the membrane module:

1. Membrane separates nitrogen (permeate side)
2. Exhaust (oxygen-enriched air) goes to PSA unit, where produces oxygen
3. Exhaust (N_2-rich gas) is recovered again as nitrogen

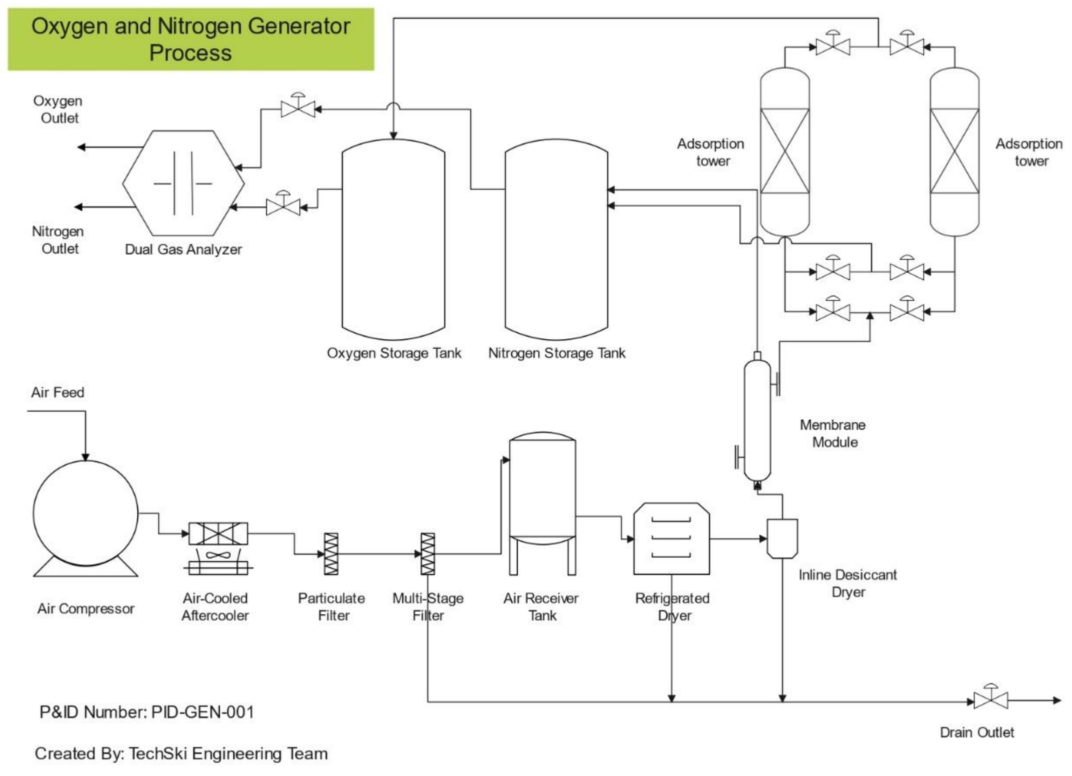


Figure III.1: P&ID – Oxygen and Nitrogen Generator System

III.2. Feed Air Estimation

Maximum Target Output is 50 Nm³/h

Technically, for every 100 Nm³of air we have:

- 78 Nm³ is Nitrogen
- 21 Nm³ is Oxygen

So, for our target moderate scale maximum capacity we can estimate:

Nitrogen is 39 Nm³/h:

With:

$$N2 = \frac{50\frac{Nm^3}{h} \times 78}{100} = 39\frac{Nm^3}{h} \tag{III.1}$$

Oxygen: 10.5 Nm³/h:

With:

$$O2 = \frac{50\frac{Nm^3}{h} \times 21}{100} = 10.5\frac{Nm^3}{h} \tag{III.2}$$

Oxygen from PSA:

Standard oxygen PSA recovery is 40 %:

$$\text{PSA Input Air (from membrane retentate)} = \frac{10.5}{0.40} \approx \frac{26.25\ \text{Nm}^3}{\text{h}} \quad \text{(III. 3)}$$

Nitrogen from Membrane and PSA Exhaust:

- The Membrane Sends 65% of the air as nitrogen (permeate) and 35% of the air as oxygen-rich air (retentate)

For typical membrane system configurations designed for moderate-purity nitrogen generation (95–99%) we have at 35% = 26.25 Nm³/h, then:

$$\text{Air in to membrane} = \frac{26.25}{0.35} \approx \frac{75\ \text{Nm}^3}{\text{h}} \quad \text{(III. 4)}$$

Nitrogen from Membrane:

$$75 \times 0.65 = \frac{48.75\ \text{Nm}^3}{\text{h (nitrogen)}} \quad \text{(III. 5)}$$

Nitrogen from PSA Exhaust:

Let's take your PSA feed flow: 26.25 Nm³/h (oxygen-rich feed)

If the PSA recovers 40% of this as oxygen, That leaves:

$$26.25 \times 0.6 = \frac{15.75\ \text{Nm}^3}{\text{h (exhaust gas)}} \quad \text{(III. 6)}$$

- 85–95% Nitrogen
- 3–10% Oxygen
- 1% argon

So, the nitrogen in the exhaust is:

$$15.75 \times 0.92 = \frac{14.5\ \text{Nm}^3}{\text{h (of Nitrogen)}} \quad \text{(III. 7)}$$

Total Nitrogen:

$$48.75 + 14.5 = \frac{63.25\ \text{Nm}^3}{\text{h}} \quad \text{(III. 8)}$$

To achieve 50 Nm³/h of total product gas (39 N_2 + 10.5 O_2), the system requires: 75 Nm³/h of dry air input.

III.3. SolidWorks Description

III.3.1. Definition of Solidworks

Solidworks is a computer-aided design (CAD) and computer-aided engineering (CAE) software developed by Dassault Systèmes for engineers, designers, and manufacturers how want to work mainly in 3D parametric mechanical design, creating 2D technical drawings, simulation and various applications related to modeling, the types of editions available in the market of this software are:

- SolidWorks Standard
- SolidWorks Professional
- SolidWorks Premium

And we will use **SolidWorks Premium 2022**, which is the most comprehensive version, offering advanced design, simulation, and analysis tools.

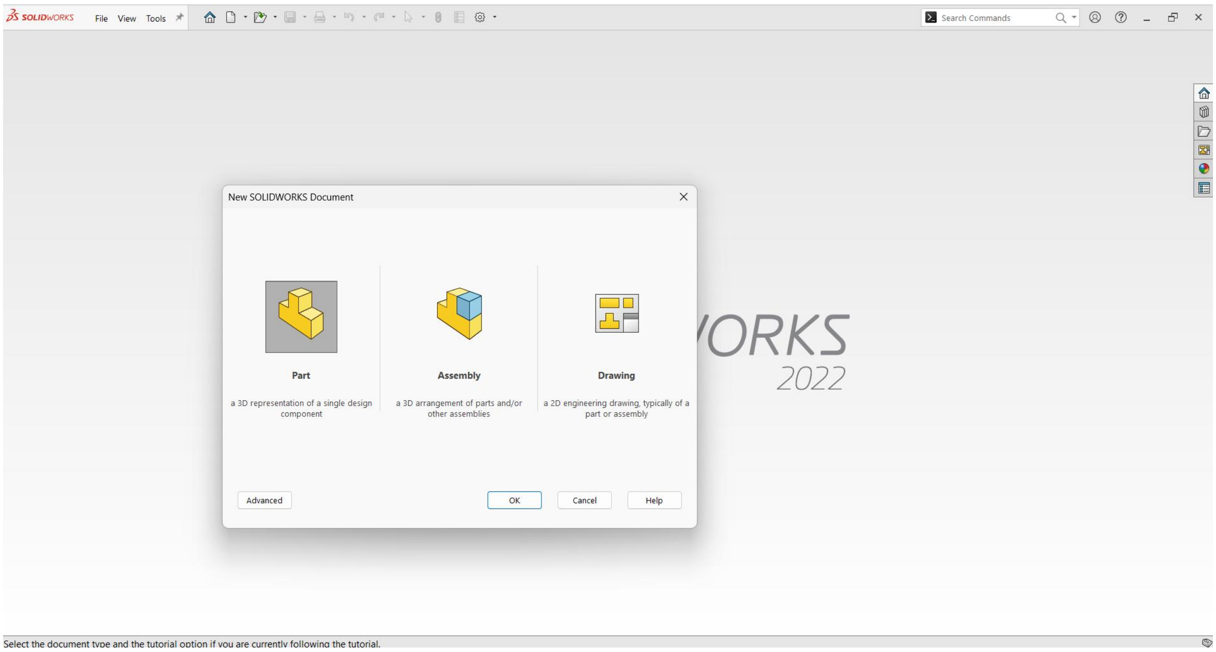


Figure III.2: SolidWorks Premium 2022 User Interface

III.3.1. Capabilities of Solidworks

SolidWorks provides tools for:

- Three-Dimensional Modeling
- Two-Dimensional Drafting and Drawing
- Assembly Design
- Simulation and Analysis
- Product Data Management
- Electrical and Printed Circuit Board (PCB) Design
- Sheet Metal, Weldments, and Surface Modeling

- Manufacturing Support (CAM)
- Rendering and Visualization

III.4. The components of the generator

III.4.1. Introduction

The choice of component characteristics is generally based on our market observations regarding medium-sized components, The following sections will cover:

- **How It Works:** Describes the operating principle and functional purpose of the component.
- **Pressure Capacity:** Defines the maximum pressure limits for safe and efficient operation of components directly affected by fluid or gas pressure.
- **Dimensions:** describes the physical dimensions of the device, including height, width, and weight.
- **Component Configuration:** This section presents the SolidWorks drawings and technical setup for each major component in the system.
- **Energy Consumption:** Specifies the power consumption for components requiring energy input to operate.
- **Energy production capacity:** refers to the maximum amount of energy generated by a component in this system.
- **Model:** Specifies the version or design of a device or machine preconstructed and possibly will be used in our generator.

III.4.2. Piping

a) How It Works:

A pipe uses pressure to move liquid or gas in the desired direction.

b) Material:

Stainless steel for compatibility with Nitrogen and Oxygen

c) Pressure Capacity:

Based on the Hoop Stress formula from Thin-Walled Pressure Vessel Theory, we will calculate the maximum pressure our pipes can handle:

The exact formula:

$$\sigma = \frac{P \times D}{2 \times t} \tag{III.9}$$

Rearranging for pressure:

$$P = \frac{2 \times t \times \sigma}{D} \tag{III.10}$$

With:

- P: internal pressure (Pa)
- t : wall thickness (m)
- σ : allowable stress (Pa)
- D: mean diameter (m)

Firstly, we need to check the Thin-Wall Assumption validation for our choices:

$$\frac{D}{t} > 10 \quad (III.11)$$

If D / t > 10, thin-wall theory is valid

For our cases we Have chosen D=32 mm with t = 2mm and D = 107.5 mm with t = 7.5 mm:

$$\frac{32}{2} = 16 > 10 \quad (III.12)$$

$$\frac{107.5}{7.5} = 14.33 > 10 \quad (III.13)$$

From (III.12) and (III.13) we can say Thin-wall assumption is valid for both pipes.

Since we are using AISI 304 Stainless Steel in our design:

$$\sigma(\text{allowable}) = \frac{\sigma\ (\text{yield})}{\text{Safety Factor}} = \frac{205}{2} = 102.5\ \text{MPa} \quad (III.14)$$

So, we will calculate the maximum pressure with a safety factor of 2:

- For Pipe 1: (D = 32 mm, t = 2 mm):

$$P = \frac{2 \times 0.002 \times 102.5}{0.032} = 12.812500\ MPa \quad (III.15)$$

- For Pipe 2 (D = 107.5 mm, t = 7.5 mm):

$$P = \frac{2 \times 0.0075 \times 102.5}{0.1075} = 14.302325.58\ MPa \quad (III.16)$$

The calculated maximum working pressure of 128.125 bar and 143.0233 bar confirms that both pipe designs with a 30 mm inner diameter or 100 mm inner diameter, and constructed from AISI 304 stainless steel operates within a safe pressure range above the minimum required pressure of 1 bar. (atmospheric pressure) [16].

III.4.3. Air Supply System

III.4.3.1. Air Compressor (Variable Speed Compressor)

To Compress ambient air to 7-12 bar for PSA and membrane

a) How It Works:

Due to the Variable Frequency Drive (VFD) or inverter, the VSC can adjust its motor speed based on the demand for compressed air, where the components work together and each having a role listed in the Detailed below:

- Compressor Motor: drives the air compressor using the rotary mechanism.
- Variable Frequency Drive (VFD): Converts alternating current (AC) to direct current (DC)
- Sensors: send real-time data (temperature/pressure) to the control board in the electrical box.

b) Dimensions: 800.00 mm (Length) x 0.5 m (Width) x 600.00 mm (Hight)

c) Energy Consumption:

variable speed saves up to 30% energy compared to fixed-speed units [17].

By using the isentropic Compression Power Equation [18]:

- Flow: 75 Nm^3/h = 0.02083 m^3/s
- Inlet pressure: 1 bar = 100 kPa
- Outlet pressure: 12 bar = 1,200 kPa
- Ambient temperature: 293 K
- Isentropic efficiency: 0.85
- Motor efficiency: 0.90
- Adiabatic index (k): 1.4

Remark:

Isentropic efficiency (η): accounts for real-world (non-ideal) compressor behavior.

Motor efficiency (η_m): accounts for electrical-to-mechanical conversion losses.

As a result, the power is:

$$P = \frac{k}{k-1} \times \frac{P1 \times F}{\eta \times \eta_m} \times [\left(\frac{P2}{P1}\right)^{\frac{k-1}{k}} - 1] \qquad (III.17)$$

Numerical application:

$$\mathrm{P} = \frac{1.4}{0.4} \times \frac{100 \times 0.02083}{0.85 \times 0.90} \times \left[\left(\frac{1200}{100}\right)^{\frac{0.4}{1.4}} - 1\right] = 3.5 \times 2.723 \times 1.034 = 9.854 \text{ kW} \qquad (III.18)$$

Mechanical shaft power: Pshaft = 9.85kW

Motor efficiency: η_m = 0.90

Electrical Power Input:

$$Pelectrical = \frac{\text{Pshaft}}{\eta_m} = \frac{9.85}{0.90} = 10.949 \quad (III.19)$$

So, The Energy Consumption per Hour will be:

$$\text{Energy (kWh)} = \text{Power (kW)} \times \text{Time (hours)} = 10.949 \times 1 = 10.949 \text{ Kwh} \quad (III.20)$$

d) Component Configuration:

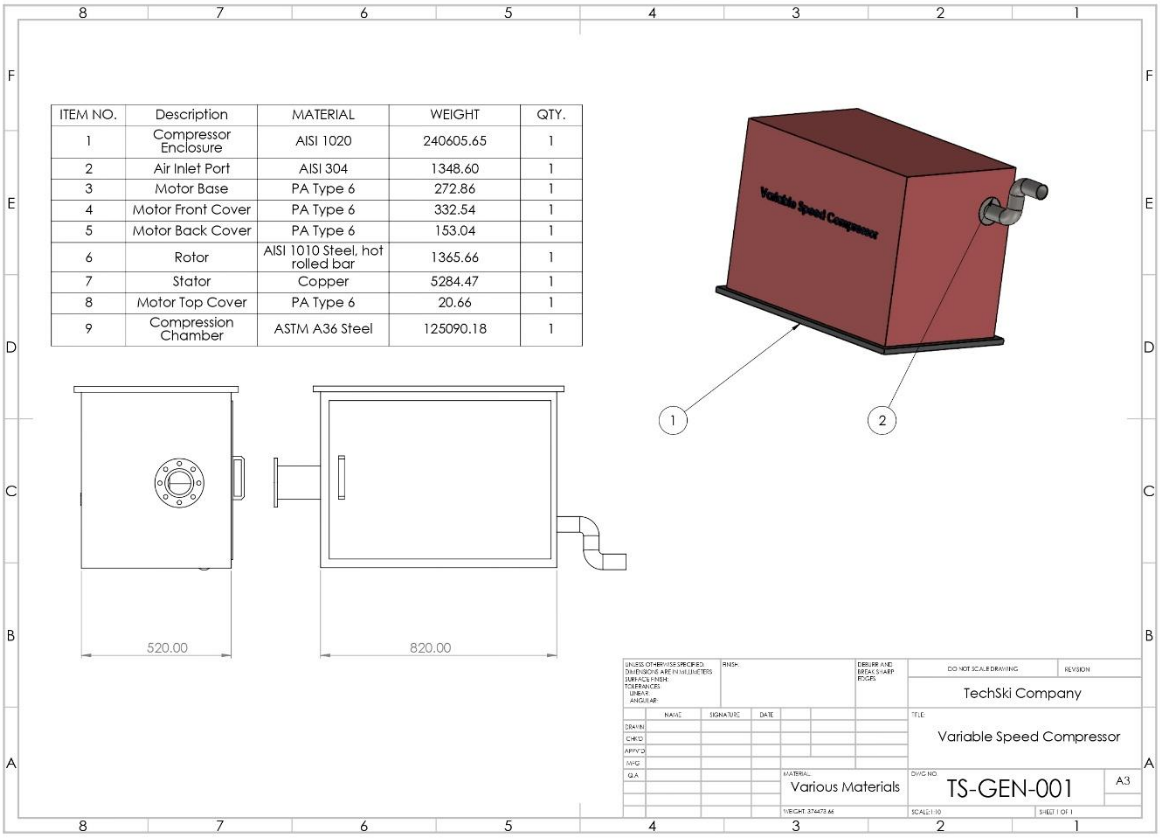


Figure III.3: Variable Speed Compressor Technical Drawing

III.4. 3. Air Treatment & Drying System

III.4.3.1. Post-Compression Heat Exchanger (Air-Cooled Aftercooler)

To Cool compressed air to condense and remove moisture

a) How It works:

Air-cooled aftercoolers use ambient air to cool the hot compressed air. Compressed air enters the air-cooled aftercooler and travels through either a spiral finned tube coil or a plate-fin coil design, while ambient air is forced over the cooler by a motor-driven fan. The cooler ambient Air removes heat from the compressed air.

Most air-cooled aftercoolers are sized to cool the compressed air to within 15°F to 20°F of ambient cooling air temperature, also called approach temperature. As the compressed air cools, up to 75% of the water vapor condenses into a liquid that should be removed [19].

b) Dimensions: 930.00 mm (Length) x 415.00 mm (Width) x 500.00 mm (Height)

c) Energy Consumption:

The basic energy calculation formula:

$$\text{Energy Consumption (kWh)} = \text{Fan Power (kW)} \times \text{Time (h)} \quad \text{(III. 21)}$$

A typical industrial fan motor with a 290 mm diameter fan consumes around 0.115kW per hour [20].

With tow fans in our air-cooled aftercooler:

$$\text{Energy Consumption (kWh)} = 0.115\ \text{kWh} \times 2 = 0.23\ \text{kWh} \quad \text{(III. 22)}$$

The two 290 mm fans in the aftercooler consume about 0.23 kW of electrical energy per hour.

d) Component Configuration:

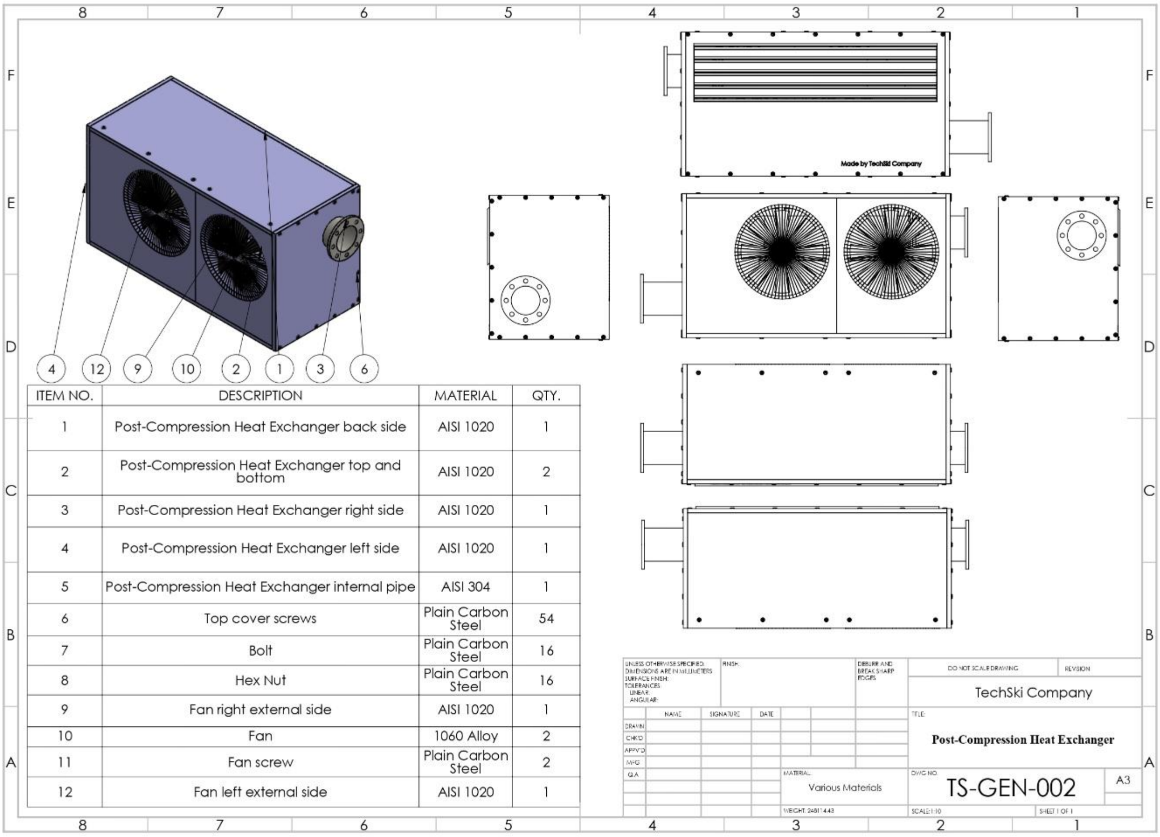


Figure III.4: Post-Compression Heat Exchanger Technical Drawing

III.3.3.2. Pre-Filters (Multi-stage & Particulate Filters)

We will put the pre-filters first to protect our system

a) How It Works:

- **Particulate Filter:**

Removes dust, rust, and other solid contaminants

- **Multi-stage filter:**

composed of two filter stages connected in series

First Stage: Coalescing Bed

➢ Traps oil, water, and mist, combining them into larger droplets that can be easily drained away.

- Only the coalescing filter has a drain outlet pipe to remove collected liquids. The Particulate Filter does not include a drain.
- Compact sensors embedded directly into the housing head of each pre-filter monitor the pressure differential or airflow through the prefilters to detect clogging or filter degradation. When a filter approaches the end of its usable life, the indicator sends a signal or visual alert, prompting timely replacement [21].

Second Stage: Activated Carbon Bed

Due to physical and chemical interactions and based on adsorption, molecules of gas or vapor stick to the surface of the carbon material to:

- Remove odors and volatile organic compounds (VOCs).
- Remove Many Gas or Chemical Contaminants

b) Dimensions: 300.00 mm (Diameter) x 810.00 mm (Height) each (2 filters in series)

c) Component Configuration:

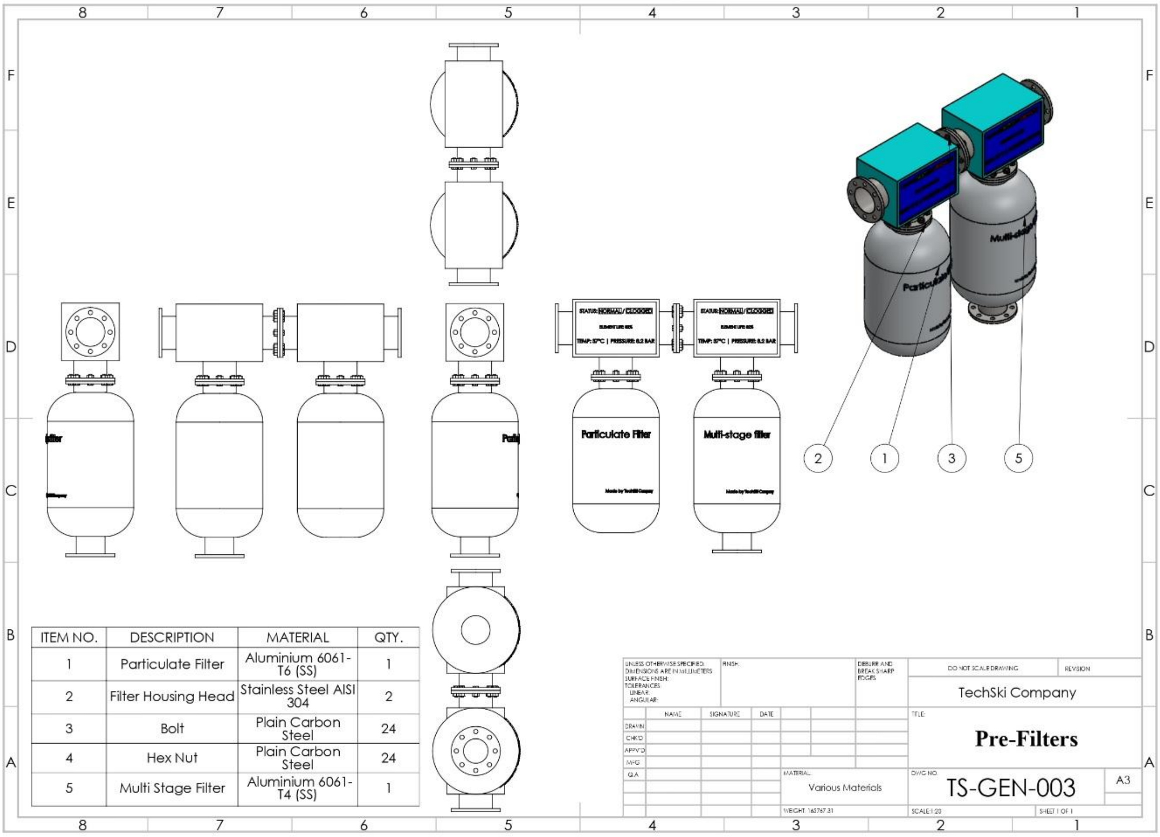


Figure III.5: Pre-Filters Technical Drawing

III.3.3.3. Air Receiver Tank

To store compressed air

a) How It Works:

Acting as a temporarily storage tank for the air generated by the compressor at a pressure higher than atmospheric pressure.

b) Dimensions: 520.00 mm (Diameter) x 1356.45 mm (Height).

c) Volume Sizing :

- D=520 mm which make The Radius: R=260mm.

- Hight: h=1356 mm.

By **s**ubstituting the values into the equation number (III.23):

$$V(cyl) = \pi \times R^2 \times h = 3.14 \times 260^2 \times 1356 = 287829984 \qquad (III.23)$$

From (III.23) we can say that the air receiver has a volume of approximately 287.82 liters.

d) Pressure Capacity:

Tank Parameters:

- Tank diameter (D): D=520.00 mm.
- Wall thickness (t): t=5 mm.
- Allowable stress of the tank material (S): S= 110.297.

Where:

$$S = \frac{\text{Yield strength}}{\text{Safety factor}} = \frac{220.594\ \text{MPa}}{2} = 110.297\ \text{MPa} \qquad (III.24)$$

- Weld efficiency (E): usually between 0.7 and 1.0 depending on weld type and inspection for our system we can assume that E=0.85
- Corrosion allowance (CA): CA = 1 mm, recommended for indoor installations like ours

By applying the formula from ASME Boiler and Pressure Vessel Code for internal pressure in a thin-walled cylindrical vessel:

$$P = \frac{2 \times S \times t \times E}{D - 2 \times CA} = \frac{2 \times 110.297 \times 5 \times 0.85}{520 - 2 \times 1} = 1.81\ \text{MPa} \qquad (III.25)$$

We can conclude that the Maximum allowable internal pressure (P) ≈ 1.81 MPa which is equivalent to 18.1 bar.

e) Component Configuration:

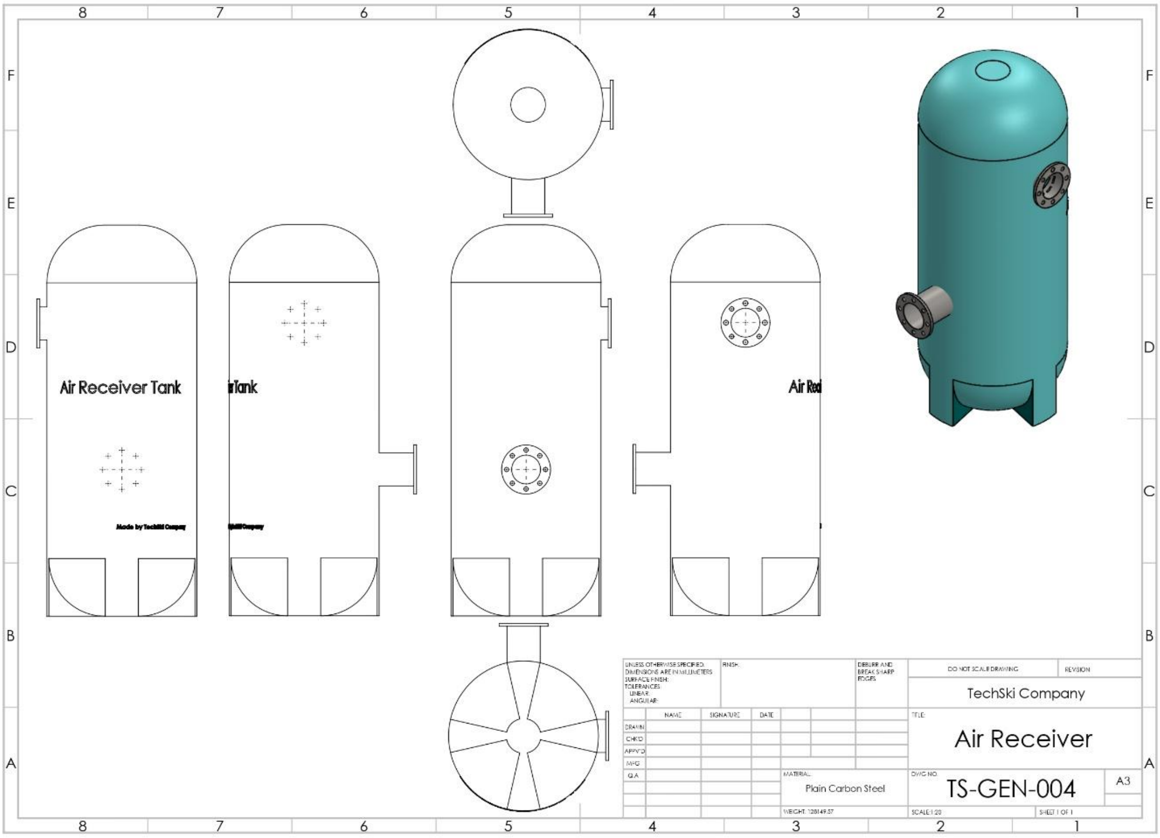


Figure III.6: Air Receiver Technical Drawing

III.3.3.4. Refrigerated Dryer

Cools air to 3–5°C to condense water vapor

a) How It Works:

In the process of removing moisture from the compressed air we use this device which we observe that:

- The Compressor compresses the refrigerant gas.
- The Condenser cools and condenses the refrigerant by using a fan.
- The Liquid Receiver Ensures that only liquid refrigerant reaches the expansion valve, which is essential for effective cooling.
- The Filter drier dries moisture and also filters solid particules they are absent in our system because of the pre filtering process.
- The Expansion Valve reduces refrigerant pressure and temperature.
- The Heat Exchanger cools the compressed air by allowing the refrigerant to absorb its heat and evaporate.
- The Air Outlet delivers dry, reheated compressed air to the system.

b) Dimensions: 620.00 mm (Length) x 420.00 mm (Width) x 640.00 mm (Height)

c) Energy Consumption:

The energy is mainly utilized by:

1. The refrigeration compressor (electrical):

From industrial data: the refrigeration compressor uses 0.6–0.8 kW per 170 Nm^3/h [22].

So,

$$\text{Pcompressor} = \frac{0.7 \times 75}{170} = 0.7\text{kw} \qquad (III.26)$$

2. The condenser fan (electrical):

We will use the same type of fan for the aftercooler because it meets the airflow and temperature same requirements.

So, P(fan)=0.115kW

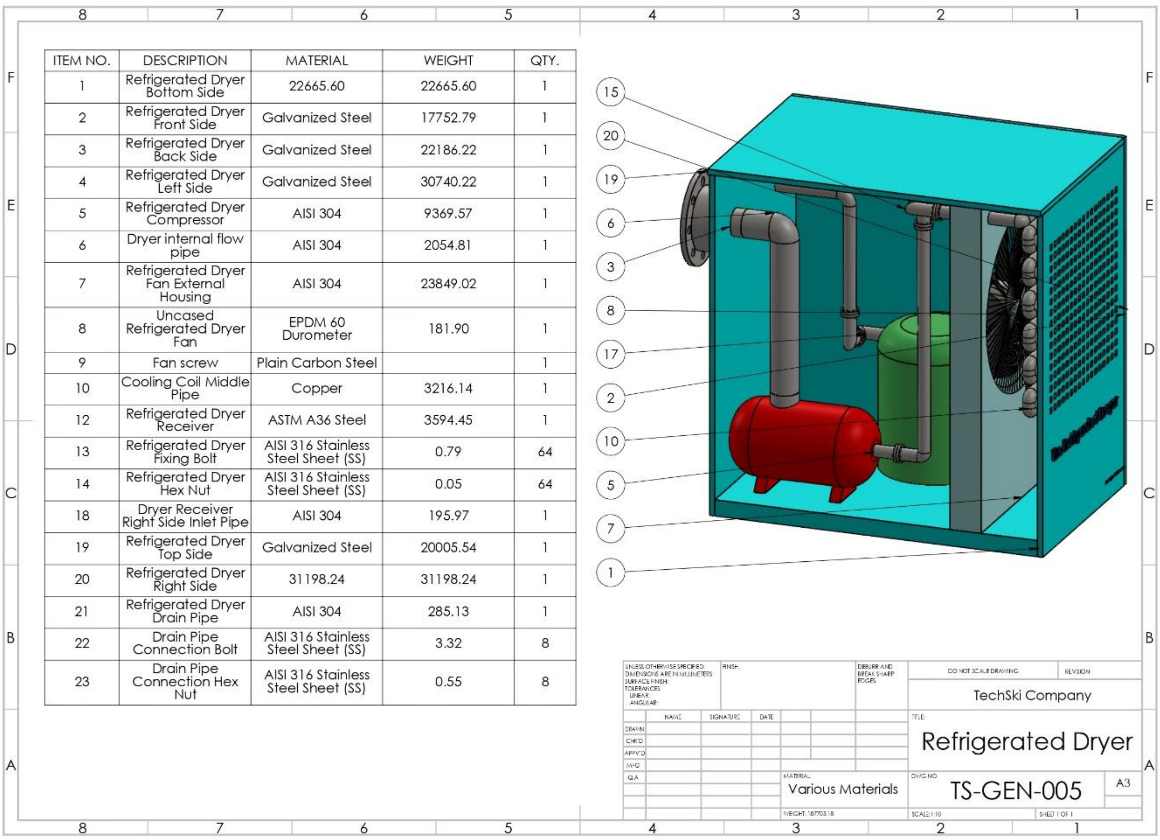
Total Power Consumption per Hour:

$$\text{Ptotal} = \text{Pcompressor} + \text{Pfan} = 0.7 + 0.115 = 0.815\text{kw} \qquad (III.27)$$

Total Energy Consumption per Hour:

$$\text{Energy Consumption (kWh)} = \text{Refrigerated dryer power (kW)} \times \text{Time (h)} = 0.815\text{kwh} \qquad (III.28)$$

d) Component Configuration :



ITEM NO.	DESCRIPTION	MATERIAL	WEIGHT	QTY.
1	Refrigerated Dryer Bottom Side	22665.60	22665.60	1
2	Refrigerated Dryer Front Side	Galvanized Steel	17752.79	1
3	Refrigerated Dryer Back Side	Galvanized Steel	22186.22	1
4	Refrigerated Dryer Left Side	Galvanized Steel	30740.22	1
5	Refrigerated Dryer Compressor	AISI 304	9369.57	1
6	Dryer internal flow pipe	AISI 304	2054.81	1
7	Refrigerated Dryer Fan External Housing	AISI 304	23849.02	1
8	Uncased Refrigerated Dryer Fan	EPDM 60 Durometer	181.90	1
9	Fan screw	Plain Carbon Steel		1
10	Cooling Coil Middle Pipe	Copper	3216.14	1
12	Refrigerated Dryer Receiver	ASTM A36 Steel	3594.45	1
13	Refrigerated Dryer Fixing Bolt	AISI 316 Stainless Steel Sheet (SS)	0.79	64
14	Refrigerated Dryer Hex Nut	AISI 316 Stainless Steel Sheet (SS)	0.05	64
18	Dryer Receiver Right Side Inlet Pipe	AISI 304	195.97	1
19	Refrigerated Dryer Top Side	Galvanized Steel	20005.54	1
20	Refrigerated Dryer Right Side	31198.24	31198.24	1
21	Refrigerated Dryer Drain Pipe	AISI 304	285.13	1
22	Drain Pipe Connection Bolt	AISI 316 Stainless Steel Sheet (SS)	3.32	8
23	Drain Pipe Connection Hex Nut	AISI 316 Stainless Steel Sheet (SS)	0.55	8

Figure III.7: Refrigerated Dryer Technical Drawing

III.3.3.5. Inline Desiccant Cartridge

a) How It Works:

The inline desiccant cartridge operates on the principle of adsorption and within the steps listed below:

- Compressed air enters the cartridge through the inlet port.
- In the drying zone the desiccant captures water molecules through adsorption.

In the industry there is types of Desiccants used and we will discover the characteristics of each of them and chose the one how much with our system [23] [24] [25]:

Table III.2: Technical Comparison of Desiccant Materials

Property	Activated Alumina	Silica Gel	Molecular Sieves
Adsorption capacity	15% to 25%(wt) High	30% to 40%(wt) Moderate	20% to 24%(wt) Very High
Dew- point achievable	233.15 K to 183.15 K	233.15 K to 193.15 K	203.15 K to 88.15 K
Relative Humidity performance	High humidity	Moderate humidity	Low humidity
Regeneration Temperature	473.15 K to 673.15 K	373.15 K to 523.15 K	473.15 K to 623.15 K
Cost	Moderate	Cheap	Expensive

Since we already have a refrigerated dryer which removes bulk moisture and regarding that:

- The Activated Alumina handles high humidity better than silica gel.
- The Activated Alumina cheaper than the Molecular Sieves.
- The Activated Alumina more durable under pressure and temperature fluctuations.
- Achieves a dew point of -40°C to -80°C, which is sufficient for our application.

We will select The Activated Alumina as desiccants.

- The dry air exits through the outlet port.
- Liquid water is drained out via a drain line.

b) Dimensions: 175.00 mm (Diameter) x 495.00 mm (Height)

c) Component Configuration :

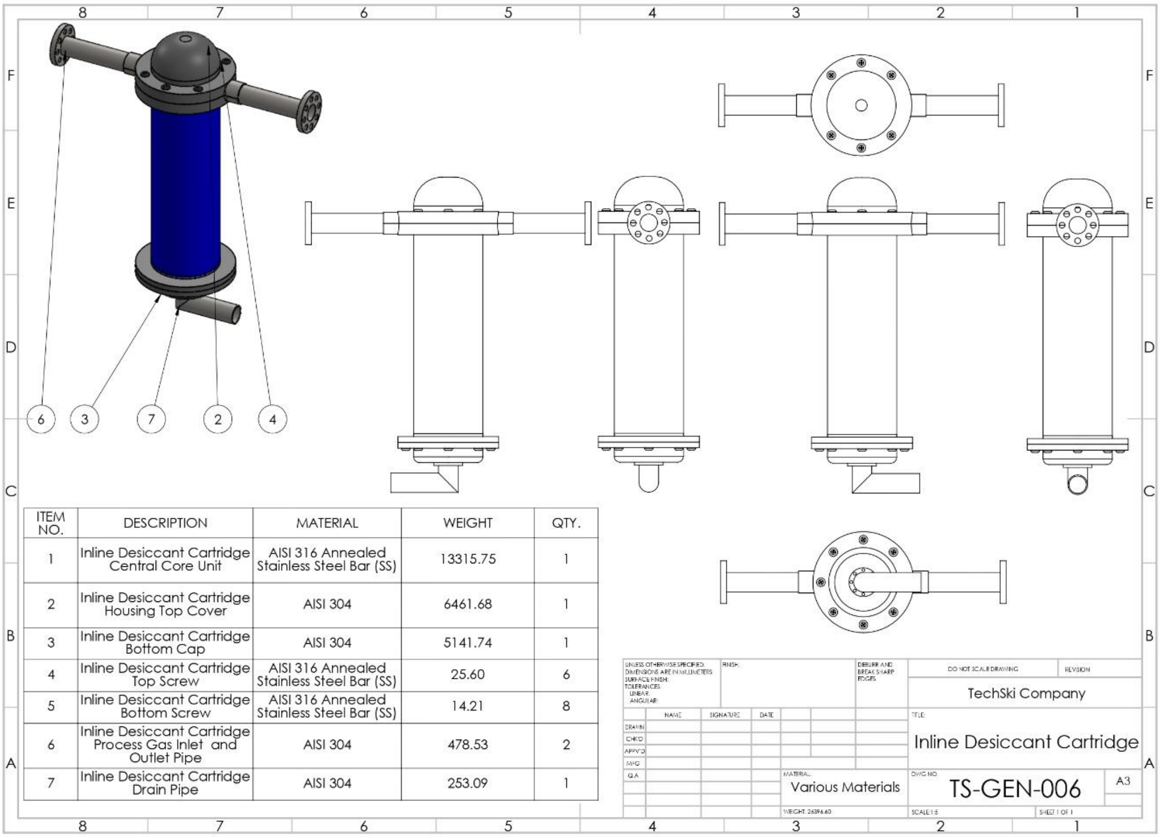


Figure III.8: Inline Desiccant Cartridge Technical Drawing

III.3.4. Gas Separation System

III.3.4.1. Membrane Separation Unit

a) How It Works:

The compressed air inters the inlet port of the membrane were based on the difference in permeation rates of gas molecules through a selective fiber membrane the faster-permeating gases like oxygen (O_2) pass through the membrane walls quickly to the outside of the fibers and slower-permeating gases mainly nitrogen (N_2), remain inside the fiber and continue along the flow path to the outlet port.

b) Dimensions: 200.00 mm (Diameter) x 1500.00 mm (Length)

c) The choice of The Membrane:

We have chosen to use a hollow fiber membrane module, specifically the **MN2-11000 model** from Nordic Filtration, for our nitrogen generation part. This decision is primarily due to the current lack of local technology to develop our own membrane. However, creating an innovative, customized membrane remains one of our long-term strategic goals. In the meantime, this membrane provides a reliable, high-performance solution that meets our design requirements.

Dimensions & Weight :

- Length : 1580 mm
- Diameter : 200 mm

- Weight : 26 kg

The other details are in technical data of Nitrogen Generation Membrane Module, Model: **MN2-11000.**

However, our objective is to manufacture the membrane module with a stainless-steel housing (316L) for enhanced durability:

Let's apply relation (1) to the characteristics of our membrane:

Since we want to work in pressure around 12 bar topically Pmax =10 bar to 15 bar

The Formula (III.9) rearranged for t:

$$t = \frac{P \times D}{2 \times \sigma(\text{allow})} \quad (\text{III}.29)$$

With:

- Design pressure: P=12 bar =1.2×10^6 Pa

the maximum allowable pressure for the membrane has been determined in the design.

- Outer diameter: D=0.2 m
- From Solidworks we can obtain σ(yiled) = 170 MPa for the housing material: Stainless Steel 316

Which make the Allowable stress:

$$\Sigma(\text{allowable}) = \frac{\sigma\ (\text{yield})}{\text{Safety Factor}} = \frac{170}{2} = 85\ \text{MPa} = 85 \times 10^6\ \text{Pa} \quad (\text{III}.30)$$

By Numerical application on (III.29):

$$t = \frac{1.2 \times 10^6 \times 0.2}{2 \times 85 \times 10^6} = 0.00141176\ \text{m} = 1.41\text{mm} = 2\text{mm} \quad (\text{III}.31)$$

A 2 mm wall thickness is sufficient for a stainless-steel housing operating at 12 bar.

However, the flow rate has not been calculated, as it is expected to vary depending on the end user's application and requirements.

d) The Volume of the Membrane:

$$V = \pi r^2 \times h \quad (\text{III}.32)$$

r is the radius (diameter ÷ 2)

h is the height

Since the diameter of our Membrane equal 200 mm and The Height equal 1500mm The Volume will be:

$$V = \pi \times 0.02^2 \times 1.5 = 1.884 \times 10^{-3} \text{m}^2 \quad (\text{III}.33)$$

The Flow in The Membrane from Mass Balance Equation for Membrane Separation:

$$\text{N2(Flow)} = \frac{\text{Feed Flow Rate} \times \text{N2 Recovery}}{\text{Membrane Volume}} \quad \text{(III. 34)}$$

Since the N_2 recovery cannot be calculated without feed composition and product purity data, the calculation shall be retained here [26] [27].

e) Component Configuration:

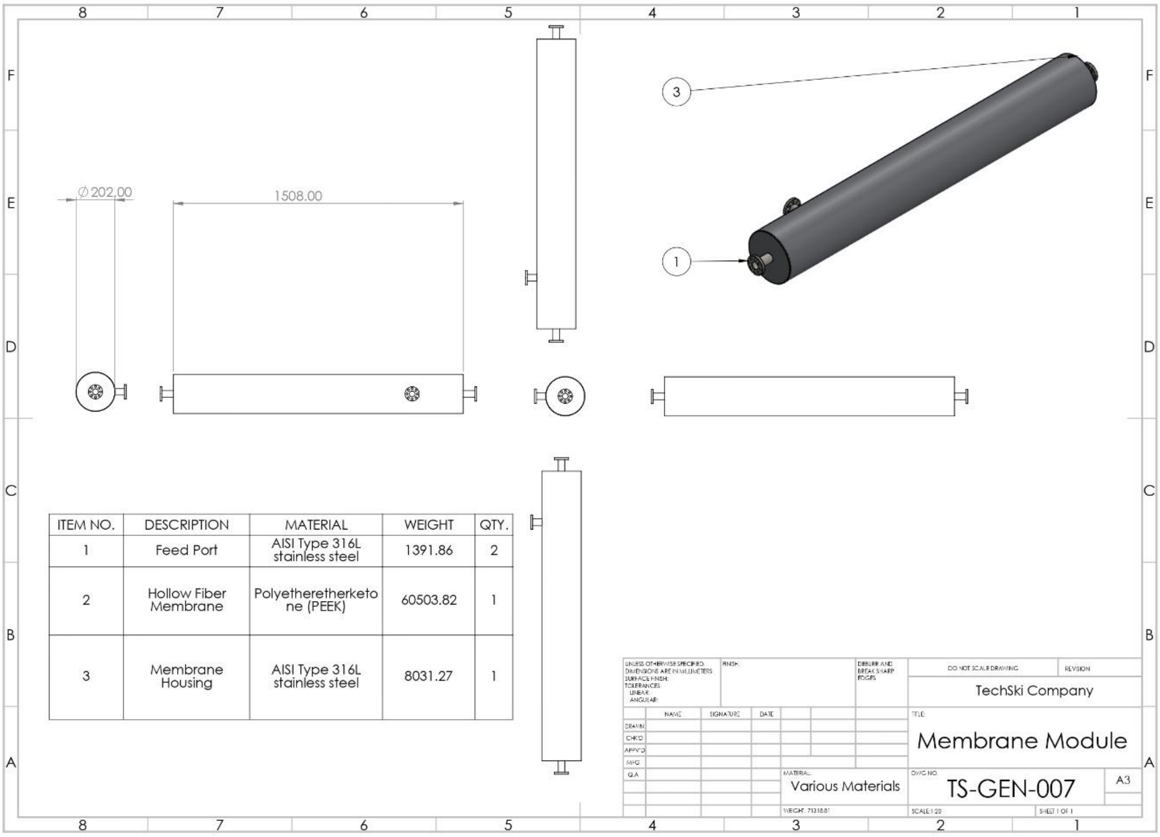


Figure III.9: Membrane Module Technical Drawing

III.2.4.2. PSA (Pressure Swing Adsorption)

Unit containing Tow Adsorption Towers

a) How It Works:

The main condition to perform this operation is by providing high pressure. In this process, two tanks are required: while one tank is being pressurized, the other tank is being depressurized where the unwanted nitrogen will be released and we will recover it. In our case, since we want to produce oxygen in the PSA unit so we need to adsorb the other gases using zeolite at the bed level [28].

b) Dimensions: 2 towers, each 300.00 mm (Diameter) x 1000.00 mm (Height)

c) Pressure Capacity:

The maximum pressure can handle the one Tower is 23 bar:

Where:

- Material: SS316 (Stainless Steel 316)

$$\sigma(\text{allowable}) = \frac{\sigma\text{ (yield)}}{\text{Safety Factor}} = \frac{172.3689323}{2} = 86.18446615\text{ MPa} \quad (III.35)$$

- Wall thickness: t= 4 mm = 0.004 m
- Diameter: D=0.3 m

By using the equation (III.9):

$$P = \frac{2 \times t \times \sigma}{D} = \frac{2 \times 0.004 \times 86.18446615}{0.3} = 2.298252431\text{ MPa} = 22.98252431\text{ bar} \quad (III.36)$$

We can conclude that the maximum allowable internal pressure (P) = 2.298252431 MPa which is equivalent to 22.98252431 bar.

d) Zeolite Type: The most commonly used in Industry

Table III.3: Zeolite Selection Table

Zeolite LiX (Lithium-exchanged Low-Silica X)	Zeolite 5A (Calcium-exchanged A-type)
High-Purity oxygen (90–95%)	Moderate Oxygen Purity (85–93%)
Expensive	Cheaper
Higher N_2 adsorption capacity	Lower N_2 adsorption capacity
Moderate pressures (5–10 bar)	Requires higher pressure (8–15 bar)

Since we are using a membrane before the PSA unit (likely producing 95% N_2-enriched air), the remaining gas entering our PSA for oxygen generation will be oxygen-rich so we will use Zeolite 5A (Calcium-exchanged A-type).

e) Zeolite mass per Tower:

$$m(\text{zeiolite}) = \rho(\text{zeiolite}) \times V(\text{bed}) \times (1 - \epsilon) \quad (III.37)$$

With:

- m(zeolite): mass of zeolite per tower (kg)
- ρ(zeolite) : bulk density of zeolite pellets (kg/m³)

$$\rho\text{ (zeolite)} = 700\text{ kg/m}^3$$

- V(bed): total volume of the adsorption tower (m³)

$$V(\text{bed}) = \pi r^2 \times h = 3.14 \times \left(\frac{0.3}{2}\right)^2 \times 1 = 0.07065 m^3 \quad (III.38)$$

- ϵ : Bed void fraction, $\epsilon = 0.4$

Which gave ass the mass of the zeolite:

$$m(\text{zeiolite}) = 700 \times 0.07065 \times (1 - 0.4) = 29.673\text{ Kg} \quad (III.39)$$

f) Energy Consumption:

In this process, energy is primarily consumed by solenoid valves due to adsorption and desorption mechanism, which rely on pressure changes.

Based on standard industrial solenoid valves:

Power per valve: 8 watts (W)

The Number of Valves used: 6

$$\text{Total Power} = 6 \times 8\text{W} = 48\text{W} \tag{III.40}$$

So, The Energy will be:

$$\text{Energy per hour} = 1000 \times 0.048 = 0.048 \text{ kWh}$$

g) Component Configuration:

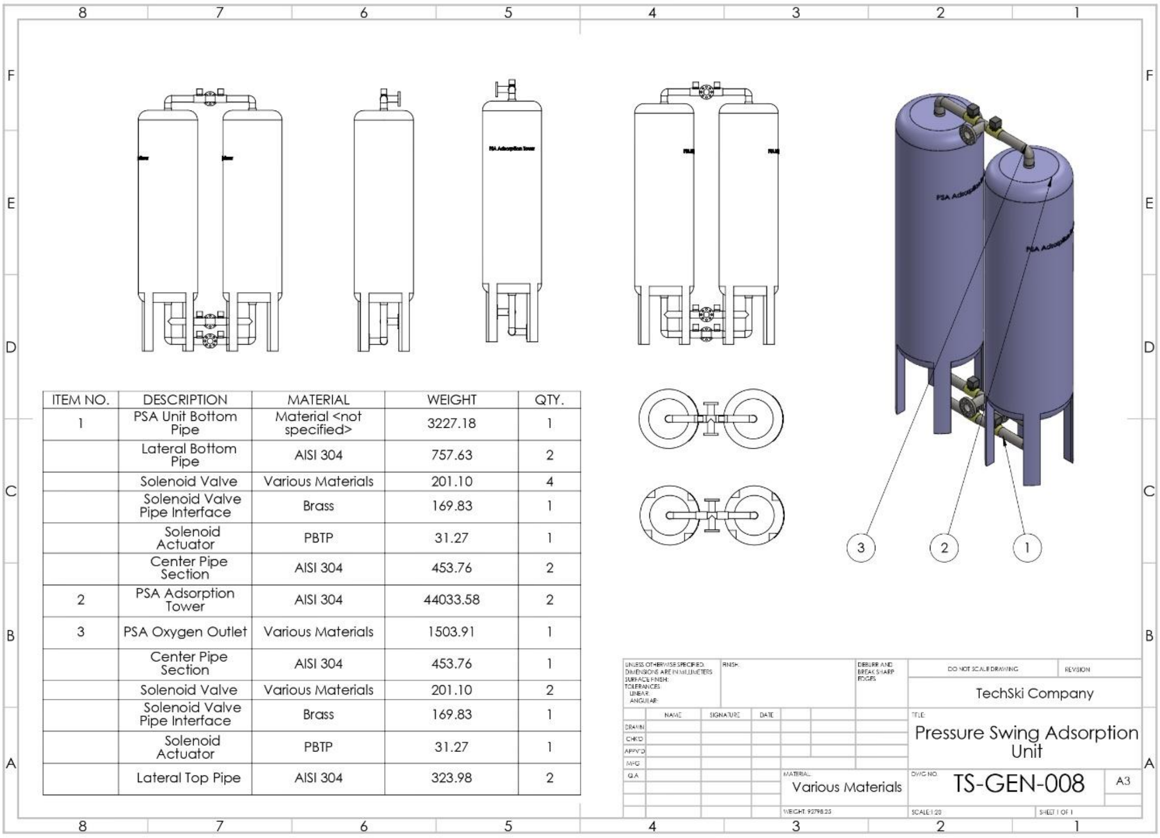


Figure III.10: Pressure Swing Adsorption Unit Technical Drawing

III.3.5. Gas Storage & Distribution System

III.3.5.1. Oxygen Storage Tank

To store pure oxygen

a) How It Works:

Controlled by solenoid valves, the oxygen storage tank accumulates oxygen produced by the PSA unit, serving as a buffer before supplying it to the analyzer.

b) Dimensions: 508 mm (Diameter) x 1000.00 mm (Hight)

c) Volume Sizing:

- D=508 mm which make The Radius: R=254 mm
- Hight: h=1000 mm

By **s**ubstituting the values into the equation number (6):

$$V(cyl) = \pi \times R^2 \times h = 3.14 \times 254^2 \times 1000 = 202580240 \quad mm^2 \tag{III.41}$$

From (III.41) we can say that the Oxygen Storage Tank has a volume of approximately 202.58024 liters.

d) Pressure Capacity:

Tank Parameters:

- Tank diameter (D): D=508.00 mm
- Wall thickness (t): t=5 mm
- Allowable stress of the tank material (S): S= 110.297

Where:

$$S = \frac{\text{Yield strength}}{\text{Safety factor}} = \frac{170 \text{ MPa}}{2} = 85 \text{ MPa} \tag{III.42}$$

- Weld efficiency (E): usually between 0.7 and 1.0 depending on weld type and inspection for our system we can assume that E=0.85
- Corrosion allowance (CA): CA = 1 mm, recommended for indoor installations like ours

By applying the formula from ASME Boiler and Pressure Vessel Code for internal pressure in a thin-walled cylindrical vessel:

$$P = \frac{2 \times S \times t \times E}{D - 2 \times CA} = \frac{2 \times 85 \times 4 \times 0.85}{508 - 2 \times 1} = 1.143 \text{ MPa} \tag{III.43}$$

We can conclude that the maximum allowable internal pressure (P) ≈ 1.43 MPa which is equivalent to 14.3 bar.

e) Component Configuration:

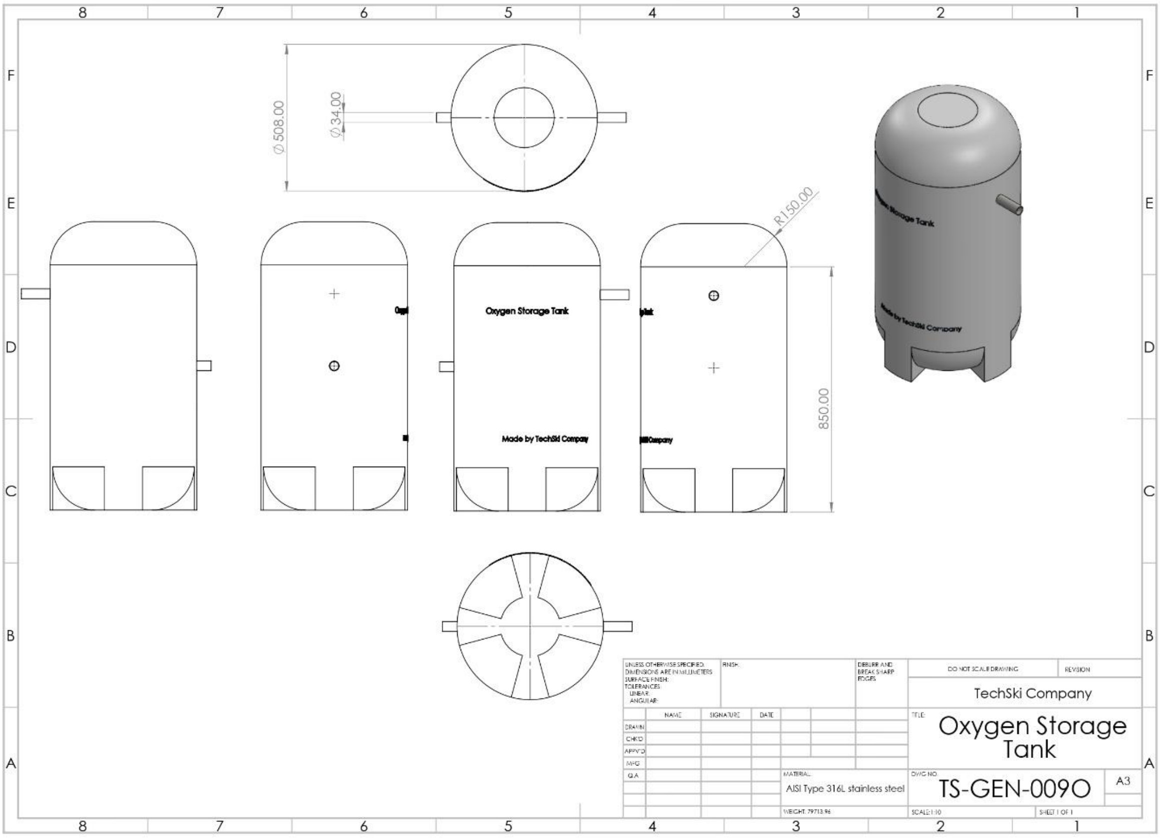


Figure III.11: Oxygen Storage Tank Technical Drawing

III.3.5.2. Nitrogen Storage Tank

To store pure Nitrogen

a) How It Works:

The storage tank collects nitrogen from both the membrane module and the PSA unit outlet, storing it before supplying it to the analyzer

b) Dimensions: 508.00 mm (Diameter) x 1000.00 mm (Hight)

c) Volume Sizing :

- D=508 mm which make The Radius: R=254 mm
- Hight: h=1000 mm

By substituting the values into the equation number (6):

$$V(cyl) = \pi \times R^2 \times h = 3.14 \times 254^2 \times 1000 = 202580240 \quad mm^2 \tag{III.44}$$

From (III.44) we can say that the Nitrogen Storage Tank has a volume of approximately 202.58024 liters.

d) Pressure Capacity:

Tank Parameters:

- Tank diameter (D): D=508.00 mm
- Wall thickness (t): t=4 mm
- Allowable stress of the tank material (S): S= 110.297

Where:

$$S = \frac{\text{Yield strength}}{\text{Safety factor}} = \frac{282.685049 \text{ MPa}}{2} = 141.3425245 \text{ MPa} \quad \text{(III. 45)}$$

- Weld efficiency (E): usually between 0.7 and 1.0 depending on weld type and inspection for our system we can assume that E=0.85
- Corrosion allowance (CA): CA = 2 mm, recommended for indoor installations like ours

By applying the formula from ASME Boiler and Pressure Vessel Code for internal pressure in a thin-walled cylindrical vessel:

$$P = \frac{2 \times S \times t \times E}{D - 2 \times CA} = \frac{2 \times 141.3425245 \times 4 \times 0.85}{520 - 2 \times 2} = 1.91 \text{ MPa} \quad \text{(III. 46)}$$

We can conclude that the maximum allowable internal pressure (P) ≈ 1.91 MPa which is equivalent to 19.1 bar.

e) Component Configuration:

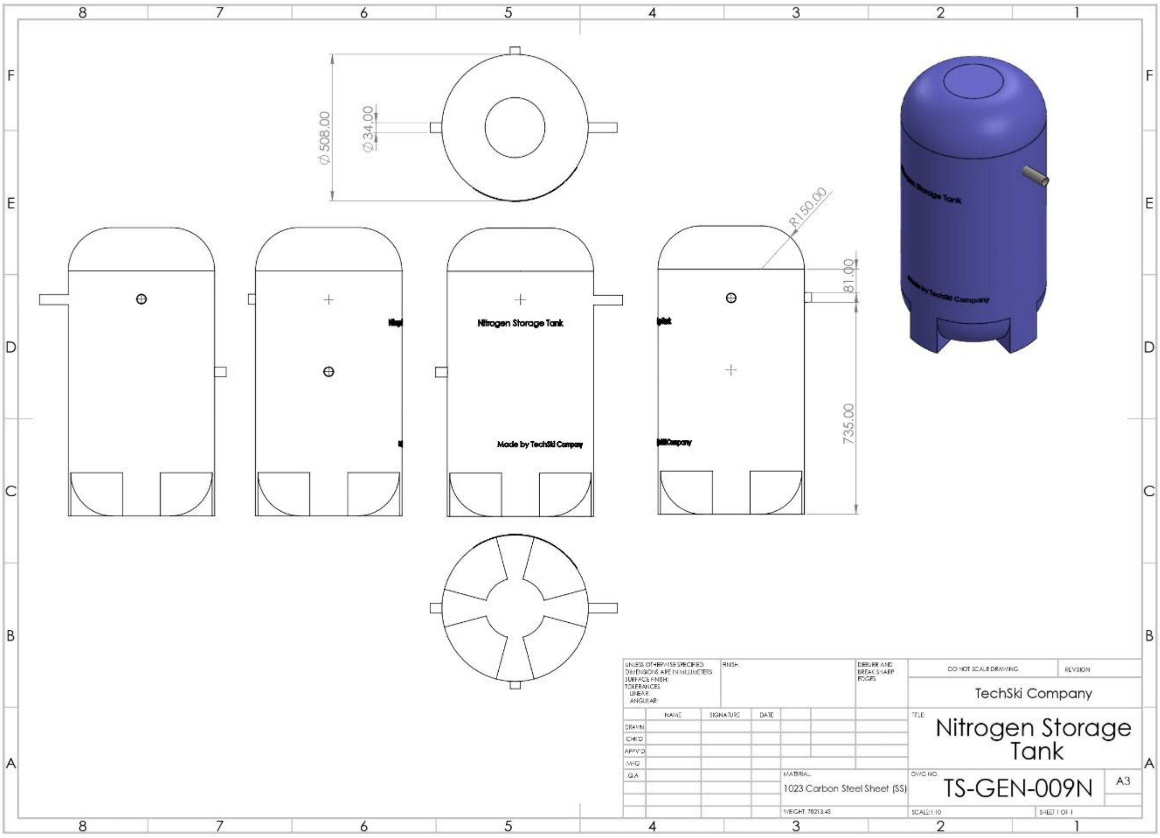


Figure III.12: Nitrogen Storage Tank Technical Drawing

III.3.5.3. Dual Gas Analyzer

To continuously Check the purity of Nitrogen and Oxygen produced by the generator

a) Dimensions: 1124.00 mm (Length) x 270.00 mm (Width) x 700.00 mm (Height)

b) Technology Used:

Introduction:

There are several technologies used to measure the concentration of oxygen or Nitrogen. Below is a brief analysis conducted by our team to highlight the main differences between them [29] [30] [31].

Table III.4: Comparison of Gas Purity Measurement Technologies

Technology	Principle	Avantages	Disadvantages
Paramagnetic Oxygen Detector	Oxygen is attracted to magnetic field due to its unpaired electrons	-Specific to oxygen -Quick Response time -Highly accurate	-Expensive -Sensitive to magnetic interference - Sensitive to vibrations
Zirconia Oxygen Detector	Due to the difference in oxygen partial pressure, ions move through the zirconium dioxide, creating an electrochemical potential.	-High Temperature Resistance -Quick Response time - Wide Measuring Range - High Stability	- Expensive -High Power Consumption -Incompatible with inert gases - Sensitive to by Contaminants
Electrochemical Oxygen Detector	Based on (oxidation reduction) which is a chemical reaction that generates an electric current proportional to oxygen levels.	-Cheaper Highly sensitive - Low Power Consumption	- Affected by Temperature and Humidity - Limited Lifespan
Laser Based Spectroscopy	By analyzing light absorption at specific wavelengths using Tunable Diode Laser Absorption Spectroscopy	-Quick Response time - Low maintenance Needed -Highly precise	-Expensive -Limited to gases with absorption lines
Thermal Conductivity Detector	Based on the fact that each gas has specific thermal conductivity	-Quick Response time - Suitable for gas mixtures	- Less accurate -Sensitive to contamination

	so, measuring the heat dissipation can lead to the identification of the gas concentration	- Wide range of gases	- Low selectivity
Mass Spectrometry	Based on mass To charge ratio, the gas sample is ionized, and the resulting ions a detected to determine the gas composition and concentration	- Multi-gas detection simultaneously -high accuracy	-Expensive - Requires vacuum System -Requires Maintenance

Conclusion:

For our dual gas analyzer, we aim to choose A Paramagnetic sensor for O_2 combined with Thermal Conductivity Detector (TCD) for N_2.

c) How It Works:

The flow is directed through the analyzer via controlled solenoid valves, where a paramagnetic sensor directly measures oxygen concentration and a thermal conductivity detector indirectly determines nitrogen concentration based on heat conductivity differences, before being exhausted through dedicated valves.

d) Energy Consumption:

From industry data sheets we can estimate that:

- Paramagnetic O_2 Sensor consume 5 watts.
- Thermal Conductivity Detector consume 10 watts
- Solenoids Valves consume 2 watts per one

So, The Total Estimated Power ≈ 25 W

Which make the Energy consumed:

$$\text{Energy(analyzer)} = 25\ \text{W} \times 1\ \text{h} = 25\ \text{Wh} = 0.025\ \text{kWh}$$

e) Component Configuration:

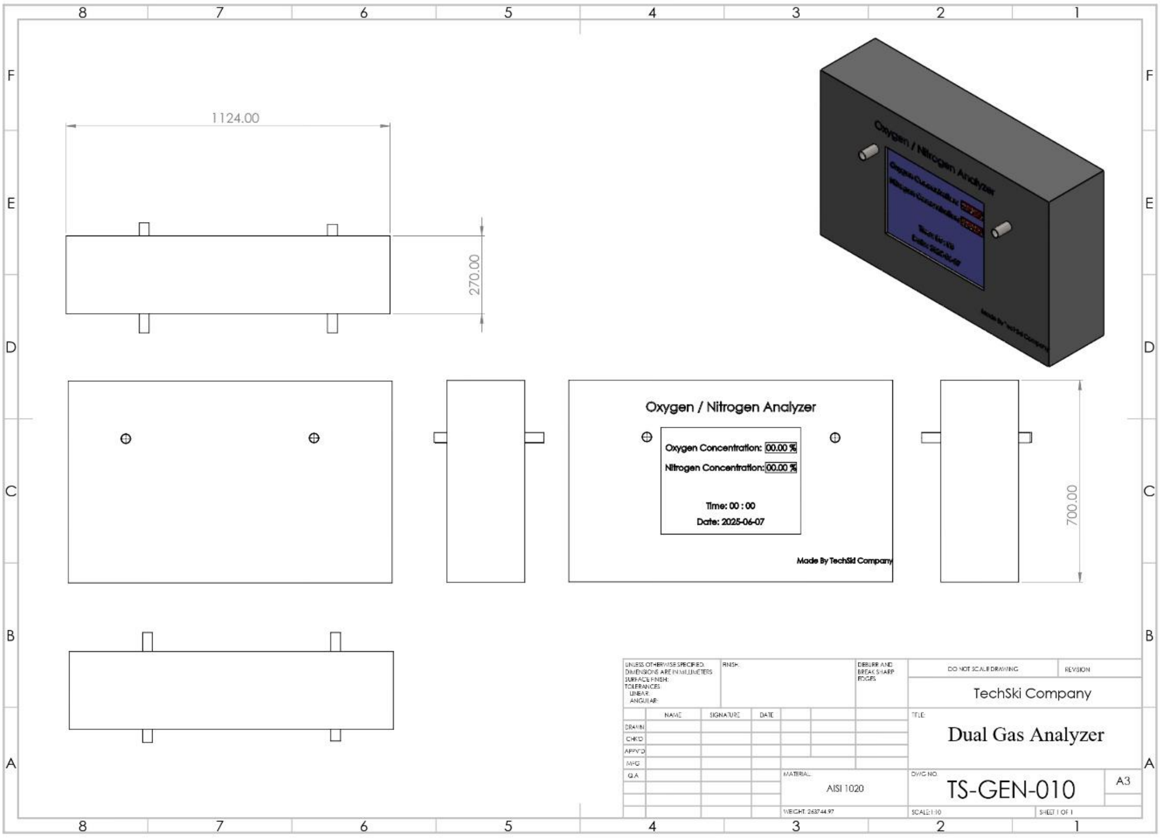


Figure III.13: Dual Gas Analyzer Technical Drawing

III.3.6. Automation and Control System

III.3.7.1. Electrical Box

Contain all the components related to Automation and Control System

a) Dimensions: 1000.00 mm (Height) x 600.00 mm (Width) x 250.00mm (Depth)

b) Component Configuration:

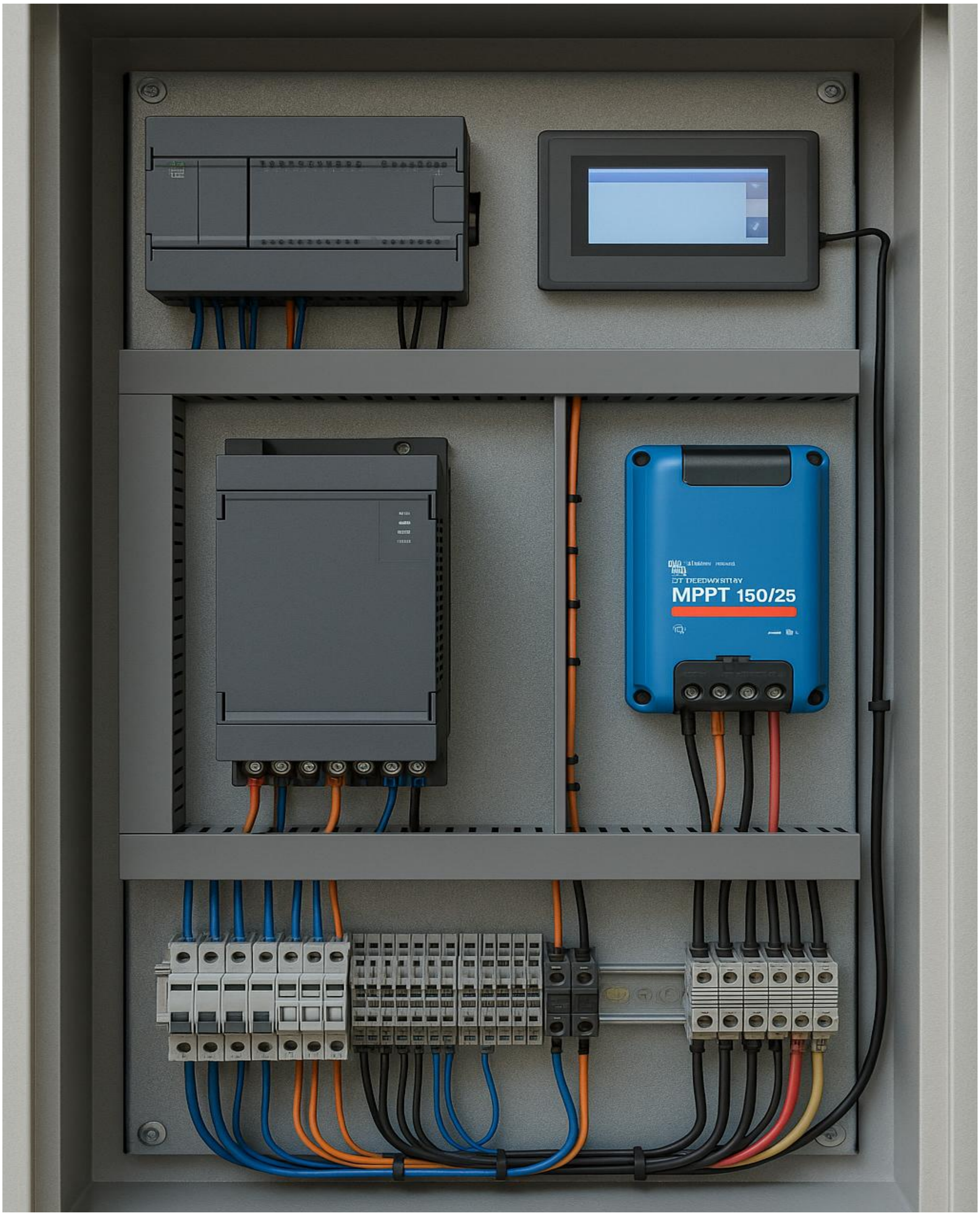


Figure III.14: Internal View of the Electrical Box

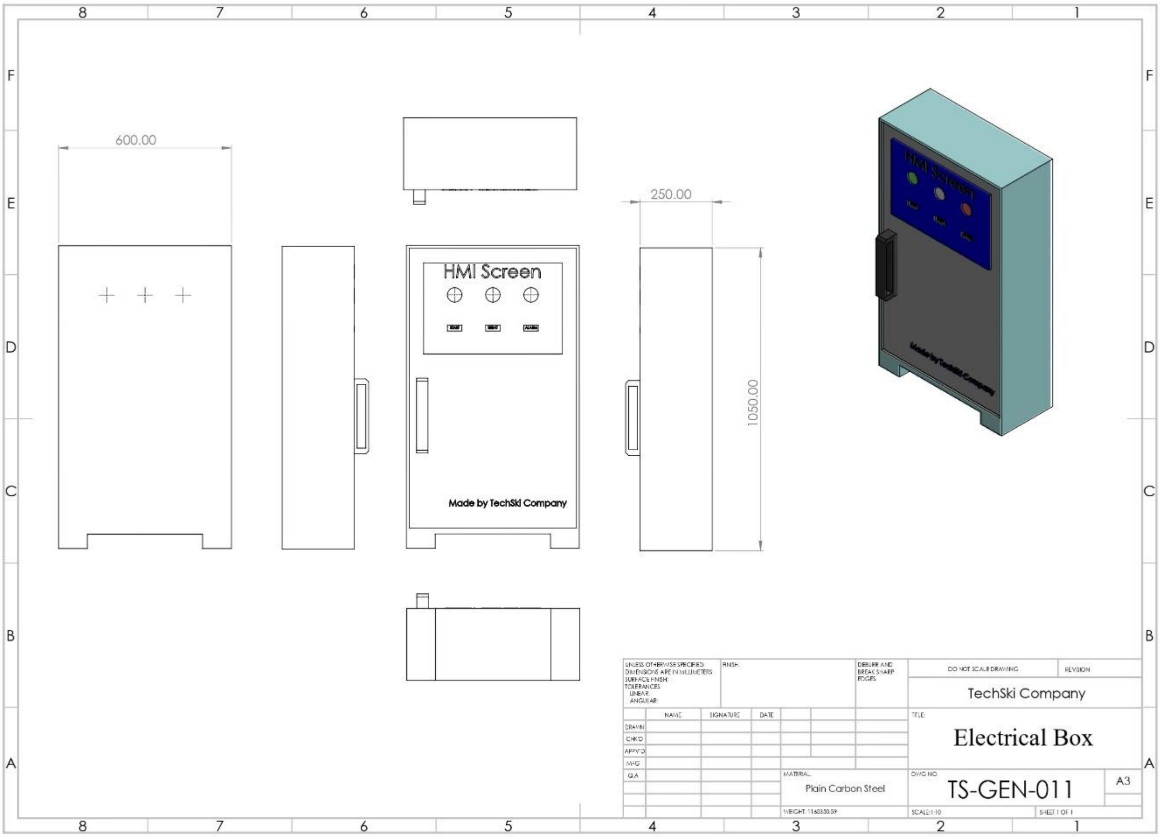


Figure III. 15: Electrical Box Analyzer Technical Drawing

III.3.6.2.PLC (Programmable Logic Controller)

a) Model: Siemens S7-1200

b) How It Works:

The PLC receives signals from:

- Pressure switch from the compressor
- Level switch from the tanks
- Prefilters data
- Pressure transmitters

And send signals to:

- Compressor contactor
- Alarms

Integrated with small Human machine interface (HMI) on site and capable to connect to internet for monitoring via specific application developed by TechSki Team.

c) Dimensions: 125.00 mm (Height) x 220.00(Length) mm x 75.00 mm (Depth)

Figure III.16: First Page of Siemens S7-1200 PLC Datasheet

III.3.6.2. Power Conversion Unit

To Convert DC to AC for motors, sensors, and fans.

a) Model: SINAMICS V20

b) How It Works:

Include :

- Rectifier (AC to DC)
- Inverter (DC to AC)
- DC/DC converter
- Fuse, protection
- Power relays and contactors

c) Dimensions: 204.00 mm (Height) x 184.00 mm (Width) x 150.00 mm (Depth)

III.3.6.2. Solar Charge Controller (MPPT Controller)

To Regulate battery charging

a) Model: Victron Energy Smart Solar MPPT 150/35

b) How It Works:

The MPPT controller tracks the maximum power point of the solar panel voltage and current to extract the highest efficiency, it then regulates the charging of the battery bank by adjusting the input power according to battery condition (bulk, absorption, float stages) which protects the battery from overcharge, deep discharge and overvoltage.

c) Dimensions: 250.00 mm (Length) x 180.00 mm (Width) x 90.00 mm (Height)

III.3.7. Power Supply System

III.3.7.1. Solar Panels

To generate electricity

a) How It Works:

By using the process called the photovoltaic effect, Solar panels convert sunlight into electricity

b) Dimensions: 1600 mm(length) × 1100 mm(width)

- Generator Total surface Area:

S = 3240 mm × 3304 mm = 10704960 mm²= 10.70496 m²

- Calculate The Number of Panels:

Divide surface Lenth by panel width:

$$\frac{3304}{1100} = 3.004 = 3 \text{ panles} \qquad (\text{III}.47)$$

Divide surface Width by panel Length:

$$\frac{3240}{1600} = 2.028 = 2 \qquad (\text{III}.48)$$

From the equations (III.47) and (III.78) the total Number of Panels is: 6 panels

Panel area: Pa=1.6m × 1.1m = 1.76 m².

c) Energy production capacity:

- We will use high-quality panels which make their Efficiency around 20%.
- Under Standard Test Conditions defined by the solar industry (IEC 61215, IEC 61646), the Peak Solar Irradiance is 1000 W/m².
- The Power Output per m² from the fundamental photovoltaic principle:

$$\text{Power Output per m}^2 \left(\frac{\text{W}}{\text{m}^2}\right) = \text{Solar Irradiance} \left(\frac{\text{W}}{\text{m}^2}\right) \times \text{Panel Efficiency (\%)} \qquad (\text{III}.49)$$

By Numerical application:

Power output=1000×0.20=200 W/m²

By Applying the previous calculations to our system, we can define the power produced by one panel in one hour:

$$\text{P1} = 1.76 \text{ m}^2 \times 200 \frac{\text{W}}{\text{m}^2} = 352 \text{ W} \qquad (\text{III}.50)$$

The power produced by all the panels in one hour:

Ps=352×6=2112 w

The Total Energy produced is:

$$\text{Energy (Wh)} = \text{Power (W)} \times \text{Sunlight Hours Efficiency Factor} \qquad (III.51)$$

In Normal Weather conditions the efficiency factor is 0.85

So, By Numerical application:

$$\text{Energy} = 2112 \times 0.85 = 1795.2\text{Wh}$$

At 8 hours of working per day The Total Energy produced is:

$$\text{Total Energy} = 1795.2 \times 8 = 14361.6\text{W} = 14.3616 \text{ Kwh}$$

d) Component Configuration :

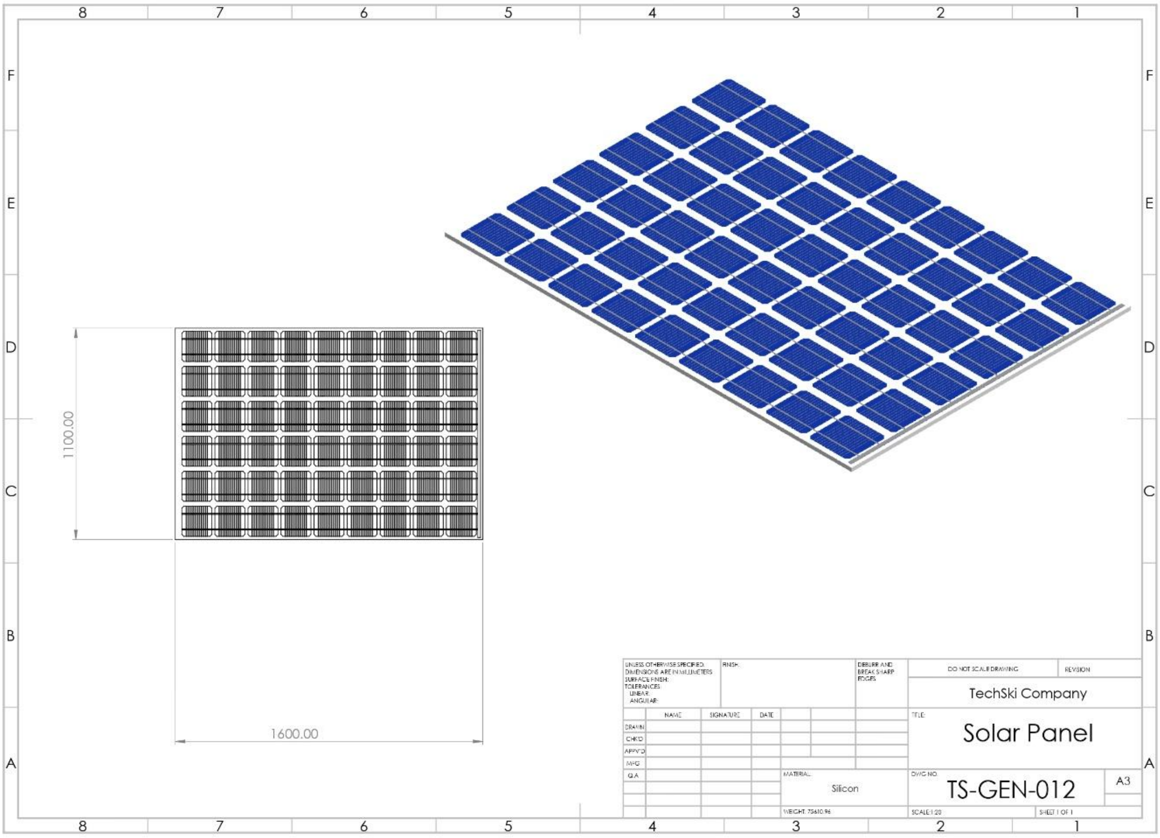


Figure III.17: Solar Panel Technical Drawing

III.3.7.2. Battery Bank

a) How It Works:

Operates based on the electrochemical reaction flowing these main steps:

- The battery bank receives Electrical energy from a power source.
- The charge controller regulates the input.
- The battery bank keeps this energy in a standby state.

- When power is needed, the battery bank supplies DC (Direct Current) electricity to the connected system such as the compressor or control system.

b) The choice of the Battery Bank:

The Energy consumed by the generator in one Hour:

By Numerical application to previous calculations under Energy Consumption Sections

$$Eg = 10.949 + 0.23 + 0.815 + 0.048 + 0.025 + 0.023 + 1.0 = 12.26612 \text{ KWh} \approx 13 \text{ KWh} \quad (III.52)$$

For 5 Hours of Working our generator needs 60 KW to deliver this amount we need to implement Battery Bank.

Lithium-ion batteries are 90 % the energy storage we will need is:

Eb=60/0.90=66.66 ≈ 67 KW

We applied the formula of Energy Density by Volume:

$$\text{Capacity (Wh)} = \text{Volume (m}^3) \times \text{Energy Density} \left(\frac{\text{Wh}}{\text{m}^3}\right) \quad (III.53)$$

Where :

- **Volume** is the physical space the battery occupies (in m^3) in our system there is around 0.6 m3
- **Energy (Capacity)** is the amount of energy that can be stored in our system equal to 67 KW
- **Energy Density** is measured in watt-hours per cubic meter

$$\text{Energy Density} = \frac{67000}{0.6} = \frac{111666.67 \text{ Wh}}{\text{m3}} \quad (III.54)$$

So, we need Battery Bank with these characteristics:

- Minimum Capacity: 67 kWh
- Maximum Volume: 0.6 m^3
- Minimum Energy Density: ≥ 111,666.67 Wh/m^3
- Technology: Lithium-ion
- Dimensions: 1000 mm (Height) 1200 mm 500 mm (Depth)

c) Component Configuration :

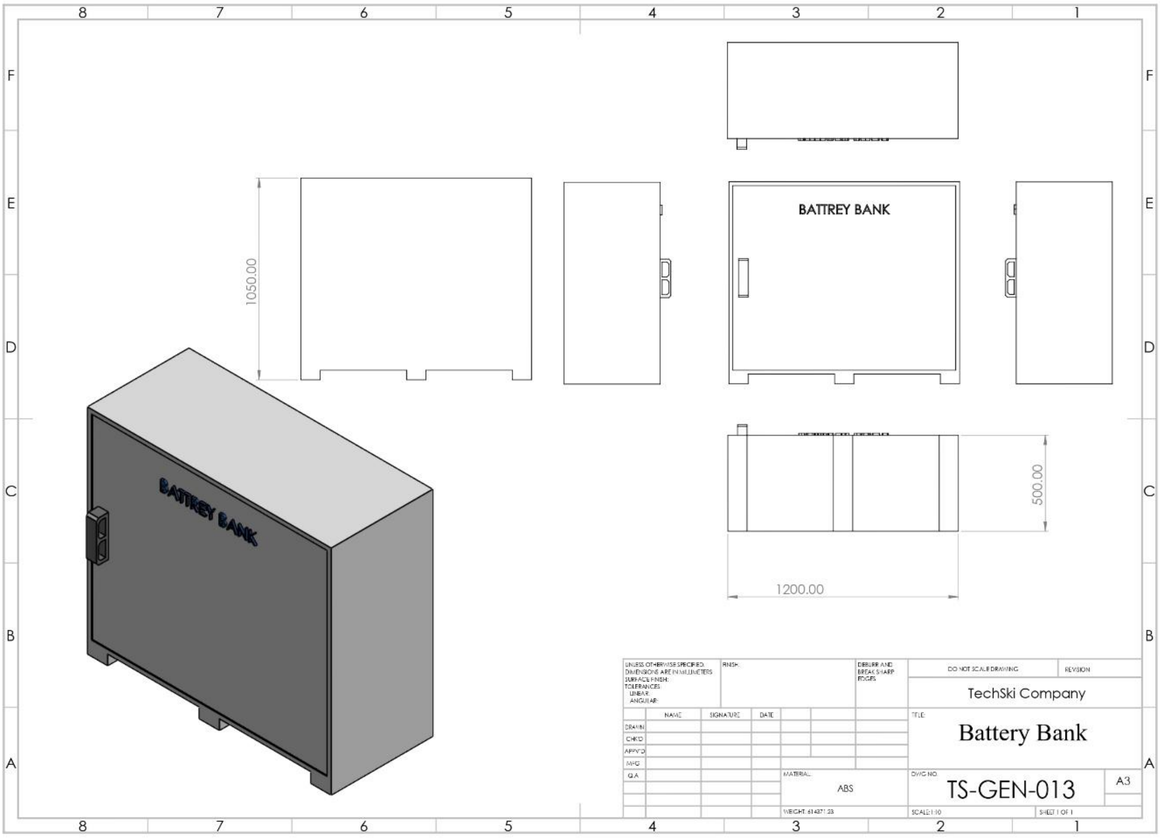


Figure III.18: Battery Bank Technical Drawing

III.3.7.3. Cooling Fans

To Cool components in hot weather

a) How It Works:

They work under the principle of moving air to dissipate heat from a system or environment, since these fans are used to cool components in sunny days, we will connect them directly to the solar power unit after electronic configurations such as putting temperature sensors to Control Fan speed.

b) Dimensions: 682.46 mm (Diameter) x 100.00 mm (Hight) each (two fans)

c) Energy consumption:

Based on fan manufacturer data a fan of 680 mm diameter consumes about 500 W.

So, two fans would consume around 1.0 kWh per hour.

d) Component Configuration:

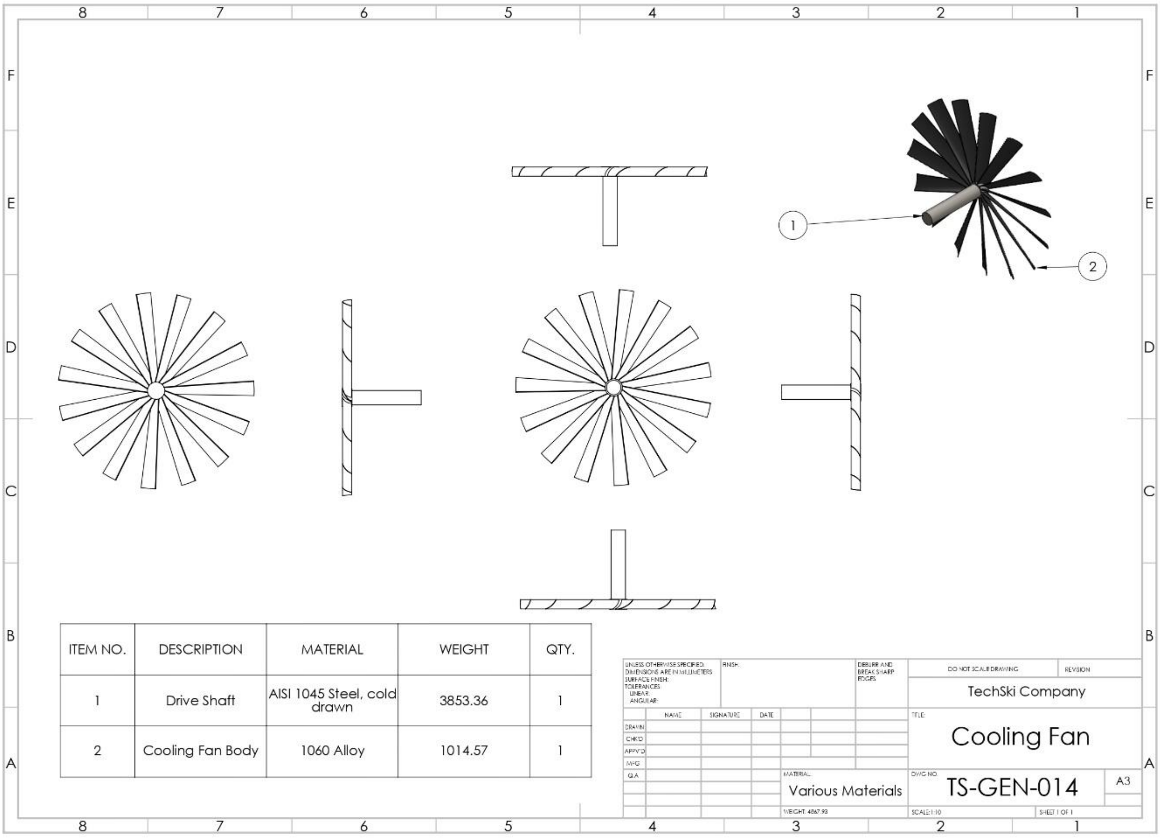


Figure III.19: Cooling Fan Technical Drawing

III.3.8. External Box

Most gas generators do not come with an external enclosure, but offering this feature will provide added protection, especially for sensitive components, reducing the risk of damage.

a) Component Configuration :

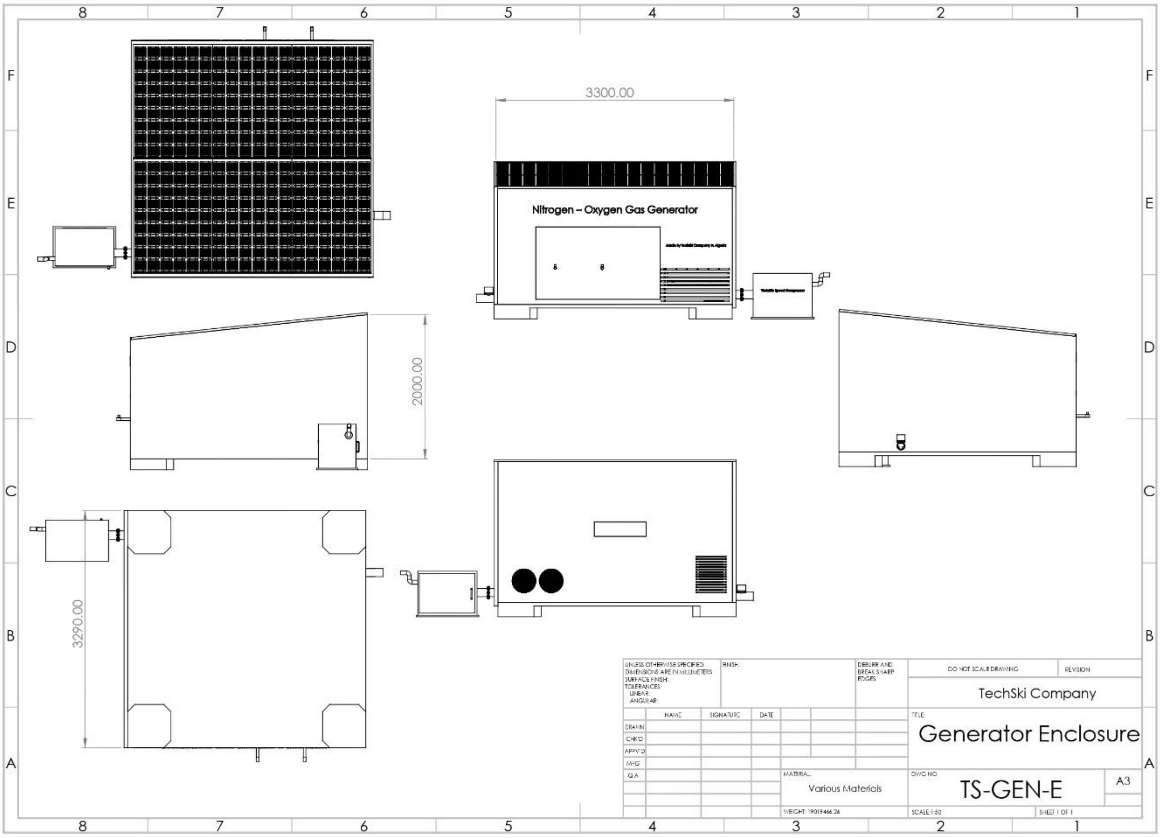


Figure III.20: Generator Enclosure Technical Drawing

III .4. Presentation of the 3D Prototype in SolidWorks:

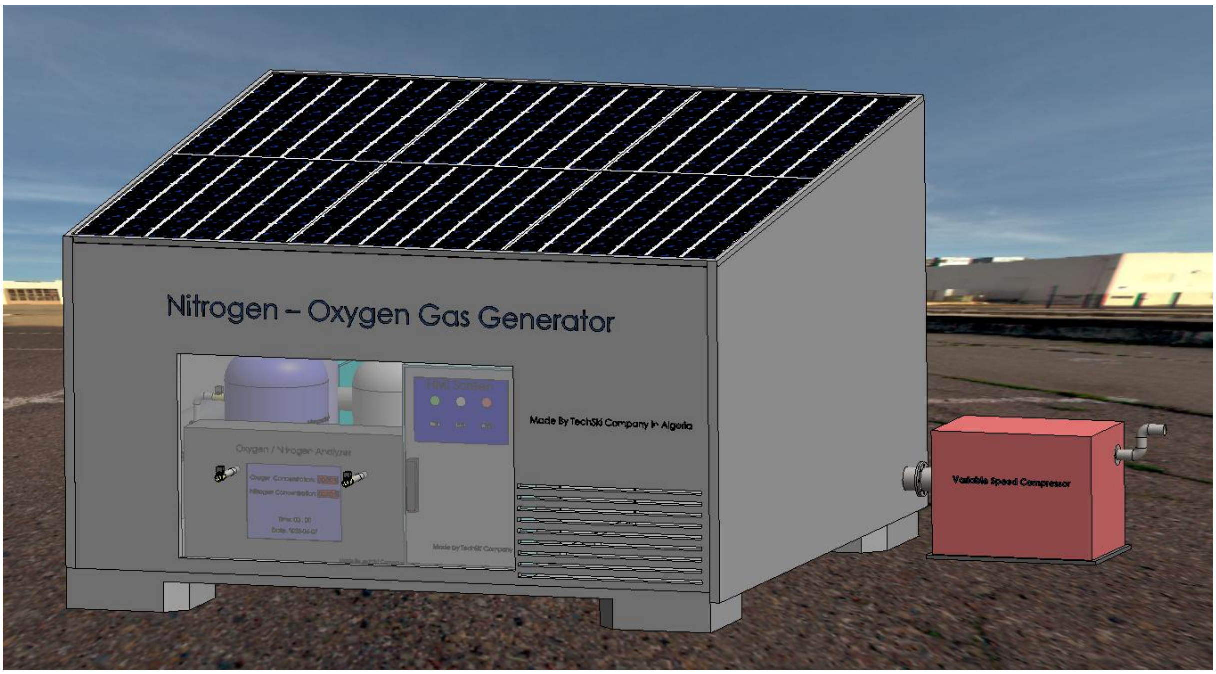


Figure III.21: Image illustrating the external view of the generator

The full SolidWorks presentation is available via the following Google Drive link:

https://drive.google.com/drive/folders/1S3qWr6FpQAEZCSA1gomn2Ei89Ou2cSqA?usp=drive_link

Chapter IV
Innovative Aspects

IV.1. Introduction

Our project is not devoid of innovative aspects which are specifications related to our generator listed below:

IV.2. Architecture Optimization

IV.2.1. Separated Air Supply

For several reasons outlined below, we have chosen an architecture based on physically separating the air compressor from the generator unit.

- Installation flexibility.
- Simplified maintenance.
- Reduction of vibration and noise to protect the system's sensitive components.
- Optimized Power Management System, specifically when the solar energy provided by the generator is insufficient.

IV.2.2. Gas Flow Regulation based on demand

Due to the variable speed compressor implemented into our system, the gas production will dynamically adapt to meet real-time demand.

IV.2.3. Drying Configuration

Since the desiccant air dryer requires more energy and space, we will use a refrigerated dryer along with a small inline desiccant cartridge placed just before the Membrane unit as a safety dryer, to remove any remaining moisture after the aftercooler and the coalescing filter.

IV.3. Pressure and Energy Optimization

IV.3.1. Cascade Setup

We use the membrane separation unit first because it operates at a higher pressure (8–12 bar), whereas the PSA unit operates at a lower pressure (4–6 bar). Since the compressed air enters the system at high pressure, it is more efficient to feed it to the membrane unit first before reducing the pressure for the PSA unit.

IV.4.1.PSA Stream Exploitation for Enhanced Nitrogen Recovery

In our system, we want to produce nitrogen using a membrane, while also recovering the nitrogen waste stream from the PSA system used for oxygen production, in order to optimize ambient air utilization and reduce losses.

IV.5. Designing for Safety using

Adding a safety factor is both original and professional. While many machine designers ignore this step, we chose to work with a safety factor of 2, especially in some calculations provided in the sections above. This means our system is designed to handle twice the required capacity, making it very robust.

IV. Conclusion

The Smart Designer consistently is committed to integrating intelligent configurations and that’s exactly what we did in this version and we're also considering adding new features like recovering clean water from the drying process.

General Conclusion

combining gas engineering, renewable energy, automation, and 3D design we made a clear vision to our project which consists of developing a compact, hybrid gas generator that produces nitrogen (N_2) and oxygen (O_2) from ambient air using membrane and PSA (Pressure Swing Adsorption) technologies.

The generator's architecture is not universal or rigid, it can be adapted or modified even while in use.

Even so, realizing this project and make it true on site will going to show ass some differences between the calculation we did and the real behavior of the system.

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DEMOCRATIC AND POPULAR ALGERIAN REPUBLIC

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

20 AUGUST 1955 UNIVERSITY SKIKDA

FACULTY OF TECHNOLOGY

DEPARTMENT OF PETROCHEMISTRY

Thesis

In pursuit of obtaining the Master's degree

Field: Petrochemical Industries

Specialization: Automation in the petrochemical industry

Conception and Realization of Tracking Device

Realized by:

Laouacheria Nidal

Bouabdellah Badreddine

Supervised by:

Mr. Bendib Riad

2024-2025

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Finally, we wish to express our deepest gratitude to everyone who has supported us, whether near or far, through their unwavering kindness, encouragement, and invaluable contributions. Your presence and assistance have made a profound impact.

It is with great pleasure that I dedicate this modest work:

- ❖To the dearest person in my life, my mother.
- ❖To the one who made me a man, my father.
- ❖To my brother and my sister.
- ❖To my partner, Badrou.
- ❖To all my friends.
- ❖To all the members of my family.

I dedicate this work to all those who have contributed to my success.

“Laouacheria Nidal”

I dedicate this thesis

- ❖ To my dear family, for their love, patience, and constant support throughout my journey.
- ❖ To my friends, for their presence, encouragement, and advice.

And to all those who, in one way or another, helped me reach this goal.

“Bouabdellah Badreddine”

الملخص

أصبحت تقنيات التتبع ضرورية في العديد من القطاعات مثل النقل والخدمات اللوجستية، والسلامة الشخصية وإدارة الأصول لذلك قررنا استكشاف هذا المجال وتطبيقاته وأشكاله المختلفة من خلال تطوير نموذج أولي لجهاز تتبع يدمج بين المكونات الصلبة والبرمجية، لتمكين التتبع في الوقت الحقيقي مع ضمان كفاءة في استهلاك الطاقة ودقة في معالجة البيانات.

الكلمات المفتاحية: تقنيات التتبع، الوقت الحقيقي، معالجة البيانات.

Résumé

Les technologies de suivi sont devenues essentielles dans de nombreux secteurs tels que le transport, la logistique, la sécurité personnelle et la gestion des actifs et c'est pourquoi nous avons décidé d'explorer ce domaine, ainsi que ses différentes applications et formes, en développant un prototype de dispositif de suivi intégrant à la fois des composants matériels et logiciels, en mettant l'accent sur l'utilisation des modules GPS et GSM pour permettre un suivi en temps réel tout en assurant une efficacité énergétique et une précision dans le traitement des données.

Mots clés : Les technologies de suivi, temps réel, le traitement des données.

Abstract

Tracking technologies have become essential across numerous sectors such as transportation, logistics, personal safety, and asset management so we decided to explore this domain and its various applications and forms by developing a tracking device prototype that integrates both hardware and software components, focusing on the use of GPS and GSM modules to enable real-time tracking while ensuring power efficiency and accuracy in data processing.

Keywords: Tracking technologies, real-time, data processing.

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Abbreviation

GPS: Global Positioning System

GSM: Global System for Mobile Communications

MQTT: Message Queing Telemetry Transport

IP: Internet Protocol

RFID: Radio Frequency Identification

General Introduction

General Introduction

In an increasingly connected world, tracking technologies play a vital role in various fields, including transportation, logistics, personal safety, and asset management. The ability to monitor the real-time location and movement of objects or individuals has become essential for improving operational efficiency, ensuring security, and enhancing user experience. This thesis, titled "Conception and Realization of a Tracking Device," aims to design and implement a reliable, efficient, and cost-effective tracking system capable of transmitting real-time data using modern communication technologies.

The project involves both hardware and software development, with a focus on integrating GPS and GSM modules, ensuring power efficiency, and providing accurate data communication. The ultimate goal is to create a functional prototype that can serve as the foundation for various practical applications such as vehicle tracking, personal safety devices, and smart logistics systems.

Through this work, we explore the full development process—from the initial concept and design phase, through component selection and circuit implementation, to programming and system testing—highlighting the challenges encountered and the solutions adopted to achieve a fully operational tracking device.

Thus, our study is separated into three chapters:

- General information about localization and embedded systems
- System hardware and material selection
- System realization

Chapter I

General information about localisation and embedded systems

I.1 Introduction

Determining geographical location has become an important part of our daily lives, whether it's tracking the location of a car, animal, or even using navigation apps on our phones. This ability relies on localisation technologies such as the Global Positioning System (GPS) which allow us to know exactly where exactly something is at any time.

However, these technologies do not work on their own they require small embedded systems within devices to collect the information, process it, and send it to the user. These systems are known as embedded systems, which are like small computers designed for single task, such as receiving location data or transmitting it over the internet.

In this chapter, we will take a simplifies look at the concepts of localisation and embedded systems, explain how each of them works, and how to integrate them to create smart solutions that serve various fields.

I.2 Principle of geolocation

I.2.1. Definition

It is technical process that aims to determine the location of person or device on the Earth, based on satellite signals, wireless network data, mobile phone networks or even IP address. This technology is used in many applications, such us vehicle or animal tracking, maps, smartphone applications, and even securing devices against theft.

I.2.2. Geographic coordinate system

A geographic coordinate system is a system three-dimensional spherical surface to determine locations on the Earth. Any location on Earth can be referenced by a point with longitude and latitude coordinates.

The following illustration shows a geographic coordinate system where a location is represented the coordinates longitude 80 degree east and latitude 55 degrees north. [1]

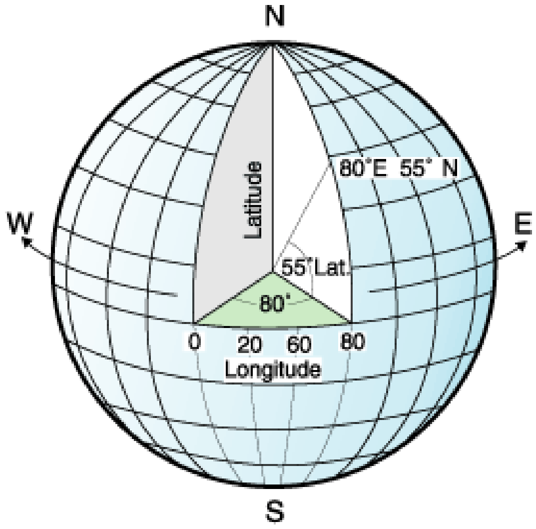

Figure I.1: Geographic coordinate system

The lines that run east and west each have a constant latitude value and are called parallels. They are equidistant parallel to one other, and form concentric circles around the Earth. The equator is the largest circle and divides the Earth in half. It is equal in distance from each of the poles, and the value of latitude line is zero. Locations north of the equator have positive latitude that range from 0 to +90 degrees, while locations south of the equator have negative latitude that range from 0 to -90 degrees.

The following illustration shows latitude lines.

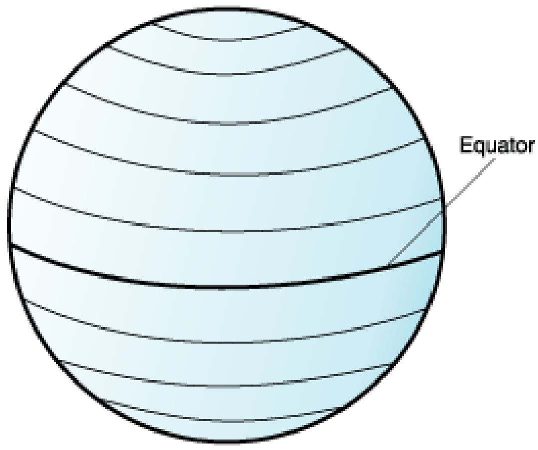

Figure I.2: Latitude lines

The lines that run north and south each have a constant longitude value and are called meridians. They form circles of the same size around the Earth, and intersect at the poles. The prime meridian is the line of longitude that defines the origin (zero degrees) for longitude coordinates. One of the most commonly used prime meridian locations is the line that passes through Greenwich, England. Locations east of the prime meridian up to its antipodal meridian have positive longitudes that range from 0 to +180 degrees. Locations west of the prime meridian have negative longitudes that range from 0 to -180 degrees.

The following illustration shows longitude lines.

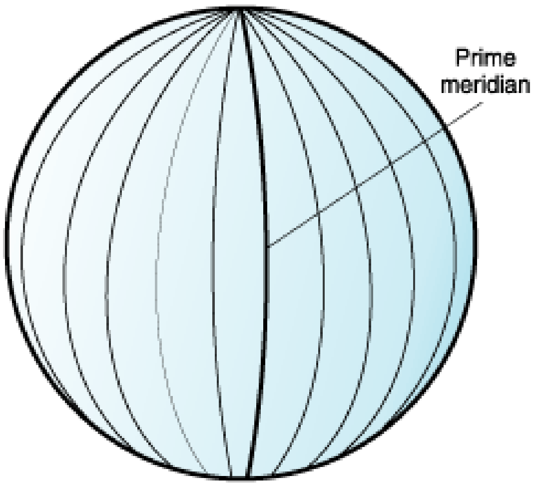

Figure I.3: Longitude lines

Latitude and longitude lines form a grid called a graticule that covers the Earth. The center point is (0,0), where the equator meets the prime meridian. At the equator, one degree of latitude and longitude covers about the same distance. But since longitude lines come colder together near the poles, this changes as you move north or south. Latitude lines are circles that shrink toward the poles, making it hard to measure
exact distances. For example, while one degree of longitude at the equator is around 111.3 km, it's only about 55.8 km at 60° latitude. So, because the distances between degrees vary, you can't measure space accurately just using degrees.

The following illustration shows the different dimensions between locations on the graticule.

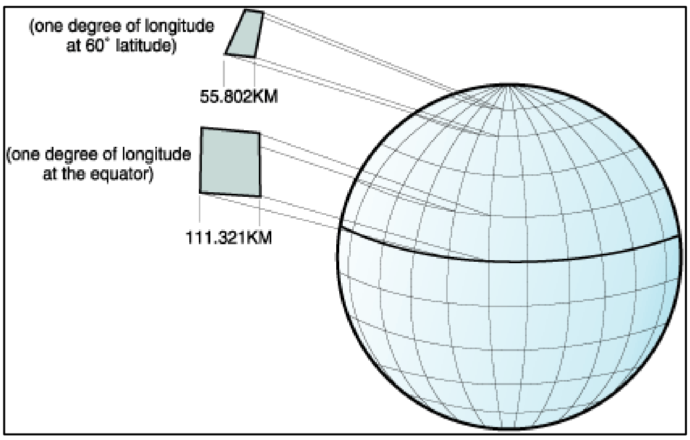

Figure I.4: Different dimensions between locations on the graticule

I.2.3. Geolocation Techniques

I.2.3.1. Geocoding

Geocoding software allows us to calculates and assings X, Y positions to an address or an object on a vector map, with an average accuracy of a few dozen meters.

I.2.3.2 Satellite Geolocation

Satellite geolocation involves calculating the current position of a device equipped with a compatible chip using signals from dedicated satellite constellation. This position is expressed in altitude, longitude, and sometimes altitude, and can be displayed on a map. The most well-known satellite positioning system is GPS, although the European alternative, Galileo, is being deployed.

I.2.3.3 Geolocation by GSM

This technique determines the location of a GSM device based on information about the GSM antennas it is connected to.

Positioning accuracy ranges from 200 meters to several kilometres, depending on whether the device is in an urban area (with high antenna density) or a rural area.

There are several methods exist:

- EOTD (Enhanced-Observed Time Difference): the device calculates the time between sending and receiving a signal to estimate its distance from the antenna.
- Time of Arrival (TOA)
- Angle of Arrival (AOA)
- Cell ID: The Cell ID is the most commonly used method today. It retrieves the IDs of connected GSM antennas and estimates the device's position.

I.2.3.4. Wi-Fi Geolocation

Just like a GSM device can determine its location using the Cell ID method on a GSM network, a Wi-Fi-enabled device can sue similar method based on the identifiers (MAC addresses) of nearby Wi-Fi access points along with their geographic locations. These databases mat be determined by private companies or community projects that offer them for free. They are built using a technique called War Driving, which involves driving through city streets with a Wi-Fi-enabled laptop connected to a GPS receiver to record as many Wi-Fi access points as possible.

I.2.3.5. Geolcation by IP address

This method determines the geographical location of a computer or any internet-connected device based on its IP address. IP addresses are managed by IANA, an organization that allocates IP address blocks in a controlled manner to requesting countries. Because these allocations are well-documented, it's possible to identify the country of a connected device using its IP address. In some cases, the location can be determined down to the city level, depending on how internet service providers distribute IP addresses.

I.2.3.6 RFID Geolocation

RFID technology can be used for indoor geolocation by deploying a series of RFID readers with various antennas to cover the desired area. The space is divided into zones or grid cells, whose size depends on the number and power of the readers. When a person with an active RFID tag enters one these zones, the system estimates their location based on how many readers detect the tag and refers to the predefined grid. In real time, this method is fairly imprecise and usually only identifies the room or hallway the person is in.

Accuracy can be greatly improved if the location data is processed after the fact. By analysing movement history and using probabilistic calculations based on reader signals and their strength, systems can achieve up to one-meter accuracy indoors under ideal conditions.

Real-time indoor localization is challenging due to constantly changing environments-like doors opening or furniture moving-which affect signal strength and range. These factors hinder accurate triangulation with RFID, so grid-based approaches are typically preferred.

This technique should not be confused with simple zone entry/exit detection, where low-power RFID readers at doors track when tagged individual passes through. This simpler method is often used in hospital. [2]

I.3. GPS

I.3.1 Definition

The Global Positioning System (GPS) is satellite-based navigation system developed by the United State Department of Defense. It enables us to determine the geographic position (latitude, longitude and altitude) anywhere on Earth. It works by receiving signals from multiple satellites and calculating the user’s precise position through the measurement of travel time of the signals.

I.3.2 History of the Global Positioning System (GPS)

The Global Positioning system (GPS) has its roots in the Cold War era, starting when the Soviet Union launched the Sputnik I satellite. This event kicked off the space age and inspired the U.S. to explore ways to use satellites to study and navigate Earth. Over time, GPS evolved into a global tool used by people all over the world. A major breakthrough came in 2000 when the U.S. government removed Selective Availability, making GPS more accurate and unlocking new technological possibilities.

Highlights in GPS history:

<u>1950-1969:</u>

- 1957 – The Soviet Union launches Sputnik I satellite.
- 1959 – The U.S. Navy builds Transit system satellites to begin tracking

submarines.

• 1963 – The Aerospace Corporation completes a military study, laying the groundwork for the modern-day GPS system.

1970-1989:

- 1974 – The first NAVSTAR test satellite is launched by the U.S.
- 1978 – The U.S. begins the launch of 11 test satellites as a part of their Block I GPS program.
- 1983 – After the Korean Air Lines Flight 007 crash, the U.S. announces it will make GPS available for civilian use to improve navigation and increase safety for air traffic.
- 1985 – The U.S. government opens contracts with private companies to create portable GPS receivers.
- 1989 – GPS Company, Magellan, introduces the first hand-held GPS device, the NAV 1000. The first fully operational satellite is launched by the U.S. Air Force as a part of their Block II program.

1990-1999:

- 1990 – The U.S. Department of Defense begins decreasing the accuracy of GPS readings for non-military use, stating fear of adversaries gaining military advantages as the reason behind the decision. This became known as Selective Availability.
- 1991 – GPS plays a significant role in U.S. operations during the Gulf War, despite the system not being fully operational.
- 1995 – The U.S. military declared Full Operational Capability (FOC) of all 24 satellites in the GPS constellation.
- 1998 – The U.S. Vice President Al Gore announces a plan for GPS III satellites to send two additional signals for civilian and aircraft use.
- 1999 – Mobile phone manufacturer, Benefon, introduces first commercial GPS phone.

2000-2019:

- 2000 – The U.S. ends Selective Availability, allowing for greater commercial GPS use and innovations.
- 2004 – U.S. electronics company, Qualcomm, successfully completes a test of live assisted GPS on a mobile phone, which allows for cellular and GPS signals to combine for better location accuracy.
- 2005 – The first of Block IIR satellites is launched, allowing for a dedicated civilian GPS channel.

- 2010 – U.S. launches first of 12 Block IIF satellites. This is the first satellite to be launched as a part of the Evolved Expendable Launch Vehicle (EELV), otherwise known as a modern rocket.
- 2016 – The last of the Block IIF satellites launches, marking an end to the extensive Block II program that ran from 1989 to 2016.
- 2018 – The U.S. Air Force successfully launches the first GPS III satellite.
- 2019 – The second GPS III satellite is launched from Cape Canaveral on a SpaceX Falcon9.

2020-present:

- 2020 – The U.S. Space Force announces that due to the Covid-19 pandemic, the SpaceX launch of the GPS III-3 satellite is delayed. [3]

I.3.3 System Architecture

The GPS system consists of three segments: space segment, control segment and user segment. [4]

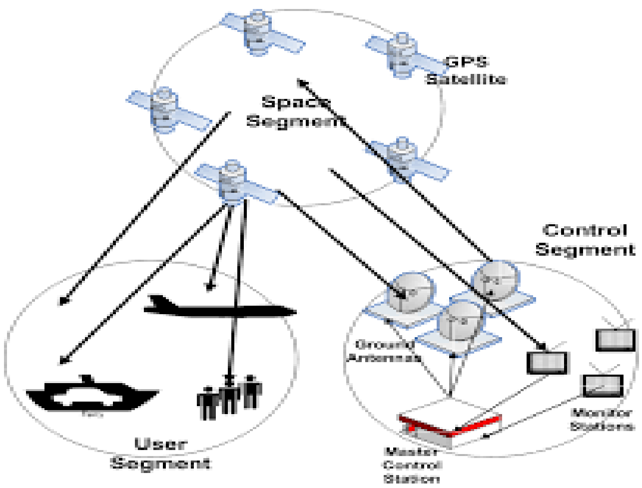

Figure I.5:GPS Segments

- **Space segment:**

The space segment represents one of the three essential components of the GPS. It consists of a network of at least 24 active satellites, orbiting the Earth at an altitude of approximately 20,200 kilometres. These satellites are arranged in six orbital planes, inclined at 55° to the equator, with each orbit taking approximately 11 hours and 58 minutes to complete. Each satellite is equipped with high-precision atomic clocks and transmits signals continuously that include its exact position and the precise time.

Figure I.6:GPS Satellite

- **Control segment:**

The control segment of the Global Positioning System (GPS) is a network of ground stations. It is responsible for tracking GPS satellites, monitoring their transmission, computing the precise orbits and synchronized satellite clocks. It ensures that the satellites are functioning correctly.

It is composed of:

- Master Control Station (MCS): Located in Colorado Springs, USA. It provides overall command and control of the GPS constellation. It processes data from monitor station to compute precise satellite position, monitors satellite health and system integrity, and performs satellite maintenance including normally resolution and repositioning.
- Monitor Stations: A network of 16 global sites (6 operated by the Air Force and 10 by the Nation Geospatial-Intelligence Agency) that track satellites as they pass overhead. They collect navigation signals, range and carrier measurements, and feed this information to the MSC.
- Ground Antennas: These communicate with the satellites by sending commands, navigation data uploads, and processor program loads. They also collect telemetry and perform ranging to support anomaly resolution and early orbit operations.

Figure I.7:Control Segment

- **User segment:**

It refers to the equipments and devices used by individuals and organizations to receive and satellites. utilize GPS signals for navigation, positioning and timing purpose. This segment includes GPS receivers composed of antennas tuned to satellite frequencies, receiver-processors, and highly stable clocks. These receivers calculate the user's precise location, speed, and time by processing signals from GPS.

Figure I.8: User Segment

I.3.4 GPS Operating Principle

GPS works by using a method called trilateration to figure out your exact location, speed, and height. It does this by collecting signals from satellites orbiting on the Earth. Many people confuse trilateration with triangulation, but they are different trilateration measures distances, while triangulation measures angles.

Satellites orbit the Earth and constantly send signals. A GPS device on or near the Earth's surface receivers these signals. To accurately find your position, the device needs to connect at least four satellites.

Each satellite goes around the Earth twice a day and sends out a unique signal that includes its location and the time. At any given moment, a GPS device can usually pick up signals from six or more satellites.

When a GPS device receives a signal from a satellite, it can calculate how far away it is. But knowing the distance from just one satellite isn't enough – it only tells you that you're somewhere on sphere around that satellite, your possible location is narrowed down to the intersection of two spheres. A third satellite further narrows it to two points and the fourth helps to confirm the correct one, which is usually closest to the Earth's surface. [5]
Here is an illustration of satellite ranging:

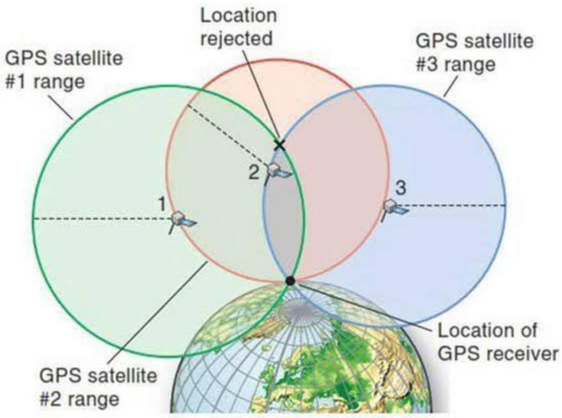

Figure I.9: Trilateration

As you move, your distance to each satellite changes and the GPS device updates your position. It also set timing data to figure out how fast you're going and how long it'll take to reach your destination.

I.4 GSM

I.4.1 Definition

GSM (**G**lobal **S**ystem for **M**obile communication) is a digital mobile network that is widely used by mobile phone users. It enables users to transmit data, make phone calls and exchange text messages seamlessly. It is originally developed in Europe in 1980 by the European Telecommunication Standards Institute (ETSI).

I.4.2 Architecture

The GSM network is built on modular architecture designed to manage mobile communication efficiently. [6]
It consists of three main subsystems, each with its own purpose**:**

- **Base Station Subsystem (BSS):** This is the part of the network that handles the radio connection between your mobile phone and the GSM system. It includes:
  - **Base Transceiver Station (BTS):** Sends and receives radio signals to and from mobile devices.
  - **Base Station Controller (BSC):** Manage multiple BTS units, allocate radio channels, and handles handovers when a user moves between cells.
- **Network and Switching Subsystem (NSS):** This is the brain of the GSM network,

managing call switching, user mobility, and subscriber data. Key components include:

- **Mobile Switching Center (MSC):** Routes calls and SMS, connecting users to other networks.
- **Home Location Register (HLR):** Database that stores permanent subscriber details, such as phone number and current location.
- **Visitor Location Register (VLR):** Temporarily holds data about users who are currently in the MSC's area.
- **Equipment Identity Register (EIR):** Verifies device identity and blocks stolen or unauthorized phones
- **Authentication Center (AC):** Ensures that only legitimate users access the network by providing security credentials.
- **Operations and Support Subsystem (OSS):** The OSS is the network's control room. It helps telecom operators monitor and maintain the network. Its roles include the monitoring network performance, configuring and updating network equipment, and diagnosing and fixing technical issues.

I.5 Embedded System

I.5.1. Definition

An embedded system is a specialized computer system designed to perform a specific function within a larger system or device. Unlike general-purpose computers, which can handle a variety of tasks, embedded systems are optimized for particular applications, embedded systems are optimized for particular applications, making them efficient and effective in their designed role. [7]

I.5.2 Components of Embedded Systems

The components of an embedded system generally divided into two main categories: [8]

1. **Hardware Components:** An embedded system's hardware includes all the electronics parts it needs to do its jobs, and this can vary depending on what the system is designed for. However, every embedded system generally includes three main parts: a **CPU** (which runs the software and control the system), **memory** (to store programs and data), and **input/output ports** (to communicate with the outside world).

Beside these core parts, other components might be added depending on the application, such as:

- **Communication ports** (like USB or wireless) to exchange data with other devices.
- **User interfaces** (like keypads, screens) to interact with people.
- **Sensors and actuators** to detect and affect physical conditions
- **Data converters** (ADC/DAC) to handle analog signals from sensors or to control analog devices.
- **Support systems** like power supplies and timers to help everything run smoothly.
- **Special chips** for advanced or specific functions.

The figure below illustrates how this hardware components integrated to provide the desired system functionality:

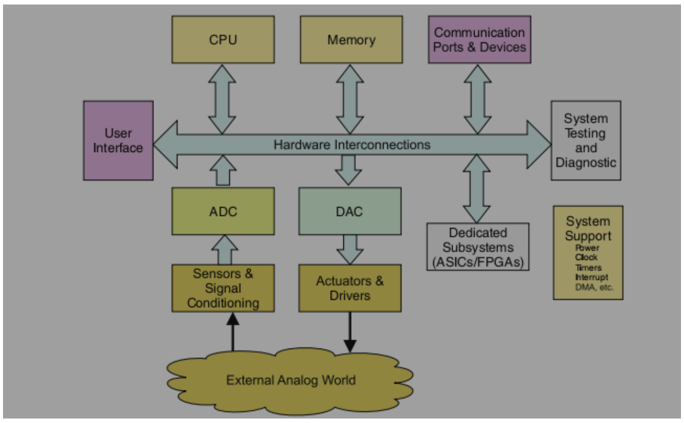

Figure I.10: Hardware components of an embedded system

2. **Software Components:** The software components of an embedded system include all the program necessary to give functionality to the system hardware. These programs, called firmware, are saved in memory that doesn't get erased when the power is off. The software is built around an operating system and specific tasks the device needs to perform.

I.5.3 Key Characteristics of Embedded Systems

- **Domain and Application Specific:** Embedded Systems are designed to perform a specific set of functions tailored to particular applications. For instance, the control unit of washing machine cannot be used in microwave oven because each is uniquely programmed for its specific tasks. This specialization ensures efficiency and effectiveness in their designated roles.
- **Real-time and Reactive:** These systems interact with real world through sensors that continuously monitor changes in the environment. They must respond to these changes in real-time meaning they need to process inputs and produce outputs without delays. For example, in a car, the airbag must deploy immediately upon impact, showcasing the critical nature of timely responses in embedded systems.
- **Operates in Harsh Environments:** Embedded systems are often deployed in challenging conditions, such as extreme temperatures, dust, or vibrations. They must be designed to withstand these adverse conditions to function reliably. For example, a system used in a desert must be built with components that can endure high temperatures.
- **Small Size and Weight:** May embedded systems are required to be compact and lightweight. This is particularly important in consumer electronics, where users prefer devices that are portable and easy to handle. The design of these systems often prioritizes minimizing size and weight without compromising functionality.
- **Power Efficiency:** Power consumption is a critical consideration in the design of embedded systems. They should be designed to use minimal power to extend battery

life, especially in portable devices. High power consumption can lead to overheating, necessitating additional cooling mechanisms that can increase size and weight.

- **Input and Output Ports**: Embedded systems utilize input ports (sensors) to gather data from the environment and output ports (actuators) to perform actions based on the data. This interaction is essential for the system to function effectively and respond to real-world conditions.

I.6 Conclusion

In this chapter, we explored the fundamental concepts of the localisation and embedded systems. We have learned that localisation helps determine the real-time position of objects n people, or animals, using tools like GPS and wireless networks. On the other hand, embedded systems are the small but powerful units that bring smart features to modern technology. Integrating GPS with embedded systems brings together the power of precise location tracking and efficient on-device processing. This integration provides a flexible and scalable for many real-world challenges.

Chapter II

System hardware and material selection

II.1 Introduction

In this chapter, we provide a detailed overview of the hardware and software components used in our project. Each component plays a crucial role in ensuring the proper functioning and performance of the system. The hardware section outlines the essential physical components selected based on functionality, performance, and system compatibility. The software section presents the development environments and programming languages utilized to program and interface with the hardware.

II.2 System architecture Overview

To build a reliable and practical tracking device, we designed a system that balances simplicity, efficiency, and performance. At the heart of the system there is a microcontroller. It is responsible for gathering data, managing communication, and controlling power usage to make the system last as long as possible on battery.

The tracking is done through GPS module this component regularly collects the location and sends it to the microcontroller. Once the data is ready, it is transmitted wirelessly using a communication module.

Because this system might be used far from power sources, it runs on rechargeable battery. To manage this battery safely, we added a charging circuit that protects it from overcharging and deep discharge.

To keep this device protected in outdoor conditions, all the parts are placed in a small, durable, and waterproof enclosure which makes the system strong enough to survive in rough environments.

Finally, the device sends the location's data to the server to store it and the user can easily view the location via an Android application, with the ability to fully control the device remotely.

II.3 System Requirement

II.3.1 Microcontroller

II.3.1.1 Definition

In our project, we have chosen to use the **ESP32** microcontroller. It is a small but powerful microcontroller chip that includes built-in Wi-Fi and Bluetooth developed by **Espressif Systems**. It's like tiny computer used to build smart devices that can connect to the internet or to each other.

It is widely used in **Internet of Things** (**IoT**) applications, wearable devices, home automation, industrial systems, and more.

Figure II.1:ESP32-WROOM-32 microcontroller

II.2.2.1 ESP32-WROOM-32 Specifications

The table below provides the specifications of ESP32-WROOM-32 [9]:

Table II.1:ESP32-WROOM-32 specifications

Categories	Items	Specifications
Wi-Fi	Protocols	802.11 b/g/n (802.11n up to 150Mbps)
	Frequency range	A-MPDU and A-MSDU aggregation and 0.4 ms guard interval support
Bluetooth	Protocols	Bluetooth v4.2 BR/EDR and BLE specification
	Radio	NZIF receiver with -97 dBm sensitivity
		Class-1, class-2 and class-3 transmitter
		AFH
	Audio	CVSD and SBC
Hardware	Module interfaces	SD card, UART, SPI, SDIO, I2C, LED PWM, Motor PWM, I2S, IR, pulse counter, GPIO, capacitive touch sensor, ADC, DAC
	On-chip sensor	Hall sensor
	Integrated crystal	40 MHz crystal
	Integrated SPI flash	4 MB
	Operating voltage / Power supply	2.7V ~ 3.6V
	Operating current	Average: 80 mA
	Minimum current delivered by power supply	500mA
	Recommended operating temperature range	-40°C ~ +85°C
	Package size	(18.00±0.1) mm× (25.5±0.1) mm× (3.1±0.1) mm

II.3.1.3 ESP-WROOM-32 Pinout Description

The ESP32-WROOM-32 is a powerful microcontroller with **38 pins** in total. These pins connect it to the outside world.

1. **Power pins:**
- **3.3V (Voltage Input):** supplies external power.
- **GND (Ground):** Connect this to the ground.
- **EN (Enable):** This is like the ON/OFF switch. Connect it to 3.3V to keep the running of the module.
2. **Input/Output Pins (GPIO):**
- The most of ESP-WROOM-32 pins are GPIOs, we can use them to:
    - Read buttons and sensors (inputs)
    - Turn on LEDs, relays, buzzers (outputs)
    - Communicate with other devices
3. **Analog Pins:**
- **18 ADC (Analog to Digital) pins:** Measure voltage levels (like reading sensor's value)
- **2 DAC (Digital to Analog):** Output analog voltages.
    - DAC1 = GPIO25
    - DAC2 = GPIO26
4. **Communication Pins:**
- **UART (Serial):** For talking to your computer or other devices.
    - TX0 = GPIO1, RX0 = GPIO3
    - TX2=GPIO17, RX2=GPIO16
- **I2C:** For talking to sensors and displays
    - SDA = GPIO21
    - SCL = GPIO22
- **SPI:**
    - MISO = GPIO19
    - MOSI = GPIO23
    - SCLK = GPIO18
    - CS = GPIO5
- **Special Pins:**
    - GPIO0: Used to enter flash mode (for programming)
    - GPIO2: Must be LOW at boot for flashing
    - GPIO4, GPIO5: Must be HIGH during boot
    - GPIO12: Can affect boot if pulled high
    - GPIO15: Must be HIGH during boot

The picture below provides a detailed description of the pins functions:

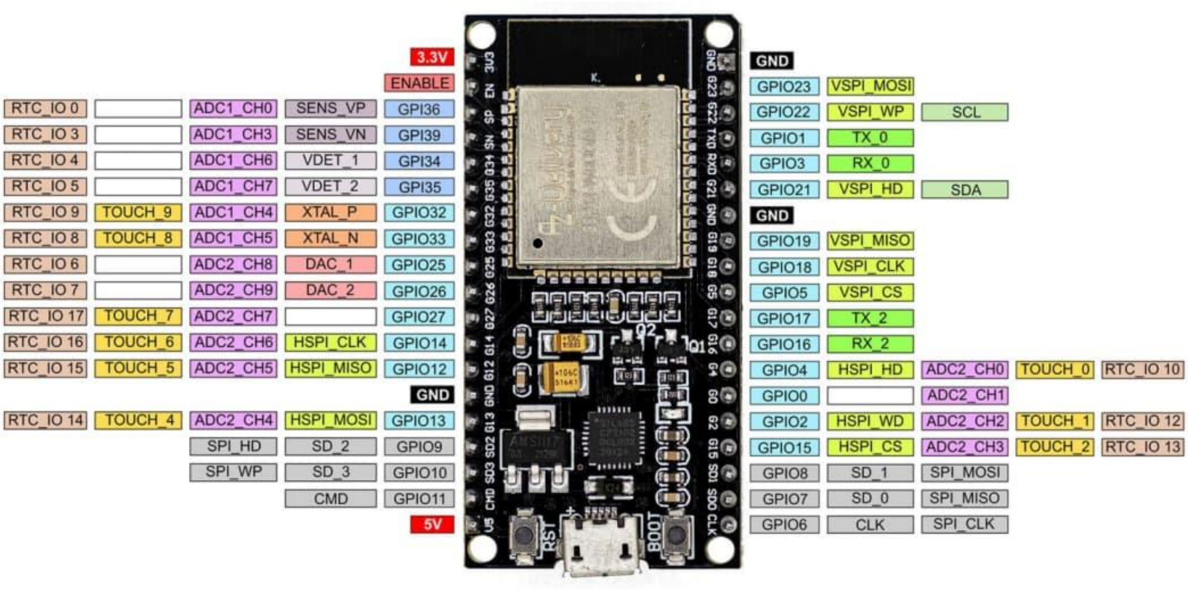

Figure II.2: Pinout of ESP-32-WROOM-32

II.3.2 Communication Module

II.3.2.1 Definition

The Communication module we choose is SIM800l it is a quad-band (ability to operate on four different frequency bands) GSM/GPRS module, designed and manufactured by SIMCom Wireless Solutions. It allows the microcontroller to make and receive calls, send SMS messages, and connect to the internet. This module enables both real-time location tracking and wireless data transmission making it suitable for Internet of Things (IoT) applications. [10]

Figure II.3:SIM800L module

II.3.2.2 SIM800L Characteristics

- **Power Supply:** 3.4V~4.4V

- **Peak Current:** 2A
- **Quad-Band:** 850/900/1800/1900 MHz
- GPRS multi-slot class 12
- **GPRS Data Transfer:** Max 85.6kbps
- Control via AT commands
- Support RTC (Real Time Clock)
- Low power consumption
- **Dimensions:** 15.8*17.8*2.4 mm
- **Weight:** 1.35g
- **Operation temperature:** -40° C to +85°C

II.3.2 GPS Module

II.3.2.1 Introduction

As a part of the system's core functionality, we need a reliable way to determine the real-time location of the tracked subject. To achieve this, a GPS module is required, one that not only provides accurate position data but also works well with the microcontroller and operate efficiently in outdoor conditions. The module should support serial communication and be easy to integrate within the electronic hardware design. After reviewing several available options, the **NEO-6M GPS module** (figure II.4) was chosen for its balance between performance, cost, and compatibility. It offers reliable NMEA- formatted data, low power consumption, and consistent results, making it well-suited to the requirement of our system.

Figure II.4:NEO-6M GPS Module

II.3.2.2 Features and Technical Specifications of the Module

1. **Key Features:**

- U-BLOX NEO-6M module with high-gain active antenna.
- TTL level, compatible with 3V/5V systems.
- Baud rate: 9600 kbps (default)
- Provided IPX interface for different antennas.
- Support hot start.

2. **Technical Parameters:**

- **Receiver type:** 50 channels, GPS L1(1575.42Mhz) C/A code, SBAS: WAAS/EGNOS/MSAS.
- **Horizontal position accuracy:** 2.5CEP (SBAS:2.0mCEP).
- **Navigation update rate:** 5Hz maximum (1Hz default).
- **Capture time:** cool start: 27s (fastest); hot start: 1s.
- **Tracking & Navigation sensitivity:** -161dBm.
- **Communication Protocol:** NMEA (default)/UBX Binary.
- **Operating Temperature:** -40°C ~ 85°C.
- **Operating Voltage:** 2.7V ~ 5.0V.
- **Operating Current:** 45mA.
- **TXD/RXD impedance:** 510 Ohms.

II.3.3 Power Supply System

II.3.3.1 Overview

To ensure that the tracking device operates reliably in the field, especially in remote areas with no access to electrical infrastructure, the system relies on a self-contained power supply. A rechargeable battery serves as the main energy source, chosen for its compact size, long life, and ability to deliver stable voltage over time.

To manage the charging of the battery safely and efficiently, a dedicated battery charging module is used. This module is responsible for regulating the charging process and providing built-in safety features.

However, since the voltage level of the battery can fluctuate depending on its charge level, a separate voltage regulation circuit is integrated into the system. This circuit ensures that all components receive a constant and suitable voltage, regardless of battery condition.

II.3.3.2 Power Requirements of the System

To keep the device running smoothly and efficiently, it’s important to understand how much power each part of the system needs. This section outlines the power requirements of the main components used in the tracking system. By knowing the voltage and current demands, we can design a power supply that matches the system’s needs, ensure reliability, and avoids overloading the battery.

The following table provides a clear summary of each component’s electrical characteristics:

Table II.2: Power Requirements of System Components

Component	Function	Operating Voltage	Current Consumption	Power Consumption
ESP32	Main Controller	3.3 V	80 mA	0.264W
SIM800L	SIM Module	3.7 V	2A	7.4W
NEO-6M GPS	GPS Module	3.7 V	45mA	0.148W

II.3.3.2. Lithium-Ion Battery

1.Introduction:

Powering a portable electronic system requires an energy source that is not only efficient but also compact and easy to integrate. For this reason, a lithium-ion battery has been chosen as the primary power supply for the device. Known for its excellent balance between capacity, size, and longevity, the lithium-ion battery provides a practical solution for embedded systems that demand mobility and energy reliability.

Figure II.5: Li-ion Battery

II.3.3.3 Battery Charging Circuit

1.Introduction:

To ensure the lithium battery used in our system can be recharged safely and efficiently, a dedicated battery charging module is required. Lithium batteries are sensitive to how they are charged, and improper charging can lead to reduced battery life, performances issues, or even safety risks. For this reason, simply connecting the battery to a power source is not enough there must be a circuit in place that controls the charging process precisely.

The battery charging module serves this purpose by regulating the voltage and current delivered to the battery. It also includes built-in protection features such as overcharge prevention, short-circuit protection, and automatic cut off when charging is completed.

By integrating this module, we ensure the battery is charged correctly, extending its lifespan and supporting the continuous operation of the entire system. In our project, we aim to utilize the TP4056 module as the core component for the battery charging circuit (figure II.4).

Figure II.6:TP4056 Module

3. TP4056 Charging Module

➢ **Features:**

- Provide the following protection features:
- Manage the constant current to constant voltage charging of a connected lithium battery.
- Over-discharge and overcharge protection.
- Overcurrent and shot-circuit protection.
- Soft-start protection limits inrush current.
- Can be powered, for charging, from a Type-C USB cable.
- Include two indicator LEDs: red LED for charging and blue LED for charging complete. [11]

➢ **Specifications:**

We will provide a table with the detail’s specifications

Table II.3:TP4056 Specifications

Charge Controller	TP4056/TC4056A
Protection IC	DW01A
Charge Method	Constant-Current/Constant Voltage
Input Supply Voltage	5V
Constant Charge Current	1000mA
Charge Complete Voltage	4.2V±1%
Overcharge Protection	
Overcharge Detection Voltage	4.3V±50mV
Overcharge Release Voltage	4.1V±50mV
Over-discharge Protection	
Over-discharge Detection Voltage	2.4V±100mV
Over-discharge Release Voltage	3.0V±100mV
Overcurrent Protection	
Overcurrent Protection Threshold	3A
Overcurrent Cutout Delay	10~20ms
Short-circuit Cutout Delay	5~50µs
Trickle Charge (Battery Reconditioning)	
Trickle Charge Threshold Voltage	2.9V±0.1V
Trickle Charge Current	130mA±10mA
Dimensions	
Length	26mm
Width	17mm
Weight	1.6g

II.4 Conclusion

In this chapter, we have carefully examined and selected the hardware components necessary for the implementation of our system.
The ESP-32-WROOM-32 was selected as the main controller for its low-power performance.
The SIM800L module enables the GSM communication and the NEO-6M GPS ensures accurate geolocation. We have selected a 3.7 Li-ion battery to power the system.
These choices helped us create a simple, low-cost, and efficient tracking device that meets the goals of our project.

Chapter III

System realization

III.1. Introduction

This chapter focuses on the practical realization of the tracking system, which consists of two main parts: the integration of the tracking device and the development of the application.

The first part focuses on system integration. It explains how the different hardware and software components of the device was connected and configured. This includes the setup of the microcontroller, communication with the positioning module, data transmission, and power management.

The second part describes the tracking application, which allows the users to monitor and interact with the system. It includes an overview of the application's architecture; its user interface and the technologies used to retrieve and display location data.

Together, these two parts form a complete and functional system capable of tracking and monitoring movement in real time.

III.2. Development tools used

III.2.1 Software tools

For developing our system, we used several software tools that facilitated the programming, communication, data management, and visualization required for our tracking device. These tools include:

III.2.1.1 Arduino IDE

The Arduino IDE (**I**ntegrated **D**evelopment **E**nvironment) shown in the figure III.1 is a software tool that lets us write, edit, and upload embedded codes.

Figure III.1: Arduino IDE logo

III.2.1.2 Visual Studio Code

Visual Studio Code (VS Code) is a free code editor developed by Microsoft. It supports many programming languages. It's popular among developer for building websites, apps, and software projects. We used it for building our tracking application. The figure III.2 illustrates the starting screen of Visual Studio Code.

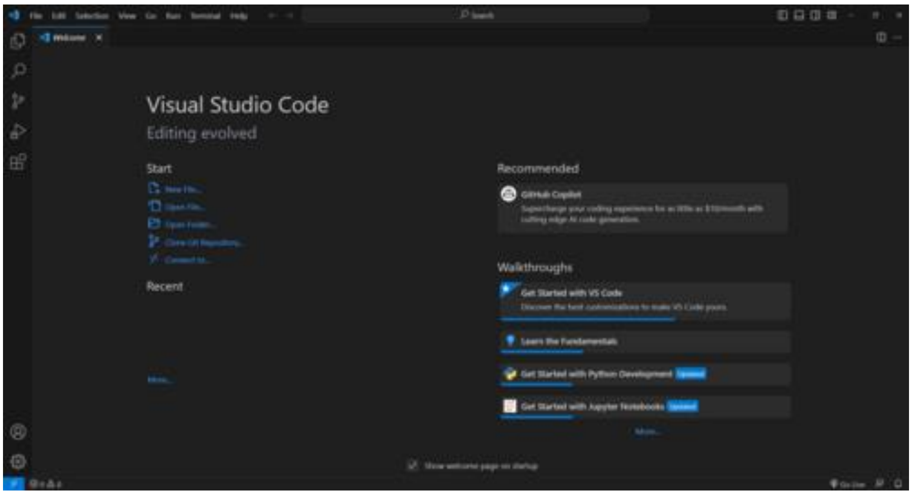

Figure III.2:VS Code starting screen

III.2.1.3 XAMPP Server

XAMPP (figure III.3) is a simple tool that helps us create a local server on our computer. It allows us to create and test web applications without needing to be online.

Figure III.3:XAMPP interface

III.2.2 Hardware tools

- **ESP32:** It is used as the main controller in our project.
- **Neo-6M GPS Module:** It is used to provide real-time geographic location data.
- **SIM800L Module:** It enables data transmission to the server over GSM network.
- **Li-ion Battery:** It provides power to operate our system.
- **TP4056 Module:** It is used to safely charge the Li-ion battery and protect it from overcharging or deep discharge.
- **CP2102 Module:** It is used to program the ESP32 by providing a USB-to-serial interface.

III.2.3 Application architecture technologies

- **React.js:** It is a powerful JavaScript library designed to create fast and responsive user interfaces.
- **Node.js:** It is JavaScript runtime used in the backend to handle MQTT data, connect the frontend to the database, and enable real-time communication between systems.
- **MySQL:** It is a relational database system that uses structures tables to store and manage data efficiently.
- **Leaflet:** It is JavaScript library using for creating map on the web applications and showing the real-time location data.
- **EMQX MQTT Broker:** It is open-source MQTT broker designed for fast and reliable message exchange between IoT devices and applications.

III.3 System Realization

III.3.1 Explanation of the system circuit

The ESP-WROOM-32 module requires a stable 3.3V power supply for proper operation, and it is essential to ensure the control of other components. For communication, the ESP32 offers multiple hardware serial ports. In this configuration, Serial Port 1 (UART1) is connected to the SIM800L GSM module for handling mobile network communication, while Serial Port 2 (UART2) is dedicated to the GPS module to receive location data.

The following table summarize the wiring connection between ESP32 and GPS module:

Table III.1:ESP32 and GPS Wiring

GPS Module	Wiring with ESP32
VCC	3.3V
RX	G17
TX	G18
GND	GND

The GSM module is connected to ESP-WROOM-32 through Serial Port 1 (UART1), using the TX and RX pins for communication, the TX pin of the SIM800L is connected to the RX pin of the ESP32. And the RX pin of the SIM800L is connected to the TX pin of the ESP32. A common ground (GND) is essential between both modules. The SIM800L requires a stable 3.7V power supply capable of delivering up to 2A of current, especially during transmission peaks.

The following table summarize the wiring connection between ESP32 and GSM module:

Table III.2:ESP32 and GSM wiring

GSM Module	Wiring with ESP32
VCC	3.7V
RX	TX
TX	RX
GND	GND

III.3.2 Embedded Software Development

The development of the embedded software for our tracking card followed a structured. The following steps summarize the implementation process:

1. **Library Integration and Environment Setup:**
   - Selection of the appropriate microcontroller (ESP32)
   - Installation and configuration of the arduino IDE with the necessary board definitions.
   - Inclusion of external libraries such as TinyGSMClient, TinyGPSPlus, PubSubClient, SoftwareSerial
2. **Peripheral Initialization:**
   - Configuration of UART interfaces for SoftwareSerial, GPS and GSM modules.
   - Definition of communication parameters (baud rate)
3. **SIM800L Configuration and Network Connection:**
   - Configuration of the SIM800L module with the appropriate APN, username, and password for GPRS connectivity.
   - Initialization of the GPRS network and verification of internet access.
   - Establishment of a connection with the MQTT broker.
4. **GPS Data Acquisition and Parsing:**
   - Continuous reading of GPS module data.
   - Parsing of GPS data using the TINYGPSPlus library to extract the latitude and longitude.
5. **Real-Time MQTT Data Publishing**
   - Formatting of GPS data into JSON structure.
   - Publishing the location data to predefined MQTT topic using the *PubSubClient* library.
6. **Error Handling and Reconnection Logic**
   - Implementation of automatic reconnection routines for both GPRS and MQTT in case of connection loss
7. **Testing and Validation:**
   - Field testing to ensure correct GOS reception and consistent data transmission.
   - Validation of MQTT connectivity and broker communication.
   - Serial output monitoring for debugging and performances analysis.

III.4 Tracking Application

III.4.1 Technologies Used for Application Development

To allow the user to track the real-time location of GPS devices, we developed a modern web application. The application consists of two main components: a frontend interface built with ReactJS, and a backend server powered by Node.js. The communication between the frontend and the backend is handled using MQTT for real-time updated and API (Application Programming Interface) for dealing with the database.

- **Frontend – ReactJS:** The frontend of the application was built using ReactJS, a JavaScript library ideal for building user interfaces. The interface consists of several components:
    - A **login page** to enable the user to access his account via email and password**.**
    - A **live map** built with **React-Leaflet**, used to display all connected devices and their current locations.
    - A **device's view** shows the list of all devices and their properties with the ability to select a specific one and display its location on the map.
    - A **historical view**, where the user can view the previous locations data of the device.
- **Backend – Node.js:** The backend server is developed using Node.js to performs the following main tasks:
    - Receive MQTT messages from tracking devices.
    - Processes and stores the current location in the database. This data is stored every 10 minutes in historical data table.
    - API routes to allow the frontend to fetch the device list and current status, location history, and user authentication data.
- **Communication Workflow:**
    1. Each device sends GPS data to the MQTT broker under a unique topic.
    2. The Node.JS server subscribes to these topics, processes the data, and updates the database.
    3. The frontend connects to the backend via WebSocket to receive real-time location data.
    4. For static or historical data, the frontend makes HTTP requests to the backend.

III.4.2 User Interface Design

When the user first opens the applications, they are welcomed by a simple and clear login page (figure III.5). This interface comes with to input fields -email and password- to keep the process fast. After logging in successfully, the user is automatically redirected to the home page.

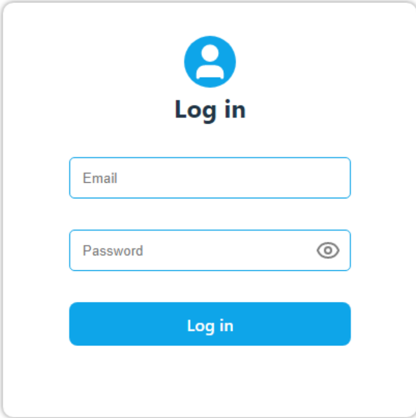

Figure III.4:login page

The home page (figure III.6) is the main interface of the system. On this page, all the registered tracking devices are shown in list format. For each device, the user can see the device name, whether it is currently online or offline, and the last time it was seen. Or also can delete the device from the registered devices.

Next to the device list there is an interactive map that displays the real-time location of the selected device. When the user clicks on a device from the list, the map updates to show its position.

Additionally, the home page includes a section where the user can choose to view either the selected device information or its history. This allows the user to switch between the current data and past movement.

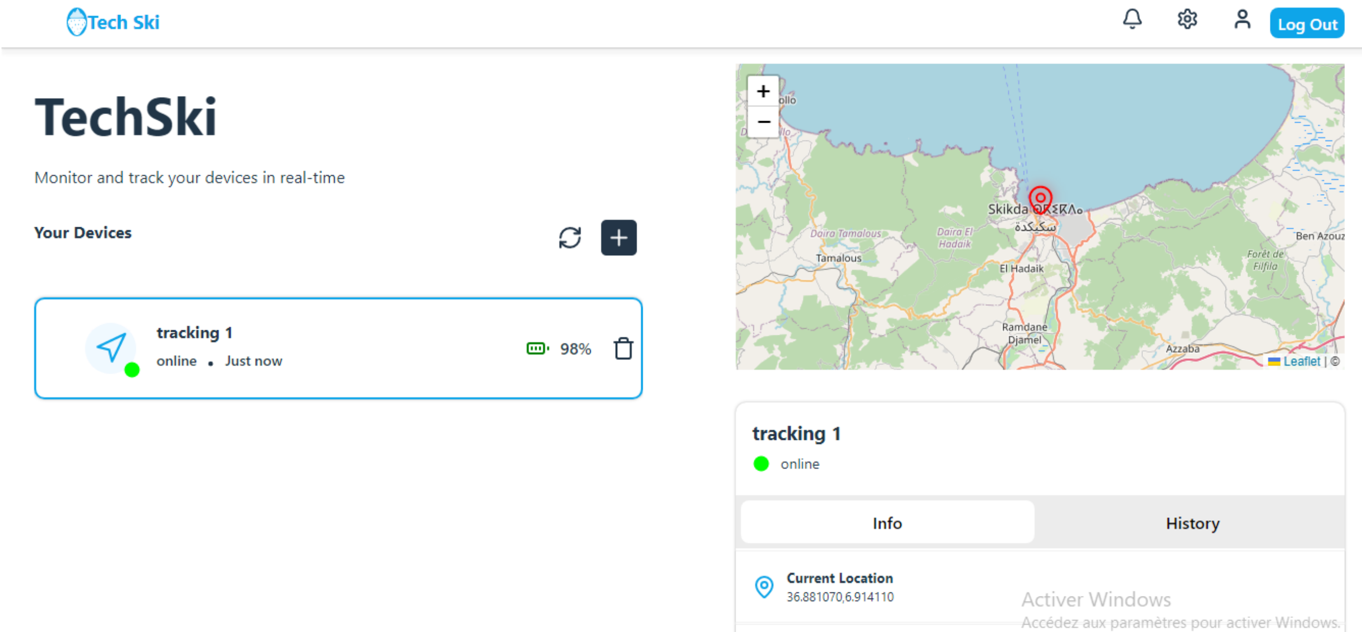

Figure III.5: Home page

To register a new device, the user can click on the **"Add Device"** button on the home page, which opens a new device interface (figure III.6). This form allows the user to input the device name, its unique identifier, and the type.

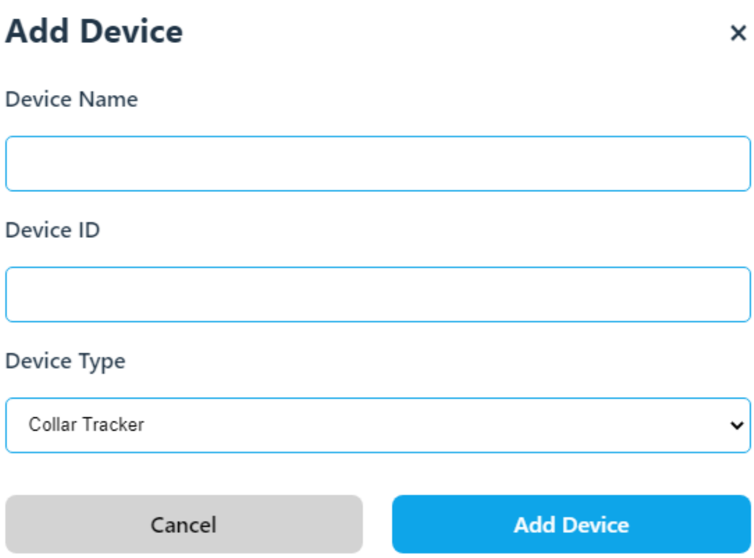

Figure III.6:add new device

III.6. Test and Validation

We tested our tracking device in the city of Azzaba and we observed its real-time location

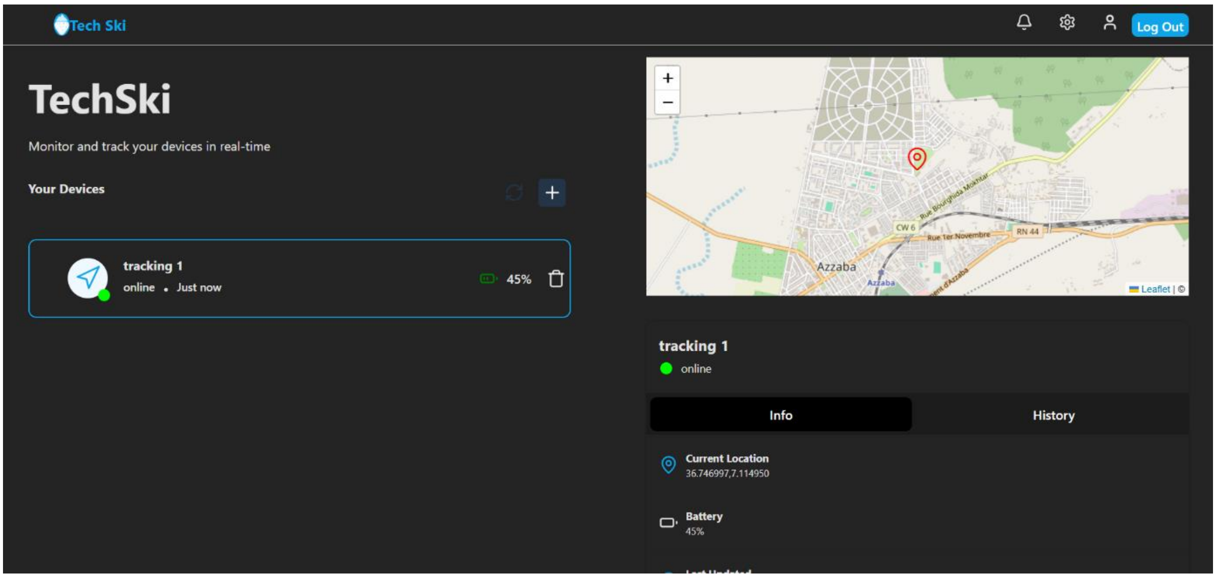

Figure III.7: Home Page int the realization phase

III.7. Conclusion

In this last chapter, we presented the different development tools used, the creation of the embedded systems (connection and programming). We explained also the technologies used in the development of the tracking application with a detailed description of the application interfaces.

General Conclusion

General Conclusion

This project was completed as part of starting point for a future startup, by designing and building a real-time tracking device, was able to apply what we learned in embedded systems, communication, and software development to a real-world solution and the experience combined academic knowledge with practical skills and showed how an educational project can lead to real and business opportunities.

We observed that the calculation part, where the controller is located, works properly. However, the energy part has some issues, and this is exactly what we plan to fix in future versions.

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DEMOCRATIC AND POPULAR ALGERIAN REPUBLIC
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

20 AUGUST 1955 UNIVERSITY SKIKDA
FACULTY OF TECHNOLOGY
DEPARTMENT OF PETROCHEMISTRY

TechSki Company developing innovative solutions that bridge the gap between Security, Industry and Education

Project for obtaining a Startup Certificate
under Ministerial Decision 1275

Logo:

Realized by:

Laouacheria Nidal
Bouabdellah Badreddine

Supervised by:

Mr. Bendib Riad

2024/2025

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Abbreviation

CAGR: Compound Annual Growth Rate.
SEO: Search Engine Optimization.
IT: Information Technology.

Supervision Team

Supervisor	Specialty
Dr. Bendib Riad	Automation
Dr. Doughmane Hala	Media & Communication

Project Team

Project Team Members	Specialty
Laouacheria Nidal	Automation in the petrochemical industry
Bouabdellah Badreddine	Automation in the petrochemical industry

General Introduction

General Introduction

The Algerian tech ecosystem is expanding, with tens of IT firms, where growth opportunities exist, especially after the encouragement of the government to this sector.

However, after analyzing the market, we found that the main activities of these companies include transportation, item delivery, food services, digital marketing, and to some extent, education.

While tech is growing, there is still a need for institutions specialized in advanced technological fields which has become indispensable.

At our core, we are dedicated to fulfilling this need by operating across multiple sectors: Industry, Security, and Digital Education.

To make our idea realizable, we need a clear vision, and this is exactly what we have done in this work under the following sections titled:

- Presentation of The Startup
- Innovative Aspects
- Strategic Market Analyses
- Production and Organisation Plan
- Financial Plan
- Experimental Prototype

First Section

Startup Presentation

I.1.The Startup Idea

The Startup is in the Technology sector, with a special focus on industry, Enhancing the tech sector in Algeria, Africa, and the Arab world requires a strategic approach that focuses on innovation, collaboration, and investment in key areas like industry, security, and education and this is the objective of creating TechSki.
We propose innovative solutions in:

I.1.1. The Industry Market

By Crating on site Nitrogen and oxygen generators powered by solar energy which offers a solution to several industrial and logistical problems, listed Below:

- Dependence on Gas Cylinders which create problems of transportation and storage.
- Buying gas repeatedly is costly, but producing it is more cost-effective in the long term.
- Transport and handling of high-pressure cylinders pose risks in Safety and Environmental Concerns.
- Process Interruptions during crises.

I.1.2. The Security Market

From car owners to farmers, material theft and waste remain significant challenges and to deal with these issues, we aim to develop a remotely monitored tracking devices for effective prevention.

I.1.3. The Education Market

In 2025, with internet access available in nearly every part of the world, we propose learning platform focused on teaching

- Programming languages
- Robotics with the possibility to deliver physical prototypes
- Technical French
- Technical English

The lessons will be offered exclusively by our engineers working on-site, which is a great approach to prioritize practice over theory.

I.2. Startup Team

Our Startup team is composed of skilled individuals from a variety of backgrounds, each with a distinct skill set, team members include and should have:

- **Laouacheria Nidal** (**Chief Executive Officer**): specializes in Automation engineering, strong leadership skilled, SolidWorks Expert, Process Designer, solid understanding of C++ and Working proficiency in French.
- **Bouabdellah Badreddine (Chief technology officer):** specializes in Automation engineering, web development, Graphic Designer and Working proficiency in English.
- **Logistics Coordinator:** monitors the supply chain, guarantee compliance with international laws and Rules, negotiate tariffs with service providers, briefly he will be

responsible for all financial-related matters.

- **Marketing Strategist**: He will develop marketing strategies that include strong video content components so he will should have a strong background in digital marketing strategy and experience in video editing.

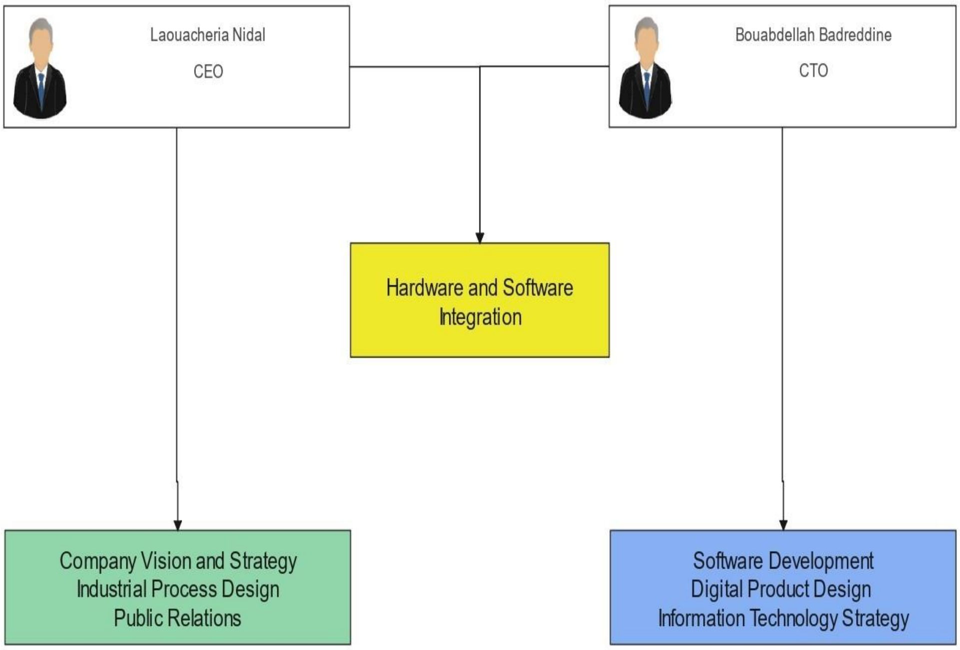

Figure.I.1: Startup Organizational and mission Structure

I.3. Justification of TechSki Branding Choices

I.3.1. Name Selection

The name "TechSki", where "Tech" reflects our commitment to innovation and excellence in the technology sector while "Ski" is a heartfelt tribute to Skikda, the vibrant coastal city in Algeria where our journey began.

I.3.2. Logo Selection

The city of Skikda is renowned for the quality of its strawberries, inspired by this reputation, we chose a logo shaped like a strawberry to symbolize not only purity and excellence but also the high standards we apply to our technology like Skikda's strawberries.

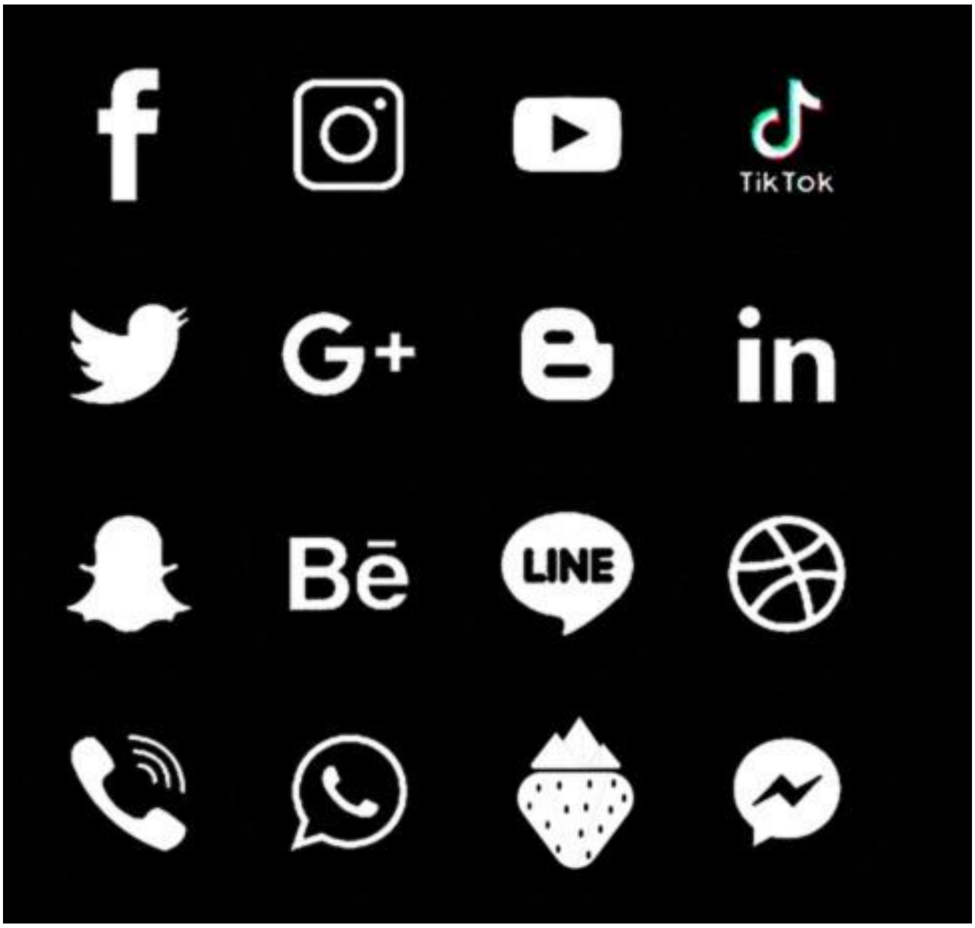

Figure.I.2: Picture showing Logo Visibility Test

In this image, our logo stands out clearly due to its unique and recognizable design where we placed our logo alongside other logos in black and white because the best way to test a logo's effectiveness is in black and white.

I.4. Strategic roadmap of the startup

We implemented this roadmap to keep our team stays focused on long term objectives and core policies where we identified our Mission, the values our group stands for and Execution plan and schedule.

Table I.1: Table of the Startup Strategic Roadmap

Mission	Develop smart solutions and make advanced technology accessible and impactful by creating creative tools in industry, education and security.
Values	**Innovation:** By integrating innovation into both new developments and existing systems to achieve better results.
	Environmentally friendly: By prioritizing environmental concerns i our designs, we favor the use of renewable energy and aim to reduce unnecessary paper use.
	Risk reduction: Ensured by comprehensive testing and detailed calculations with considerable safety factors.
	Digital Integration: From the Generator Project to the Tracking Devices that we develop are equipped with digital capabilities that enable advanced monitoring and control.
	Proportional Growth: We ensure our growth by continuously delivering updates and improvements to our services.
By year 1	• Dealing with low matters and certifications. • Securing essential resources. • Completing functional prototypes. • Starting content creation. • Identifying potential investors
By year 2	• Obtain the financial support. • Start earning income from the education sector. • Begin selling the Tracking Device.
By year 3	• Improving the Tracking Devices features such as determining the real time location of animals. • Launch the gas generator to the market. • As part of our robotics education efforts, we will start offering practical prototypes that apply reverse engineering principles.

Second Section

Innovative Aspects

II.1. Introduction

Innovation is not always about creating entirely new products it can also mean improving existing ones in smart and creative ways, including how they are marketed. This is exactly what we have done at Tech Ski.

II.2. Nature of Innovations

- **Technological Innovation :** TechSki technological innovation lies in the development of compact, energy-efficient gas separation systems that combine PSA and membrane technologies, powered by renewable energy, to deliver accessible and scalable solutions, This is not merely an incremental improvement, but a significant technological leap that enhances system performance, reduces operational costs, and promotes sustainable practices across all our projects from gas generators to educational platforms and smart safety solutions.
- **Market Innovation:** Tech Ski introduces market innovation by integrating compact gas generation, where we are introducing a new approach to gas delivery in the Algerian market, offering decentralized, on-site gas solutions. In parallel, we also provide smart tracking cards for safety and logistics, as well as digital education tools to support technical learning and workforce development.
- **Incremental Innovation:** Our strategy is based on existing gas separation and digital education technologies, but we focus on making small, smart improvements that save energy, reduce size, and better fit local market needs. We've also added new features to our tracking card to improve its use in safety and logistics. These simple but important changes help us grow step by step without starting from scratch. This approach reflects one of our core values: prioritizing proportional and sustainable growth.
- **Radical Innovation:** The idea of brings cutting-edge hybrid technology that combines membrane and PSA systems to produce nitrogen and oxygen on-site is a solution that has not been widely implemented in the region which marks a major shift in how industrial gases can be generated and delivered, enabling higher reliability, lower costs, and reduced dependence on traditional supply chains.

II.3. Fields of Innovation

- **New Processes:** In the Generator project Combining membrane and pressure swing adsorption in the gas separation and with solar power integration enables the simultaneous production of nitrogen and oxygen gases and with the adding of real time automated control, enhancing productivity and gas purity through optimized cycles, pressure management, and flow regulation.

- **New Features:** From the parallel production of two gases and the energy saving strategy in the generator, to the idea of designing tracking cards capable of monitoring animals, we offer new ways to improve our products.

- **New Customers:** Targeting the Algerian market, especially where there is a shortage of electronic devices and a rise in theft, we aim to offer solutions through the sale of our tracking cards. Additionally, we plan to market our generator to the growing food industry in Algeria. We are also targeting the Middle East market, particularly Saudi Arabia, where humid environments create a demand for eco-friendly systems, making our generator a suitable solution.

- **New Offers**: With this initiative, our startup is able to expand the range of solutions it offers by delivering automated, solar-powered generators for dual gas production and advanced tracking cards for monitoring and security applications, these innovations are tailored to meet the needs of industries such as food processing, agriculture, and logistics, making our business more competitive both in Algeria and internationally, especially in humid and eco-transitioning regions.

- **New Models:** Our business model is built around minimizing waste, optimizing resources and maximizing energy efficiency, Through the development of solar powered generators and intelligent tracking cards, we incorporate green technology to modernize outdated methods across industries, this not only supports sustainable innovation but also reflects our commitment to environmental stewardship, allowing us to stand out as a forward-thinking player in the Algerian and Middle Eastern markets.

Third Section

Strategic Market Analysis

III.1. Introduction

Great strategy comes from understanding where the opportunities are and collect internal and external data before launching any business, in this section we will study the Markets working on our Startup:

III.2. The Gas Generator Project

III.2.1. Growth of the Market

The Global Nitrogen Generators Market Size was valued at $8.1 billion in 2020, and is projected to reach $14.6 billion by 2032, growing at a CAGR of 4.8% from 2023 to 2032 [1].
The Global Oxygen Generators Market Size was valued at $4.15 billion in 2025 and is expected to grow at a compound annual growth rate (CAGR) of 9.4% [2].

III.2.2. The Market segment

a) Potential Market:
The potential market for our Nitrogen and Oxygen Generator is:

- Hospitals and Clinics
- Laboratories and Research Institutions
- Water Treatment Facilities
- Oil and Gas Industry

b) Targeted Market :
The targeted market for our Nitrogen and Oxygen Generator where the demand is High for dual N2 and O2 gas generators is:

- Food Processing Units
- Private Clinics
- Electronics Manufacturing Facilities
- Aquaponics and Aquaculture

III.2.3. Measurement of Competition Intensity

a) Direct competitors :

Our company faces strong competition in the market and it’s directly about the companies how offer the sale of Nitrogen and Oxygen Generators.

b) Indirect Competitors :

The Indirect competitors are the companies how deliver the product in cylinders or tanks not the Generator its self so they offer an alternative solution to the same need.

c) Strengths and weaknesses :

There are several benefits of the generator that is proposed by our company and we can say that They are the strengths of our project including:

- Offering both gases from a single compact system.
- Optimized for performance due the specific architecture
- Solar power integration
- Most direct competitors do not operate in North Africa or the Middle East where we want to start.

But we face challenges to make the on-site gas solution proposed by our team a realty and they are the weaknesses of our system:

- Expensive manufacturing
- limited brand recognition because we are new in the Market

III.2.4. Marketing Strategy

To reduce the effect the weaknesses facing our project specially in term of customer research we implemented a Marketing Strategy based on:

1. **Educational Marketing:**

Since we are working in the educational sector, it will be a great opportunity to introduce our generator to engineering students by creating visual explanations. Producing videos and articles that explain the benefits of our project will enhance its visibility.

2. **Event Marketing:**

Since our project is both innovative and environmentally friendly, we plan to participate in events with related subjects organized by national and international organization.

3. **Penetration Marketing:**

By directly engaging and making contact with the potential consumers and clearly communicating the benefits of our project.

4. **Search Engine Optimization :**

To increase our online visibility and attract targeted traffic to our project we aim to follow a SEO Strategies which include Conducting Keyword research, informative content.

III.3. The Tracking Device Project

III.3.1. Growth of the Market

From the Position Tracking System Market Research Report, the global market for position tracking systems was valued at US$35 billion in 2022 and is expected to reach US$78.4 billion by 2032, with an approximate CAGR of 8.4%.

III.3.2. The Market segment

a) Potential Market:

The potential market for our Tracking Device is all individuals or organizations that own valuable properties and seek to monitor their real-time location whether for safety, security, or operational tracking purposes.

b) Targeted Market:

the specific sectors and the most immediate and profitable segments we are targeting are the Smart Farming, Security Companies, organizations that need to know where their employees are in real time, car owners, I realty even the targeted market is huge, these sectors offer immediate opportunities for adoption and profitability.

III.3.3. Measurement of Competition Intensity

a) Direct and indirect competitors:

In our industry, direct rivals include companies offer products with similar features and target consumers who need to track personal items, Indirect rivals might include Companies how sell their devices or machines with integrated tracking system.

b) Strengths and weaknesses:

One of the key strengths of our tracking card is the strong demand in Algeria and the North African market, driven by the increasing need to secure properties and assets also there is another major strength lies in the innovative features we plan to integrate in future versions, such as animal tracking and bold energy-efficient charging by designing the Card like a wristwatch.

III.3.4. Marketing Strategy

1. **Digital Marketing :**

Since the price of the tracking card will be affordable and everyone can purchase one, we will focus our marketing on social media by making contracts with influencers or by being active through creating content on these platforms.

III.4. The Numerical Education Project

As a startup, our **soft power** lies in the educational sector where we support engineers and tech students in areas such as programming, robotics, and even Technical English and Technical French and in return, they will indirectly introduce our startup to others.

III.4.1. Growth of the Market

The growth of the digital education market in the word was valued form the Grand View Research at USD 26.01 billion in 2024, while there are no official statistics available for the Algerian digital education market, our observations indicate that growth is primarily concentrated in formal education initiatives driven by the Ministry of Education, with limited expansion in the technology and professional training segments.

III.4.2. The Market segment

a) Potential Market:

For everyone who is interested in learning the subjects proposed by our startup.

b) Targeted Market:

We are willing to offer our services for Engineering and tech students, high school graduates.

III.4.3. Measurement of Competition Intensity

a) Direct and indirect competitors:

We face both direct competitors offering similar services in programming, robotics, or language education and indirect competitors, such as general learning platforms or traditional institutions.

b) Strengths and weaknesses:

It is true that there are a lot of competitors, but offering a technical learning experience in the language's domain is rare, and this is among our key strengths.

II.4.4. Marketing Strategy

1. Social Media Marketing:

By exploiting the algorithms of the functional reels on TikTok and Instagram, we will share the summaries of the lessons on these platforms and the rest on our website and YouTube channel.

2. Search Engine Optimization:

We will optimize our website by providing articles with keywords related to each lesson published by our team.

3. Collaborations:

Specially with scientific clubs and organizations by offering free workshops and in exchange they will hear about ass and continue the learning journey through our platform.

III.5. Conclusion

From our work, we can conclude that the choice of our field of activity is not random, but rather based on analyses conducted to identify the needs of the global market and the Algerian market in particular.

Fourth Section

Production and Organization Plan

IV.1. Introduction

For the success of our projects, we need to define Technical and Management strategy focused on the most important elements, of course, we will highlight only the main steps, while the remaining ones can be implemented on site.

IV.2. Production Process

IV.2.1. Production Process of The Gas Generator

The Production Process of the Gas Generator pass through the main steps listed Below:
1. The Design engineering of the Generator
2. The purchase of raw materials that requires appropriate technology for handling, as listed in the table below.

Table IV.1: Purchase Table of Raw Materials for The Generator Project

The Material	The Number	The possible Suppliers
The Air Compressor	1	Airmec-Air Compressor
The Aftercooler	1	Industrial Frigo
The Multi Stage Filter	1	Commercial Filtration Supply
The Particulate Filter	1	Commercial Filtration Supply
The Refrigerated Dryer	1	Aletc-Air
The Inline Desiccant Cartridge	1	Altec-Air
The Membrane Module	1	Nordic Filtration
The Dual Gas Analyzer	1	STORAGE CONTROL SYSTEMS
The Programmable Logic Controller	1	SIEMENS
MPPT Controller	1	Lumiax
Solar Panel	6	AESOLAR
Battery Bank	1	Battle Born Batteries
Solenoid Valve	8+1	KSB
Bolt	295+32	Any Local Supplier
Hex Nut	295+32	Any Local Supplier

3. Manufacturing of raw materials that does not require advanced technological knowledge.

Table IV.2: Raw Materials Manufactured by Our Team

The Material	Description	Quantity
The Pipes	cutting and welding the Pipes	Around 3000 mm
The Air Receiver	Cutting, Rolling and welding the steel plate	In The Data Sheet
The PSA Tower	Cutting, Rolling and welding Placing the Adsorbent	In The Data Sheet
The Oxygen Storage Tank	Cutting, Rolling and welding	In The Data Sheet
The Nitrogen Storage Tank	Cutting, Rolling and welding	In The Data Sheet
The Cooling Fan -electric Motor needed	Placing The Components	Two Fans
The Electrical Box	Cutting the steel plates and placing the screws	In The Data Sheet
The External Box	Cutting the steel plates and placing the screws	In The Data Sheet

4. The Manufacturing of the Generator
5.The Testing of The Efficiency of the Generator

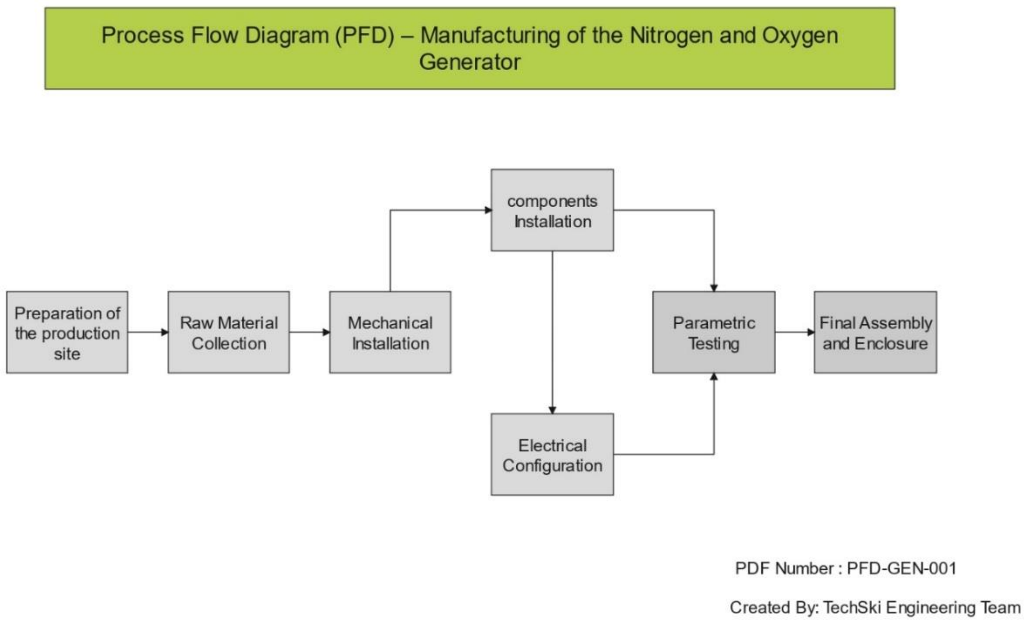

Figure IV.1:The Process Flow Diagram of The Gas Generator

IV.2.2. Production Process of The Tracking Card

The Production Process of the Gas Generator pass Through main steps listed Below:
1.The Purchase of the Raw Materials.

Table IV.3: Purchase Table of Raw Materials for The Tracking Card Project

Component	The Model	The Number
GSM GPRS Module	SIM800L	One
Wi-Fi Bluetooth Module	ESP32-WROOM-32	One
GPS Module	GPS-NEO-6M	One
Lithium Battery	Pile Lithium	One
Battery Charging module	TP4056	One
Voltage regulator	-	One
Printed case	-	One

2. Electronic Circuit Design.
3.Devoloping the program needed.
4. Functional and Power Testing.
5. Enclosure Assembly.

IV.3. Supply Chain

The supply chain plays a crucial role in the success of our project:

IV.3.1. Supply Policy

Our procurement strategy is to manufacture components within our capabilities, for those we cannot produce, we prioritize direct negotiations with reliable local suppliers, however, if a favorable agreement cannot be reached locally, we will consider international suppliers.
The purchase will be made directly from the manufacturer.

IV.3.2. Payment and Delivery Terms

We are open to various payment methods, whether through a bank or direct transactions. However, to enhance efficiency in supply chain management, all payments and raw materials delivery will be aligned with clearly defined timelines.

IV.4 Labor

Since we are a small Startup, we will consider the fabrication of One Generator per Month and Ten Tracking cards per Day, to do this we need:
Number of Jobs: The startup is expected to create 17 jobs in its field of work, including

Table IV.4: Job Distribution Table

Job Type	The Number of Positions
Process Engineer	One
Electrical Engineer	One
Mechanical Engineer	Two
Designer	One
Content Manager	One
Development Engineers	One
Electronic Engineer	Two
Programmers	One
Workforce	Two
Welders	Three
security personnel	Two

IV.5. Key Partners

To ensure the success of our projects, we need to build professional relationships with many partners, including:

- **Incubators:** Our engagement with incubators will provide us with access to mentoring, knowledge, and valuable encouragement. This is exactly what we have received from the incubator at the University of Skikda, our first association in this area
- **Suppliers:** To secure better deals, we will collaborate with our suppliers and build relationships based on long-term contracts. This approach will provide greater financial support and ensure a consistent supply of raw materials.
- **Laboratories and Research Institutes:** Since we aim to manufacture many of our raw materials such as tanks, we need to certify our products through research institutions, metrology services, or performance testing. Therefore, collaborating with these entities is extremely important.
- **Banks and Financial Institutions:** While we have implemented a strategy based on self-financing, its success is a significant challenge and will require time.
  Therefore, building strong relationships with financial institutions can help us secure the funding and credit lines needed to scale up.

Fifth Section

Financial Plan

V.1. Costs and Expenses

These tables detail the startup main expenses across all our sectors, including infrastructure costs, human resources, website development, marketing, and general services.
They provide an overview of the investments required for the proper operation of the Startup over several years.

V.1.1. Infrastructure and Equipment

Firstly, we need to estimate the cost of each material in our Projects:

The Material	The Price (DA)
The Air Compressor	129 344
The Aftercooler	12 934
The Multi Stage Filter	7 761
The Particulate Filter	1 293
The Refrigerated Dryer	50 448
The Inline Desiccant Cartridge	3880
The Membrane Module	1 370 799
The Dual Gas Analyzer	25 212
The Programmable Logic Controller	38 659
MPPT Controller	3 749
Solar Panel	16 808
Battery Bank	38 789
Solenoid Valve	15 515
Bolt	1 551
Hex Nut	1 551
The Pipes	25 212
The Air Receiver	4 008
The PSA Tower	4 008
Zeolite	7 000
The Oxygen Storage Tank	4 396
The Nitrogen Storage Tank	2 456
The Cooling Fan -electric	5 689
The Electrical Box	3 103
The External Box	17 585
Total Generator Raw Materials Cost	1 791 750
GSM GPRS Module	1 400
Wi-Fi Bluetooth Module	2 000
GPS Module	2 200
Lithium Battery	450,00
Battery Charging module	450,00
Voltage regulator	100,00
Printed case	2 000
Total Tracking card Raw Materials Cost	9600

Considering the production of one unit of each project in the first year and 12 units of the generator, and 3,600 units of the tracking card in the second year.
Considering getting better deals with the suppliers in the third year and moving ahead.

Action	N	N+1	N+2	N+3	N+4	N+5
Workspace Location	1 500 000	1 500 000	1 500 000	1 500 000	1 500 000	1 500 000
Raw Materials	1 791 750	32 500 000	32 500 000	32 500 000	32 500 000	32 500 000
Workspace layout	1 000 000	-	-	-	-	-
Total	4 291 750	34 000 000	34 000 000	34 000 000	34 000 000	34 000 000

V.1.2. Human Ressources

Action	N	N+1	N+2	N+3	N+4	N+5
Personnel Recruitment	16 320 000	16 320 000	16 320 000	16 320 000	16 320 000	16 320 000
Initial Training	170 000	-	-	-	-	-
Total	16 490 000	16 320 000	16 320 000	16 320 000	16 320 000	16 320 000

V.1.3. Website Development and Digital Tools

Action	N	N+1	N+2	N+3	N+4	N+5
Website Design and Development	500 000	-	-	-	-	-
Web Hosting	75 000	75 000	80 000	85 000	90 000	95 000
Website Maintenance	00	00	00	00	00	00
Total	575 000	75 000	80 000	85 000	90 000	95 000

V.1.4. General Services and Logistics

Action	N	N+1	N+2	N+3	N+4	N+5
Office Management	360 000	360 000	360 000	360 000	360 000	360 000
Transportation	240 000	240 000	240 000	240 000	240 000	240 000
Insurance	350 000	350 000	400 000	450 000	500 000	550 000
Total	950 000	950 000	1 000 000	1 050 000	1 100 000	1 150 000

V.1.5. Total Expenses

Action	N	N+1	N+2	N+3	N+4	N+5
Total estimated investment for startup	22 306 750	51 345 000	51 400 000	51 455 000	51 510 000	51 565 000

V.2. Revenue

This tables presents the sales forecasts for our products, showing consistent growth in production volume and pricing over the next five years, as our processes become more efficient and our client base expands, under both pessimistic and optimistic scenarios.
These figures help estimate the potential sales growth in the market.
We will refer to the generator as Product A and the tracking card as Product B.

V.2.1. Optimistic Scenario for the Product A

Our projections are based on a normal scenario of producing and selling one generator in the first year.
producing and selling one Generator per month in the other years
In the optimistic scenario, we anticipate finding clients who can afford to purchase the generator for 3 500 000 DZD.

Product A for the customer	N -2	N -1	N	N+1	N+2	N+3	N+4	N+5
Quantity of Product A	-	-	0	12	12	24	24	24
Excluding Tax Price of Product A (DZD)	-	-	0	42 000 000	42 000 000	84 000 000	84 000 000	84 000 000
Product A Sales (DZD)	-	-	0	42 000 000	42 000 000	99 960 000	99 960 000	99 960 000

Product A for the customer	N -2	N -1	N	N+1	N+2	N+3	N+4	N+5
Total Revenue (DZD)	-	-	0	42 000 000	42 000 000	99 960 000	99 960 000	99 960 000

V.2.2. Pessimistic Scenario for The Product A

In the pessimistic scenario, we expect to sell the generator for 2 500 000 DZD

Product A for the customer	N -2	N -1	N	N+1	N+2	N+3	N+4	N+5
Quantity of Product A	-	-	0	12	12	24	24	24
Excluding Tax Price of Product A (DZD)	-	-	0	30 000 000	30 000 000	60 000 000	60 000 000	60 000 000
Product A Sales (DZD)	-	-	0	30 000 000	30 000 000	71 400 000	71 400 000	71 400 000
Total Revenue (DZD)	-	-	0	30 000 000	30 000 000	71 400 000	71 400 000	71 400 000

V.2.3. Optimistic Scenario for Product B

Considering getting deals for selling one card at a price of 15 000 DA

Product B for the customer	N -2	N -1	N	N+1	N+2	N+3	N+4	N+5
Quantity of Product B	-	-	0	1500	3000	3600	4950	4950
Excluding Tax Price of Product B (DZD)	-	-	0	22 500 000	45 000 000	54 000 000	74 250 000	74 250 000
Product B Sales (DZD)	-	-	0	22 500 000	45 000 000	64 260 000	88 357 500	88 357 500
Total Revenue (DZD)	-	-	0	22 500 000	45 000 000	64 260 000	88 357 500	88 357 500

V.2.4. Pessimistic Scenario for Product B

Considering not being able to sell the card for more than 12,000 DA

Product B for the customer	N -2	N -1	N	N+1	N+2	N+3	N+4	N+5
Quantity of Product B	-	-	0	1500	3000	3600	4950	4950
Excluding Tax Price of Product B (DZD)	-	-	0	18 000 000	36 000 000	43 200 000	59 400 000	59 400 000
Product B Sales (DZD)	-	-	0	18 000 000	36 000 000	51 408 000	70 686 000	70 686 000
Total Revenue (DZD)	-	-	0	18 000 000	36 000 000	51 408 000	70 686 000	70 686 000

V.3.Projected Financial Statements

The profit and loss statement will outline income and expenses of The Company

Year	Revenue (DZD)	Total Costs (DZD)	Net Profit (DZD)
N	-	22 306 750	-
N+1	64 500 000	51 345 000	13 155 000
N+2	87 000 000	51 400 000	35 600 000
N+3	164 220 000	51 455 000	112 765 000
N+4	188 317 500	51 510 000	136 807 500
N+5	188 317 500	51 510 000	136 807 500

V.4.Cash-Flow Plan

The following is our monthly cash flow prediction for the first year after dealing with technical matters:

Month	Revenue (DZD)	Expenses (DZD)	Net Cash-Flow (DZD)
January	3 950 000	3 718 916	23 1 084
February	3 950 000	3 718 916	23 1 084
March	3 950 000	3 718 916	23 1 084
April	3 950 000	3 718 916	23 1 084
May	3 950 000	3 718 916	23 1 084
June	3 950 000	3 718 916	23 1 084
July	3 950 000	3 718 916	23 1 084
August	3 950 000	3 718 916	23 1 084
September	3 950 000	3 718 916	23 1 084
October	3 950 000	3 718 916	23 1 084
November	3 950 000	3 718 916	23 1 084
December	3 950 000	3 718 916	23 1 084

The revenue from the education sector will be directed solely towards the development of our services or to support our employees, especially the engineers who contributed by creating content.

Sixth Section
Experimental Prototype

VI.1. The Generator Project

- We designed our generator in SolidWorks, where all the main components were modeled in detail.
- The generator description and data sheet include all relevant calculations and technical specifications.

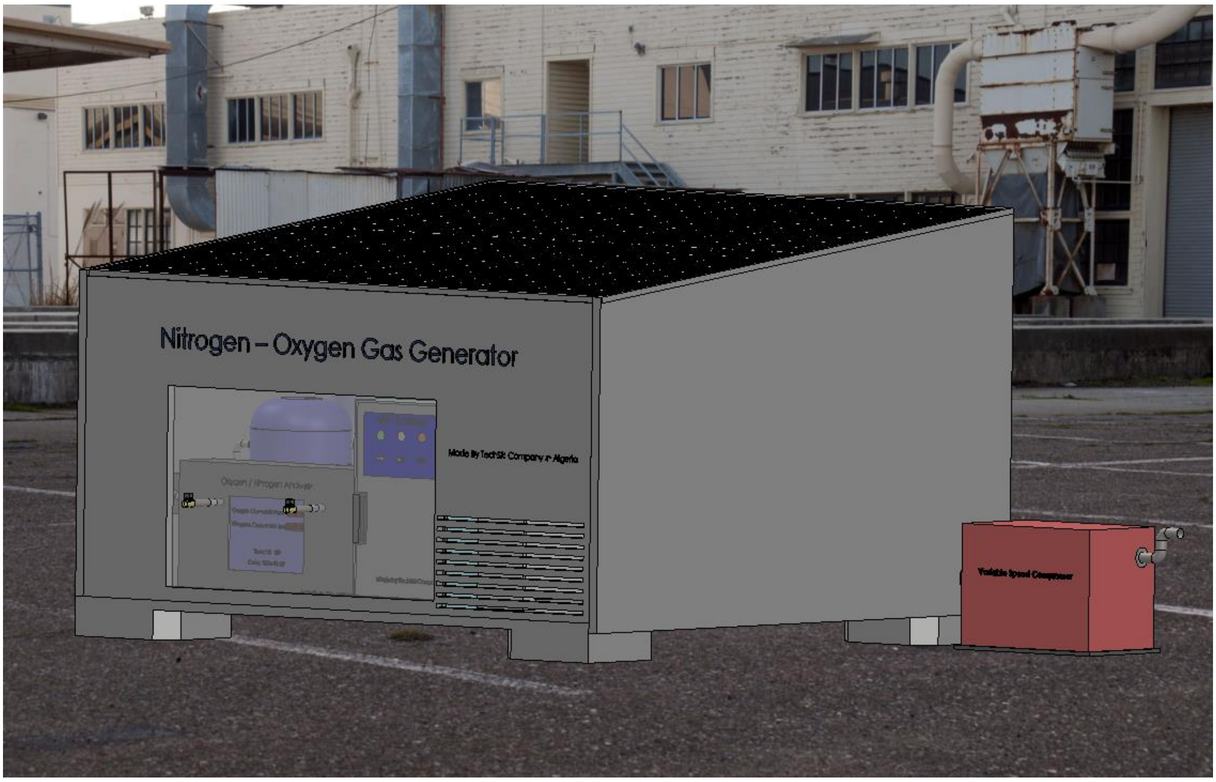

Figure VI.1: the front view of the generator

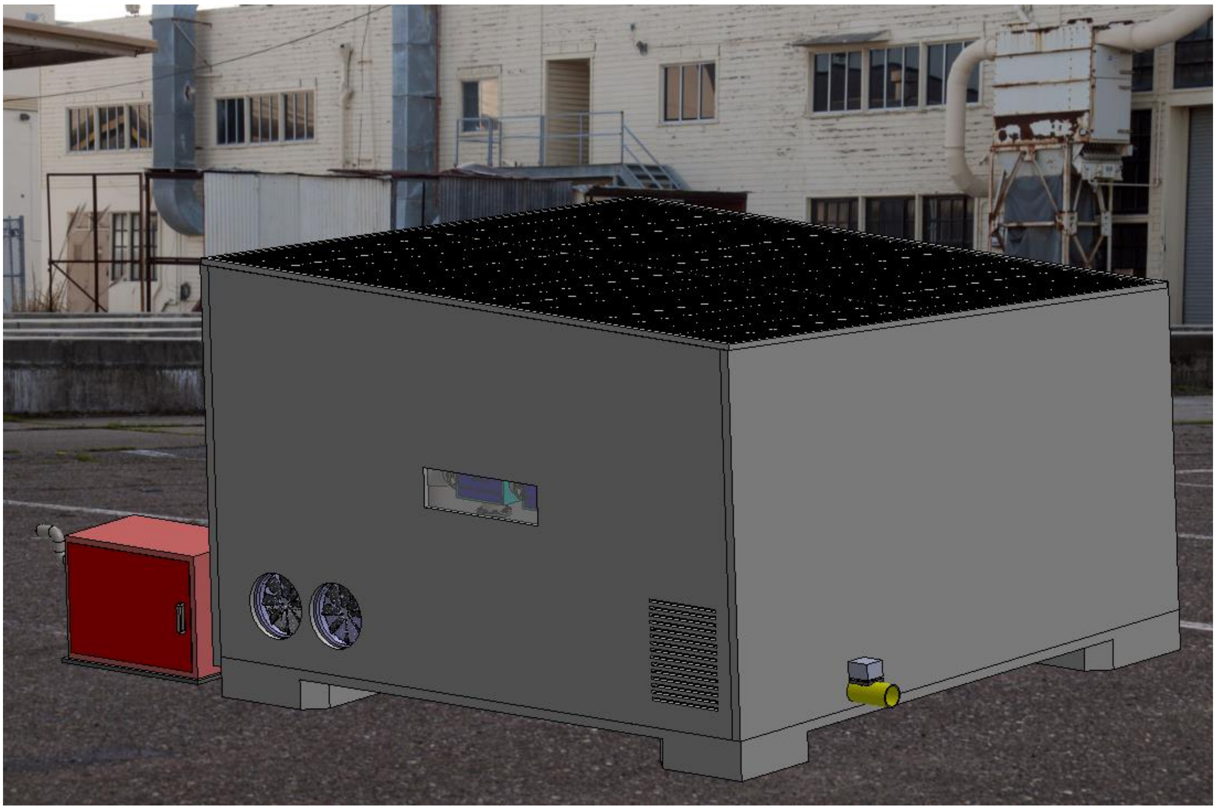

Figure VI.2:Rear view of the generator

- The full SolidWorks presentation is available via the following Google Drive link:

https://drive.google.com/drive/folders/1S3qWr6FpQAEZCSA1gomn2Ei89Ou2cSqA?usp=drive_link

VI.2. The Tracking Device Project

VI.2.1. The Software Part

When the users first open the application, they are welcomed by a simple and clear login page which comes with to input fields email and password to keep the process fast.
After logging in successfully, the user is automatically redirected to the homepage.
The home page is the main interface of the system, on this page, all the registered tracking devices are shown in list format. For each device, the user can see the device name, whether it is currently online or offline, and the last time it was seen. Or also can delete the device from the registered devices.
Next to the device list there is an interactive map that displays the real-time location of the selected device. When the user clicks on a device from the list, the map updates to show its position. Additionally, the home page includes a section where the user can choose to view either the selected device information or its history. This allows the user to switch between the current data and past movement Homepage
To register a new device, the user can click on the "Add Device" button on the home page, which opens a new device interface which allows the user to input the device name, its unique identifier,

and the type.

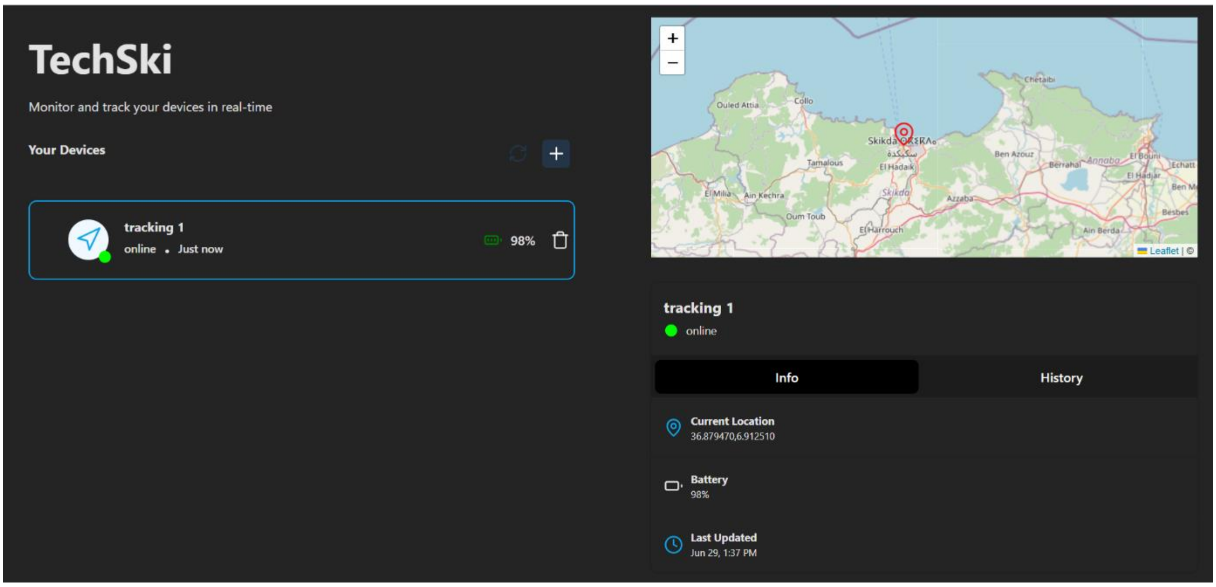

Figure VI.3:Tracking Device Software Interface – View 1

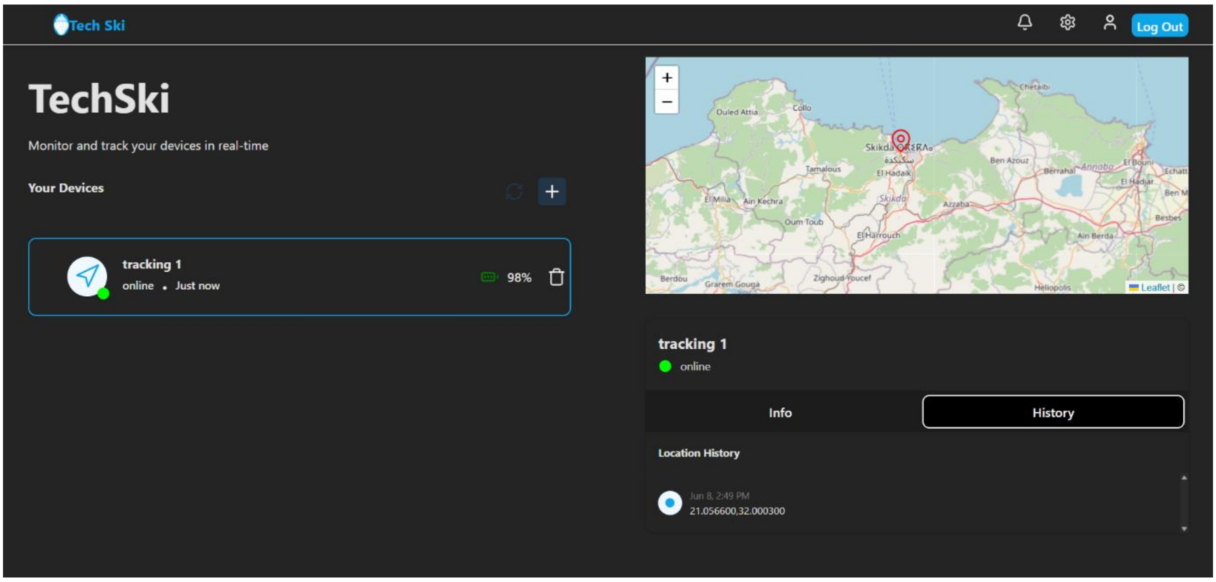

Figure VI.4: Tracking Device Software Interface – View 2

VI.2.2. The Hardware Part

The hardware of the tracking devices will come in various forms, adapted to the different applications we aim to implement. For example, a device designed for vehicle tracking will differ from one used for animal monitoring, and a device for animal monitoring will not be the same as one intended for prisoner tracking.

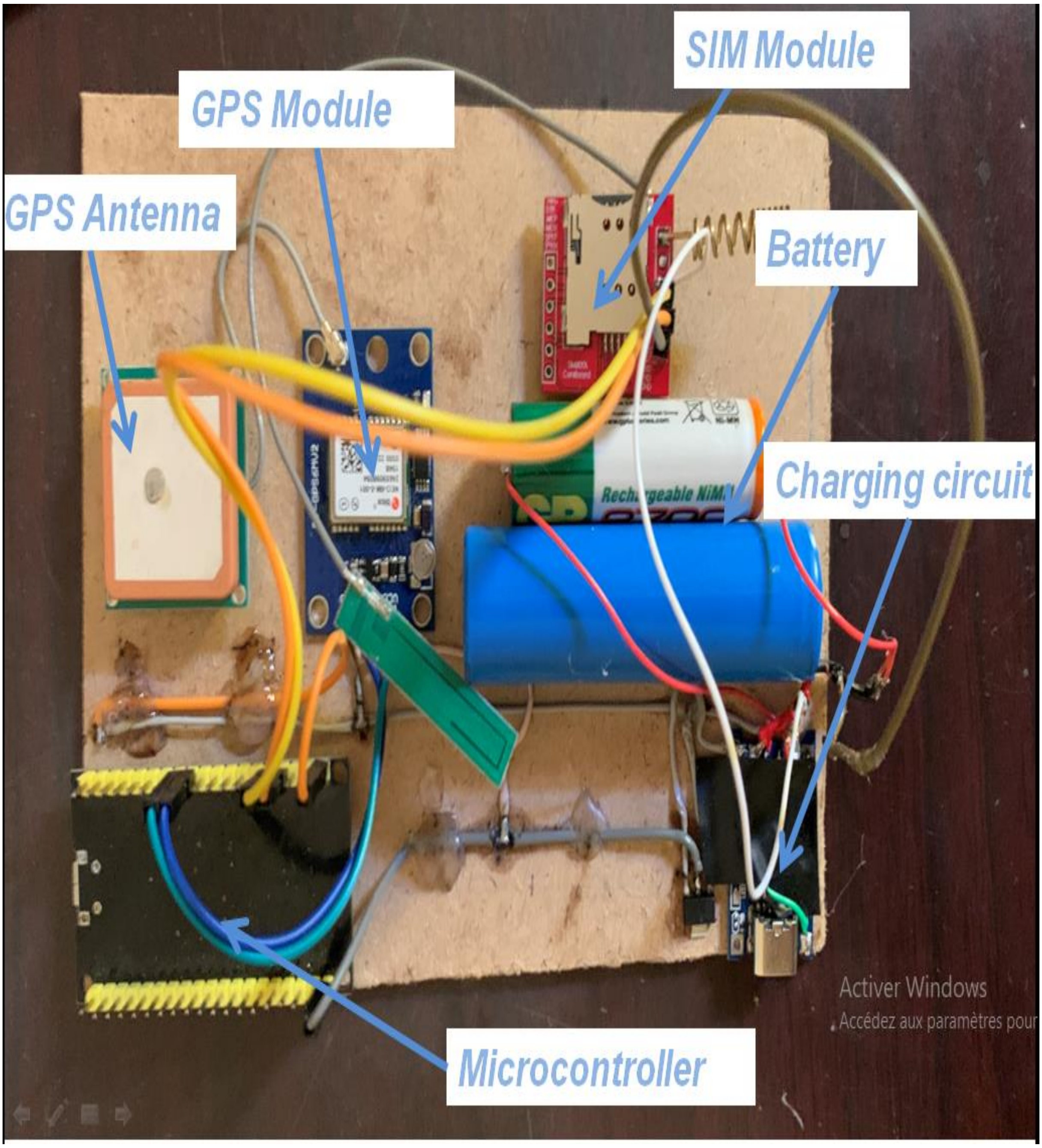

Figure VI.5:Internal View of the Tracking Device with Key Internal Components

VI.3. The Digital Education Project

TechSki Education is launching its first series of courses on YouTube, covering technical subjects such as programming and other related fields.

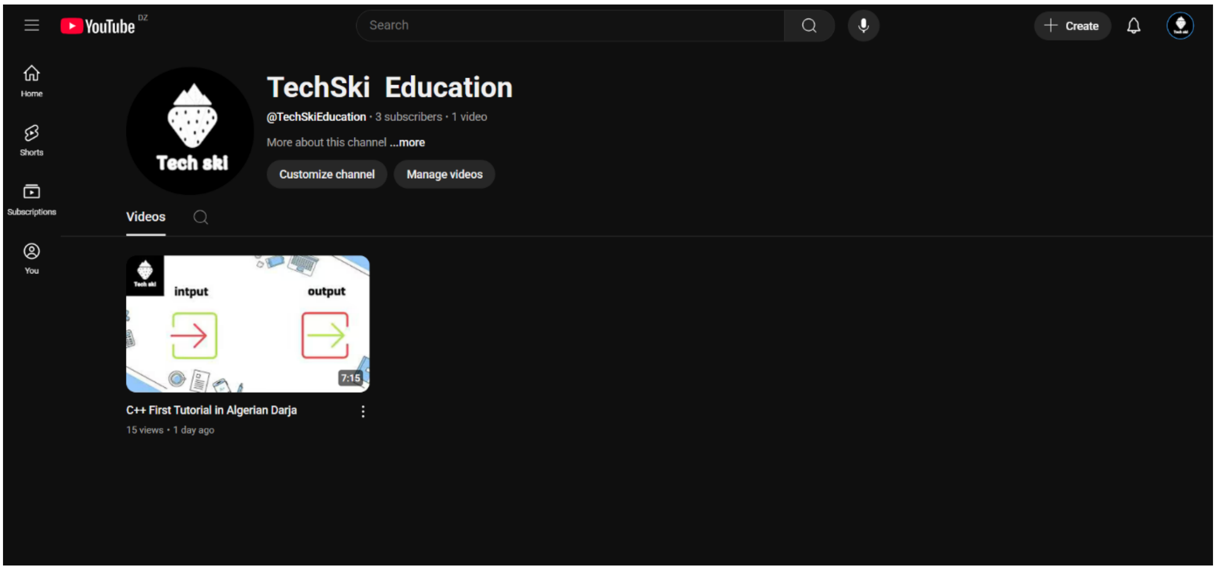

Figure VI.6:Channel Interface

- The Link of The YouTube Channel:

https://www.youtube.com/@TechSkiEducation

- The courses and interactive exercises will be offered on the company's official website via the following link:

https://techski-techskicompanys-projects.vercel.app/

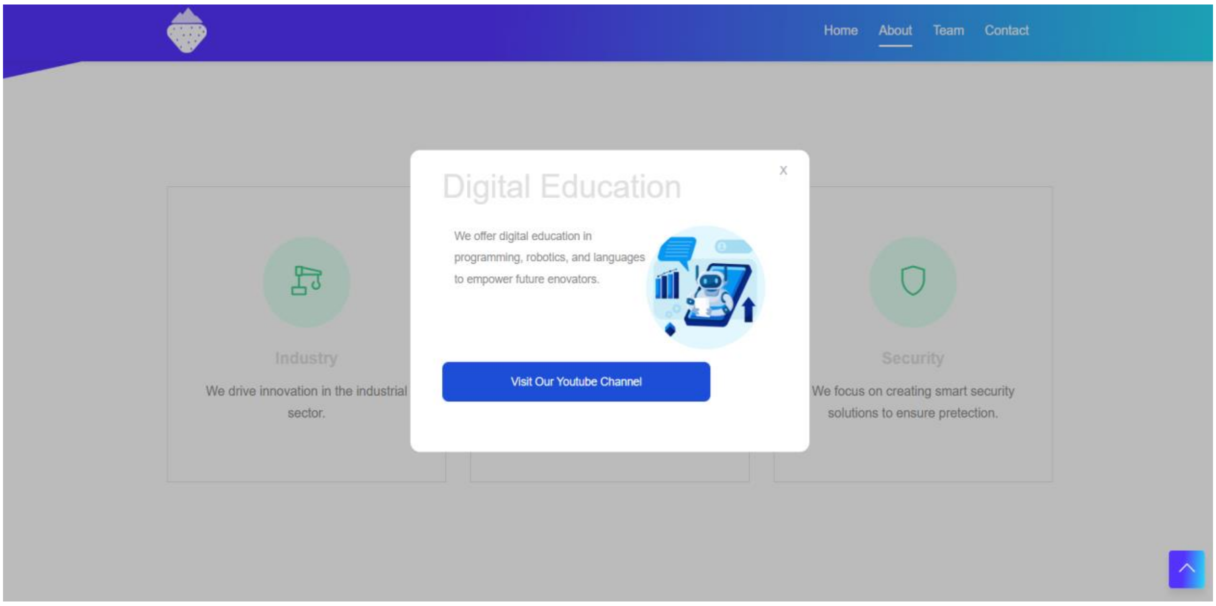

Figure VI.7: Web Interface of TechSki Platform

List of appendices

Annex 1 : Startup Budget

Balance Sheet Overview
Assets (Active)

Description	Forecast (in DZD)
Non-Current Assets	
Intangible Assets	1.7M (N+1), 1.3M (N+2), 1.75M (N+3), 2.05M (N+4), 3M (N+5)
Tangible Assets	3.3M (N), 2.7M (N+1), 2.9M (N+2), 3.3M (N+3), 3.7M (N+4), 15.9(N+5)
Land	-
Building	1.0M (N)
Other Tangible Assets	0.5M (N), 0.3M (N+1), 0.2M (N+2), 0.2M (N+3), 0.1M (N+4)
Assets in Progress	0.5M (N), 0.5M (N+1), 0.4M (N+2), 0.2M (N+3)
Total Non-Current Assets	5.3M (N), 5.2M (N+1), 4.8M (N+2), 5.45M (N+3), 5.85M (N+4), 18.9M (N+5)
Current Assets	
Inventory & Work in Progress	1.8M (N), 3.2M (N+1), 4.3M (N+2), 8.2M (N+3), 9.4M (N+4), 9.4M (N+5)
Receivables	6.5M (N+1), 8.7M (N+2), 16.42M (N+3), 18.83M (N+4), 18.83M (N+5)
Clients	-
Cash	13.15M (N+1), 48.75M(N+2), 161.52M (N+3), 298.33M (N+4), 435.14M (N+5)
Total Current Assets	1.8M (N), 22.8M (N+1), 61.75M (N+2), 186.14M (N+3), 326.56M (N+4), 463.37M (N+5)
Total Assets	7.1M (N), 28M (N+1), 66.55M (N+2), 191.59M (N+3), 332.41M (N+4), 482.27M (N+5)

Annex 1 : Startup Budget

Liabilities & Equity (Passive)

Description	Forecast (in DZD)
Equity	
Issued Capital	25M (N), 25M (N+1), 25M (N+2), 25M (N+3), 25M (N+4), 25M (N+5)
Uncalled Capital	-
Revaluation Surplus	-
Total Equity	25M (N), 25M (N+1), 25M (N+2), 25M (N+3), 25M (N+4), 25M (N+5)
Non-Current Liabilities	
Financial Debt	10M (N), 9M (N+1), 8M (N+2), 6M (N+3), 4M (N+4), 2M (N+5)
Other Liabilities	2M (N), 2M (N+1), 1.5M (N+2), 1M (N+3), 0.5M (N+4)
Total Non-Current Liabilities	12M (N), 11M (N+1), 9.5M (N+2), 7M (N+3), 4.5M (N+4), 2M (N+5)
Total Liabilities & Equity	37M (N), 36M (N+1), 34.5M (N+2), 32M (N+3), 29.5M (N+4), 27M (N+5)

Annex 2 : Financial Forecast

Description	N	N+1	N+2	N+3	N+4	N+5
Sale and products Appendices	0	64,500,000	87,000,000	164,220,000	188,317,500	188,317,500
Variation of finished product stocks	0	1,000,000	1,500,000	2,500,000	3,000,000	3,000,000
Capitalized production	500,000	600,000	700,000	800,000	800,000	800,000
Operating subsidy	1,000,000	500,000	500,000	500,000	500,000	500,000
Production of the fiscal year	1,500,000	66,600,000	89,700,000	168,020,000	192,617,500	192,617,500
Consumed purchases	4,291,750	34,000,000	34,000,000	34,000,000	34,000,000	34,000,000
External services and other consumptions	950,000	950,000	1,000,000	1,050,000	1,100,000	1,150,000
Consumption of the fiscal year	5,241,750	34,950,000	35,000,000	35,050,000	35,100,000	35,150,000
Operating value added	-3,741,750	31,650,000	54,700,000	132,970,000	157,517,500	157,467,500
Personnel expenses	16,320,000	16,320,000	16,320,000	16,320,000	16,320,000	16,320,000
Taxes and duties	500,000	600,000	700,000	800,000	900,000	1,000,000
Gross operating surplus	-20,731,750	14,730,000	37,680,000	115,850,000	140,297,500	140,147,500
Other operating income	0	1,000,000	1,200,000	1,500,000	1,500,000	1,500,000

Annex 2 : Financial Forecast

Other operating charges	0	300,000	400,000	500,000	600,000	600,000
Operating result	-20,731,750	15,430,000	38,480,000	116,850,000	141,197,500	141,047,500
Financial income	0	100,000	200,000	300,000	400,000	400,000
Financial expenses	0	50,000	100,000	100,000	100,000	100,000
Financial result	0	50,000	100,000	200,000	300,000	300,000
Ordinary result before tax	-20,731,750	15,480,000	38,580,000	117,050,000	141,497,500	141,347,500
Tax Due	0	2,941,000	7,330,200	22,239,500	26,884,525	26,856,025
Net Income for the Year	-20,731,750	12,539,000	31,249,800	94,810,500	114,612,975	114,491,475

Annex 3 : Forecast

Description	Forecast (DZD)
Cash Flow from Operational Activities	1,000,000 (N), 13,155,000 (N+1), 35,600,000 (N+2), 112,765,000 (N+3), 136,807,500(N+4), 136,807,500(N+5)
Adjustments for	
Depreciation and Provisions	500,000(N), 600,000 (N+1), 700,000 (N+2), 800,000 (N+3), 800,000 (N+4), 800,000 (N+5)
Stock Variations	600,000 (N+1), 2,000,000 (N+2), 1,500,000 (N+3), 1,500,000 (N+4), 1,500,000 (N+5)
Client and Receivable Variations	1,500,000(N+1),2,000,000(N+2), 2,500,000 (N+3), 3,000,000 (N+4), 3,000,000 (N+5)
Cash-Flow from Activities	1,500,000(N),17,255,000(N+1),39,800,000 (N+2), 117,565,000 (N+3),142,107,500(N+4) 142,107,500 (N+5)
Cash Flow from Investment Operations	
Cash outflow for fixed asset purchases	5,366,750(N),3,000,000(N+1),3,000,000 (N+2), 4,000,000 (N+3), 4,000,000 (N+4), 4,000,000 (N+5)
Cash inflows from fixed asset sales	-
Cash Flow from Financing Operations	
Capital Increase	20,000,000 (N)
Dividends paid to shareholders	3,000,000 (N+3), 5,000,000 (N+4), 6,000,000 (N+5)
Closing Cash Balance	16,133,250(N),30,388,250(N+1), 67,188,250 (N+2), 180,753,250 (N+3), 323,860,750 (N+4), 454,968,250 (N+5)

Annex 4: Business Model Canvas (BMC)

Key Partners

-Equipment suppliers
-Incubators
-Transport companies
-Financial Institutions

Key Activities

-Product Development
-Quality Control
- Customer Support & Maintenance
-Content Management
- Marketing & Sales

Key Resources

-Raw materials
-Qualified Personnel
-Intellectual Property
-Startup Capital

Value propositions

-Newness
-Digital Integration
-usability
-Risk Reduction
-Environmental Responsibility
-Proportional Growth

Customer Relationships

-Personal Assistance
-Direct communication
-After sales support
-Self-services

Channels

-Direct sales to clients
-Distribution via Intermediaries
-Digital marketing
-Networking events
-Evaluation

Customer Segments

-Industrial Companies
-Medical and Healthcare Facilities
-Agriculture and Food Storage
-Laboratories and Research Institutions
-Security Companies
-Emergency Services
-Engineering Students
-Engineers

Cost Structure

-Raw materials
-Salaries
-Facility Costs

Revenue Streams

-Sales of tracking devices
- Sales of the Oxygen and Nitrogen Generators
-Training Fees
-Assets sale

References

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