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In the name of my Creator, the facilitator of my affairs, and the protection of my affairs. All praise and gratitude be to you.

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I am hers, and if she refuses against her will, I will bring her

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Our last prayer: Praise be to God, Lord of the worlds

Bensafiddine yassine

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The trip was not short nor should it be the dream was not close and

The path was not paved easily but I did it

To the one whom God blessed with dignity and reverence, to the one

Whose name I carry with pride to the one I miss and whose memory

Makes my heart tremble to the one who left us physically and whose

Spirit still soars in the sky of my life

"My dear father" may God have mercy on him - and grant him the

Highest paradise

To my angel in life to the meaning of love and tenderness to the smile

Of life and the secret of existence to the one whose prayers were the

Secret of my success and whose kindness was the balm for my wounds

The one who was my support my compensation my first support and my

Source Strength: Thank you for everything

The Greatest Mother my dear mother may God grant her good health and

Wellness to my source of strength my support my solid ground and my

Solid support to those who believed in my success and success

It reminded me of my strength and abilities to those who never

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Abstract

Algeria, like many other countries, recognizes the necessity of addressing energy challenges amid global calls for environmental preservation. With its abundant energy resources, both fossil fuels and renewables, Algeria is strategically moving towards sustainable development.

The objective of this endeavor is to focus on integrating energy resources, namely solar and fossil fuel (GAS), into Algeria's energy mix. An important initiative is the hybrid power station in Hassi R'mel, which has a capacity of 150 megawatts. and is operated by [SPP01]. The aim of this project is to reduce emissions, enhance air quality, and promote sustainability, highlighting the pivotal role of technologies such as solar concentration and the Rankine cycle with reheating in achieving efficiency goals. Additionally, the treatment of urban wastewater, as exemplified by the Hassi R'mel plant, underscores Algeria's commitment to sustainable urban development and environmental protection. Through such initiatives, Algeria seeks to alleviate energy scarcity, economic crises, and environmental concerns, aligning with global efforts towards a sustainable future.

Keywords: **energy, hybrid, solar energy, sustainability**

ملخص

في الجزائر، تُدرك الحكومة أهمية التحديات الطاقوية وتسعى جاهدة نحو التنمية المستدامة، مستفيدة من مواردها الوفيرة من الطاقة الأحفورية والمتجددة. تتبنى الجزائر استراتيجية متكاملة تجمع بين الطاقة الشمسية والغاز الطبيعي في بقدرة 150 ميجاوات. الهدف من "spp 01" مشروعات مثل محطة الطاقة الهجينة في حاسي رمل، التي تديرها شركة هذه المبادرات هو تحسين جودة الهواء وتقليل الانبعاثات، وذلك من خلال تقنيات متقدمة مثل تكنولوجيا تكثيف الطاقة الشمسية ودورة رانكين مع إعادة التسخين، لتحقيق أقصى درجات الكفاءة.

بالإضافة إلى ذلك، بمثل هذه المشاريع مثل محطة حاسي رمل، تعكس الجزائر التزامها بالتنمية الحضرية المستدامة وحماية البيئة، مثل معالجة مياه الصرف الصحي الحضرية. تهدف هذه الجهود الشاملة إلى تخفيف ندرة الطاقة، وتحسين الاقتصاد، ومعالجة المخاوف البيئية، وهو ما يتماشى تمامًا مع الجهود العالمية لبناء مستقبل مستدام..

الكلمات المفتاحية: الطاقة، الهجين، الطاقة الشمسية، الاستدامة

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Introduction General

Introduction General

The global energy scene faces significant challenges due to resource scarcity and the urgent need for sustainability amidst economic growth and population expansion. This has prompted many countries, including Algeria, to reassess their energy strategies, emphasizing the rationalization of consumption and increased investment in renewable sources. Algeria's rich energy reserves, along with its commitment to international environmental agreements, underscore the necessity of diversifying the energy portfolio. The National Program for the Development of Renewable Energies embodies Algeria's commitment to integrating renewable energy sources more prominently, with a vision extending to 2030. Among renewable technologies, solar energy concentration stands out for its ability to harness solar energy efficiently, despite challenges such as infrastructure costs and weather variability. In parallel, initiatives such as the urban wastewater treatment plant in Hassi R'mel, operated by "Sonatrach». Represent crucial steps towards sustainability, focusing on the role of clean energy in mitigating environmental impact. The inauguration of the first hybrid power station "SPP01" in Algeria sheds further light on the country's commitment to reducing emissions and improving air quality. Through these efforts, Algeria charts a path towards a more diverse and sustainable energy future, aligning with global environmental and climate goals

Chapter I: Algeria’s plan for renewable energy in 2030

I .1. Introduction

Energy resources pose important and vital issues in the face of scarcity of these resources and the economic crises associated with them. The increase in global energy demand at the beginning of the third millennium, driven by economic and population growth, has prompted many energy-producing countries to exploit their potential to meet local and global energy demand, resulting in irrational exploitation of these resources and posing the problem of hastening their depletion. Therefore, many countries have developed plans and policies to rationalize energy consumption, in addition to programs for developing renewable energy and increasing investment in it Given Algeria's vast energy resources, whether fossil fuel sources or renewable energy sources, it seeks to increase and diversify its investments amid global calls to reduce the environmental problems caused by fossil fuel sources, without forgetting the international agreements and treaties that Algeria has concluded to preserve the environment, necessitating increased reliance on renewable energy sources as a strategic option for achieving development. In this context, Algeria, like many other countries, has worked on developing plans, policies, and laws to promote the renewable energy sector. The National Program for the Development of Renewable Energies, which extends its goals to 2030, is an ambitious program aimed at achieving sustainable development by integrating renewable energy more prominently into Algeria's energy balance.

I .2. Energy concept:[01]

Energy can be defined as:

“It is what drives the machines that we use in daily life, and to do hard work in our place in order to obtain the necessary comfort: heating, lighting, cooling...”

Energy is a scientific term that means rationalizing and organizing basic processes in nature. We cannot observe or measure them directly, but rather we study their effect on materials. It can be defined as: “Energy is the ability to accomplish work and it appears in various forms such as kinetic or potential energy, or in the form of heat, mechanical work, electrical energy, or chemical reaction energy... etc. Energy divisions: we can separate

Primary energy: We obtain it from renewable sources (hydro, thermal, solar, biomass, and to a lesser extent wind and tidal energy), or from non-renewable sources (Uarenium, coal, petroleum, natural gas...)

(The most important energy developments in Algeria, an analytical study 2010-2017)

(Journal of Economic Growth and Entrepreneurship Vol. 4, No. 3, 106-120 (2021))

Secondary energy: such as electrical energy resulting from the transformation of primary energy through an installation that may be hydraulic or a thermal center. It may also be primary condensers used directly to produce heat for the industrial, service, or family sector. These condensers are either coal, natural gas, or petroleum. After refining it.

Energy can also be in several forms, including

Mechanical energy: For example, it is the kinetic energy of a car that results from the combustion of gasoline in the engine.

Thermal energy: produced, for example, by burning energy fuel in a steam heater under pressure. This energy can be converted into mechanical energy or electrical energy in a dynamo or generator.

Radiant energy: transmitted through light rays emanating from the sun.

Nuclear energy: results from the fission or fusion of nuclei in nuclear reactors.

Electrical energy: a form of energy produced by charged particles (electrons and ions), which is flexible and can be given Heat or light is a traction force... One of its main disadvantages is the loss of energy during conversion, production, and transportation

I .3. Conventional (non-renewable) energy sources

Conventional (non-renewable) energy sources are those that come from finite resources that cannot be naturally replenished on a human time scale. These sources are usually extracted from the ground and include:

Fossil fuels:

- Coal: A sedimentary rock with a black or burnt brown color, usually found in rock layers in layers or veins.
- Petroleum (oil): A yellowish black liquid found naturally in geological formations beneath the Earth's surface.
- Natural Gas: A hydrocarbon gas mixture that naturally consists of methane.

- Nuclear Energy: Energy released by nuclear reactions, especially through processes such as nuclear fission (splitting atomic nuclei) or nuclear fusion (combining atomic nuclei). These traditional energy sources have been widely used for centuries and have supported manufacturing, transportation, and electricity generation. However, their use raises concerns about environmental pollution, greenhouse gas emissions, and limited availability, leading to efforts to transition toward renewable energy sources.[01]

I .4. Renewable energy sources

Renewable energy sources are those that are naturally replenished on a human timescale and are considered sustainable because they do not deplete finite resources or contribute significantly to environmental pollution or climate change. Some common renewable energy sources include:

I .4.1. Solar Energy:

- Energy derived from the sun's radiation, which can be converted into electricity using photovoltaic cells or used directly for heating and lighting.

I .4.2. Wind Energy:

- Energy harnessed from the wind through wind turbines, which convert the kinetic energy of the wind into mechanical power or electricity.

I .4.3. Hydropower:

- Energy generated from the gravitational force of flowing or falling water, typically captured using dams or water turbines in rivers, streams, or tidal currents.

I .4.4. Biomass:

- Organic materials such as wood, agricultural residues, and organic waste that can be burned directly for heat or converted into biofuels such as ethanol and biodiesel for transportation or electricity generation.

I .4.5. Geothermal Energy: [02]

- Heat energy derived from the Earth's internal heat, usually extracted through geothermal power plants or heat pumps for heating buildings or generating electricity.

I 4.6. Hydrogen:

- Hydrogen can be produced through various methods, such as electrolysis of water using renewable electricity or through biomass gasification. It can be used as a clean fuel for transportation, heating, and electricity generation.

These renewable energy sources offer a sustainable alternative to conventional fossil fuels and nuclear energy, helping to reduce greenhouse gas emissions, mitigate climate change, and promote energy independence.

First, the current situation of the energy balance in Algeria

I .5.Energy resources

Algeria has enormous energy potential and resources, mainly represented by fossil fuel resources (Oil and natural gas) in addition to renewable energy resources, whose potential varies from one resource to another last.

A). Oil: The first attempts to search and explore for oil were in 1913 in the region

The western part of the Relizane area was occupied by French companies that continued to pursue their ambitions exploitation, and thus continued her research during World War I in Constantine and El Alma Ain Fakroun and Sidi Aish, but these attempts did not result in any discovery. And in a year 1946 The French Petroleum Company discovered the first oil field in Qatarni, then another field Cyrenaica near Ain Salah in 1952.

The year 1956 witnessed the discovery of the first important oil field in the Algerian Sahara, the Ajila field this was then followed by the discovery of the largest oil field in Algeria, the Hassi Messaoud field, in June 1956 is the year that witnessed the beginning of the activity of the hydrocarbon industry in Algeria. Then I became after its independence, Algeria was an oil country par excellence.

B). Oil reserves:

The Algerian reserve of crude oil has witnessed great fluctuations and development since the year 1970 until 2015, due to the energy policies followed that differed from one stage to another. The entry of international oil companies into the Algerian markets with the early 1990s, after opening the energy sector to foreign investment, contributed There is no doubt that the volume of crude oil reserves will increase, as shown in the table (01).

Table 1 I.: Algeria’s crude oil reserves are (one million barrels) [01]

year	reserve	year	reserve
1970	8098	2011	12200
1974	7700	2012	12200
1984	9000	2013	12200
1994	9979	2014	12200
2004	11350	2015	12200

From Table (1) we note that the Algerian reserve witnessed development during the period 1970/2004.

It increased from about 8.1 billion barrels to 11.3 billion barrels, i.e., an increase rate of about 40 percent. During the period 2011/2015, the size of the Algerian reserves stabilized at 12.2 billion Barrel

Algeria's production of crude oil has witnessed an upward trend, reaching 39 million tons Oil equivalent in 1999 rose to 47 million tons of oil equivalent in 2000, then 89.5 million Tons of oil equivalent in 2007. This increase is due to the opening of the door to foreign partnership. And starting from in 2008, crude oil production witnessed a significant decline, reaching 74.3 million tons equivalent Oil in 2011, and this decline is due to the occurrence of the global financial crisis that resulted an economic crisis whose effects later spread to the global economy, including the oil market.[02]

As the demand for oil decreased, in order to maintain price stability, it was necessary

Reducing production as required by the law of supply and demand first and according to OPEC policy second. Table (2) shows the development of Algerian production of crude oil from 1960 to 2016.

Table 2 I: Development of Algeria’s production of crude oil (1,000 barrels/ day)

Year+	production	year	production
1960	181.1	2012	1199.8

1970	1029.1	2013	1202.6
1980	1019.9	2014	1192.8
1990	783.5	2015	1157.1
2000	796	2016	1146.3

Rise and fall. During the period 1960/1980, production increased from 181.1 thousand barrels/day to 1019.9 thousand barrels/day, a period that witnessed increased demand for energy Two global energy crises occurred in 1973 and 1979, and in 1990 production declined to 783.5 thousand barrels/day, primarily due to the decrease in global demand due to... The economic recession that affected some European countries, which negatively affected oil prices in those countries Period. But at the beginning of the twenty-first century, Algerian oil production gradually increased to reach It reached its highest level in 2013 at about 1.2 million barrels per day, then gradually decreased initially Since 2014, due to increased supply versus demand and lower oil prices in international markets.

C). Natural gas: The development of natural gas production in Algeria is always subject to changes in consumption Internal requirements and fulfillment of obligations of contracts concluded with consumers because these conditions are Which determines production levels, with the increasing importance of natural gas as a clean source of energy, Algeria worked to provide a suitable climate for the development of natural gas reserves Allows it to increase production volume.

D). Natural gas reserves: by tracking statistics issued by the Organization of Nations Exporting Petroleum (OPEC) It turns out that the Algerian reserves of natural gas are known Different stages of development and decline during the period extending from the end of the seventies of the century in the past, until 1987, Algerian reserves of natural gas declined from About 3.7 to 3.16 trillion m3, i.e. a decrease of about 16% during the period in which It extended from 1987 to 1999, and the reserve increased from 3.16 to 4.5 trillion. m3, i.e. an increase of about 43%. The discrepancy in the path of development of the size of the Algerian reserves During the previous periods it is due to several reasons:

• The recorded decline in the Algerian natural gas reserves in the first stage is due To the decision to completely nationalize natural gas reserves, unlike oil, wherever nationalization took place Partially, it is limited to an Algerian participation of about 51% in the capital of production companies Foreign.

• As for the remarkable development in the size of the Algerian reserves in the second phase, i.e., 1987/1999 It dates back to the enactment of the 1986 law, especially the 1991 amendments, which allowed the opening of... Greater exposure to the hydrocarbons sector to foreign investment and intensifying the size of the partnership between Sonatrach and foreign companies.

F). Natural gas production:[03]

The development of natural gas production in Algeria is always subject to changes Internal consumption and requirements for fulfilling contract obligations concluded with consumers because these Conditions determine production levels, with the increasing importance of natural gas as a source clean energy: Algeria worked to provide a suitable climate for the development of gas reserves Natural, which allows it to increase the volume of production. Algeria's production of natural gas has reached in 2014,[03] through self-effort (Sonatech Company) and within the framework of the partnership, it reached 130.9 billion m3 distributed as follows:

Figure I 1 : Distribution of primary natural gas production in Algeria

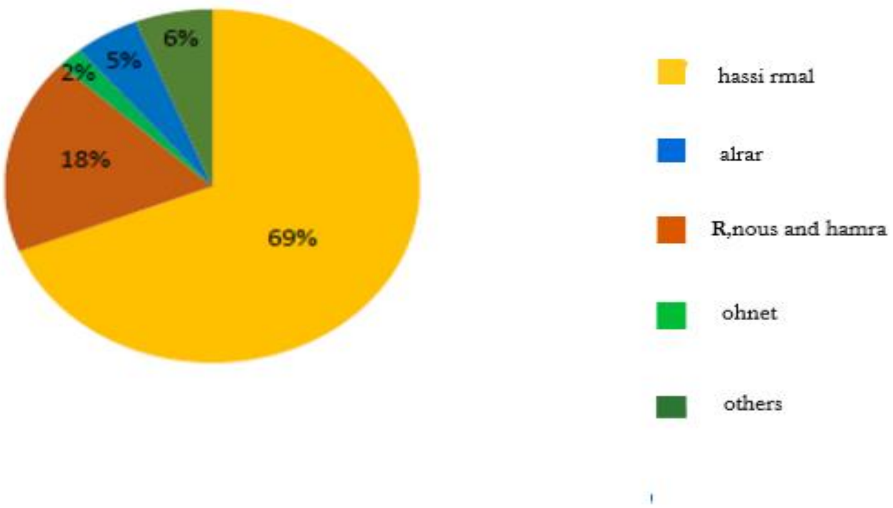


Figure I 2: The most important natural gas production fields in Algeria

I .6.Algeria's strategy for developing renewable energies

I .6.1. Renewable energy potential

Algeria has a diverse potential for renewable energies, mainly manifested in resources Solar, wind and hydropower, in addition to biomass and geothermal resources, despite their diversity Renewable energy resources in Algeria, but their abundance varies from one resource to another as they constitute resources Solar is the most important of all due to the vast area that the desert constitutes of the total area Algeria However, Algeria's potential for renewable energy resources can be limited to the following:

I .6.2 Water Resources:

Water resources in Algeria are considered modest due to the nature of the climate The prevailing climate in Algeria is the desert climate, which is characterized by lack of rain with its variation from one region to another, the rate of rainfall in the regions The northern regions are larger than the desert regions, and Table (03) shows the annual rates Rainfall in various regions of Algeria. As for surface water resources in Algeria, they are mainly limited to part of the northern slope of the Atlantic Mountain chain, and Algeria's water potential is estimated at less than 20 billion m3, 75% of which Renewable. The number of surface waterways in Algeria is estimated at about 30, most of them in Al-Tall region and flows into the Mediterranean Sea, [03] and its capacity is estimated at about 12.4 billion m3

Table 3 I.: Annual rates of rainfall in various Algerian regions (mm) [03]

regions	The west	The middle	The east
The coast	400	700	900
The hill atlas	600	1000-700	1400-800
High plateaus	250	250	400
Saharan atlas	150	200	400-300
The desert	150-20	150-20	150-20

I .6.3. Solar Resources:

Algeria has one of the most important solar capacities in the world. The duration of sunshine over the entire Algerian territory exceeds 2,000 hours annually and reaches 3,900 hours in the high plateaus and the desert. The energy obtained daily on a horizontal area estimated at about 1 m2 is 5 kilowatt-hours, or about 1700 kilowatt-hours/m2/year in the north, and Table (04) shows the solar resources in Algeria.

Table 4 I: solar resources in Algeria [04]

regions	**Coastal area**	**High plateaus**	**desert**
Space (%)	4	10	86
Average duration of sunshine (hours/year)	2650	3000	3500
Rateof energy obtained in kilowatt hours /m2/year	1700	1900	2650

I .6.4. Wind resources:[05]

The wind resource in Algeria changes from one place to another, and this is a result Mainly due to the topography, the very diverse climate and the large area it occupies Algeria consists of two large, distinct geographical regions, the north of which it borders The Mediterranean Sea is characterized by a coastline extending over 1,200 km and mountainous terrain It has two chains, the Hill Atlas and the Saharan Atlas, and between these two chains it exists Plains and high plateaus with a continental climate. The south has greater wind speeds in the north, especially in the southeast, wind speeds exceeded 7 m/s and greater than 8 m/s in the Tamanrasset region (Ain Amqel). As for the north, we note in general, the average wind speed is not very high, however there are detailed climates In the coastal sites of Kahran, Bejaia, Annaba and in the high plateaus of Katbessa, Biskra, Al-Masila, eggs at a speed of (6-7 m/s).

I.6.5.The Geothermal resources: Algeria has a significant potential of geothermal resources, which in total reach a capacity of 700 megawatts and have been fully exploited, as there are more than 200 water sources. It is hot in the north of the country, 33% of which are hotter than 45 degrees Celsius, and there are sources that reach... Its temperature reaches 96 degrees Celsius, like Hammam Miskhoutine in Qalma. As for the southern regions, the country contains a vast reservoir of hot water that extends to thousands of square kilometers and is called the alpine layer, whose temperature reaches about 57 degrees Celsius.

I .6.6. Biomass resources: Algeria is divided into two regions: the tropical forest region It occupies an area estimated at about 25 million hectares, or slightly more than 10% of the area The country's total and barren desert area, which covers more than 90% of Country area. In the north, which represents 10% of the country's area, forests cover 1.8% million hectares, while the terraced forest formations in the mountains account for 1.9 million

Hectares: Maritime pine and Eucalyptus are considered two important plants for energy use but they currently occupy only 5% of the Algerian forest.

I .7. the current status of the renewable energy sector

Installed energy: Despite the potential that Algeria has in terms of renewable energy sources, most notably solar resources, its contribution to the total installed energy remains limited. The table below shows the development of installed energy from various renewable energy sources during the period 2011/2016.

Table 5 I: Installed renewable energies for the year 2011-2016 (MW) [05]

year	2011	2012	2013	2014	2015	2016
Hydorelectric energy(large stations)	**227.6**	**227.6**	**227.6**	**227.6**	**227.6**	**227.6**
Soler energy(Csp)	25	**25**	**25**	**25**	**25**	**25**
Soler energy(pv)	-	**-**	**-**	**-**	**49.1**	**219.1**
Wind energy	**0**	**0**	**0**	**10.2**	**10.2**	**10.2**
total	**252.6**	**252.6**	**252.6**	**262.8**	**311.9**	**481.9**

From the above table it is clear the development of installed renewable energy as installed capacity increased from 252.6 MW in 2011 to 481.9 MW in 2016, that is, a growth of 91%. This is mainly due to the use of wind energy, which began in 2014, and solar energy systems Photovoltaics, the use of which increased in 2016.[05]

I .7.1. Electrical energy: The electricity sector in Algeria depends mainly on power stations It operates on fossil fuels through the use of thermal stations with its technologies Various types of steam, gas, combined cycle and diesel combinations in power generation electrical. The total electrical energy generated in Algeria reached 69,914 Gigawatt-hours in 2016, including 69,913 gigawatt-hours from fuel sources Fossil and 583 GWh of renewable energy sources as shown in Table (06).

Table 6 I: Electrical energy generated in Algeria 2011-2016 [06]

Year	2011	2012	2013	2014	2015	2016
Total electrical energy generated (GWh)	51313	56985	60121	64527	67111	69914
Electrical energy generated from fossil (GWh)	51062	56776	59560	63988	66553	69331
Electrical energy generated from hydropower plants (GWh)	173	126	330	254	260	267

Electrical energy generated form solar and profitable plants (GWh)	78	83	231	285	298	316

Completed projects in the renewable energy sector: Algeria has implemented many energy-related projects Renewable energy within the framework of achieving sustainable development requirements, including:

▪ within the rural electricity program 1995/1999, 906 homes were electrified, distributed over

18 isolated villages in the greater south in the states of Tamanrasset, Adrar, and Illizi.

▪ a hybrid electricity generation station (solar gas) in the Hassi R’Mel region with a capacity of up to 150 MW, including 25 MW with solar thermal energy (CSP), has been operated The station in 2011.

▪ A wind farm with a capacity of 10 MW in Adrar. The station was operated in June 2014

▪ A solar photovoltaic power plant with a capacity of up to 20 MW in Adrar Tam

The station was commissioned in October 2015.

▪ A solar photovoltaic power plant with a capacity of up to 13 MW in Tamanrasset Tam

The station became operational in November 2015

▪ A photovoltaic solar energy station with a capacity of up to 9 MW in Tindouf Tam

Commissioning of the station December 2015

▪ A solar photovoltaic power plant with a capacity of up to 9 MW in Timimoun

Badrar, the station was operated in February 2016.

▪ A photovoltaic solar energy station with a capacity of up to 15 MW in Wadi Sulfur

In Souk Ahras, the station was operated in April 2016.

I .7.2. The National Program for the Development of Renewable Energies:

The program focuses on establishing a capacity with renewable assets estimated at approximately 22,000 megawatts during.

The period 2011/2030, including 12,000 megawatts, is directed to cover the Algerian demand for electricity And 10,000 megawatts for export. Algeria's national potential for renewable energies is very important.

Especially solar energy, so Algeria considers this energy as an opportunity and engine for economic development Social and this is through the establishment of creative industries to create wealth and jobs. The program consists ofThrough it, Algeria seeks to promote renewable energies through 5 basic axes:

1. Renewable Energy Development Program
2. Program for developing energy efficiency and energy economy
3. Industrial capabilities that must be developed to accompany the program c
4. Research and development
5. Legal and regulatory framework and incentive procedures.

About four years after the launch of the program for developing renewable energies and energy efficiency, which...

It was approved by the government in February 2011 and appeared during the pilot and testing phase Technological elements are new and urgent on the energy scene, whether national or international Reviewing the program for developing renewable energies and energy efficiency, and thus the program for renewable energies The solution is to establish renewable energy from the beginning with a capacity of 22,000 megawatts by 2030.

Thanks to this new program, renewable energies and energy efficiency will be at the core the energy and economic policies pursued by Algeria, where by 2030, 37% of the existing capacity and 27% of the electrical production destined for national consumption will be of origin Renewed. Table No. (7) Shows the program for developing renewable energies in Algeria.

Table 7 I: Renewable energy program during the period 2015/2030 (MW)

	First stage 2020-2015	Second stage 2021-2030	total
Photovoltaic cells	3000	10575	13575
Wind	1010	4000	5010
Solar thermal energy	-	2000	2000
Cogeneration	150	250	400
Living masse	360	640	1000
geothermal	05	10	15
total	4525	17475	22000

Algeria's strategy in this field aims to achieve real industrial development of renewable energies, accompanied by... With a program in training and research, as well as acquiring the necessary experience, which is possible in the near term to exploit Algerian capabilities in all stages of development in these areas. Production is expected to reach Electricity to 90 terawatt-hours in 2020 and 170 terawatt-hours in 2030.

I .7.3. Economic

Economic benefits of the national program for developing renewable energies in Algeria: seeks, through the establishment of a national program for the development of renewable energies, which aims to achieve greater integration of renewable energy sources into the energy landscape of Algeria.

A set of benefits are:

▪ providing an energy reserve of 63 million tons of oil equivalent, which represents 38 billion dollars.

▪ Avoid building a station with a capacity of 1,500 megawatts, meaning a saving of $2 billion.

▪ Reducing more than 193 million from 2co, saving $1.1 billion.

▪ Opening 500,000 new jobs.

B. Obstacles facing the renewable energy development program in Algeria The obstacles facing Algeria's plan to develop renewable energies can be summarized within:

The National Program for Renewable Energy and Energy Efficiency, from my point of view, is as follows:

▪ the absence of a real will by government officials to implement the program and their lack of seriousness, especially among Energy sector officials.

▪ Focus investment efforts in the near and medium term on the hydrocarbons sector Without renewable energies.

▪ Abundance of traditional energy resources (natural gas and oil) at comparatively low costs with renewable energy resources

▪ The absence of a sufficient financial base necessary to finance renewable energy projects in light of The Algerian economy relies on fuel revenues to finance various forms of development.

▪ Fuel prices fluctuate in international markets, which negatively affects the implementation of the program related to renewable energies within specified deadlines, especially in the event of low oil prices Globalism.

I.2. Conclusion:

The plan for developing renewable energies in Algeria, through the Renewable Energy and Energy Efficiency Program, is ambitious and important in the country's efforts to diversify its energy resources and rationalize their use to ensure sustainability for future generations. In addition to the economic and environmental benefits that can be achieved by integrating renewable energies into the Algerian energy landscape, these efforts face significant challenges. These challenges include the dominance of fossil fuel sources, high investment costs for renewable energy projects, the immaturity of some related technologies, as well as the decline in hydrocarbon prices, which affects the revenues of the energy sector, a major source of funding for renewable energy projects. Despite these difficulties, continuous efforts are being made in this field, in line with the global trend towards achieving sustainable development that relies on inexhaustible energy resources, such as renewable energies.

Chapter II: Concentrated Solar Power (CSP)

II .1 Introduction

Solar concentrating is a technology used to generate thermal or electrical energy by focusing sunlight at a central point. This method relies on collecting solar energy from large areas and directing it towards a small central point using mirrors or lenses. This concentration increases the energy density at the central point, which increases the efficiency of solar energy use.

Solar concentrating technologies are used in a variety of applications, including generating electricity and heating water for domestic or industrial use. Solar focusing technologies can be divided into several types, including straight tubes, solar towers, solar dishes, and central wick.

Although solar concentrating technologies are effective in generating clean and sustainable energy, they may face some challenges such as infrastructure and operating costs and the impact of changing weather conditions on their efficiency. However, the growing interest in renewable energy and environmental technology makes solar concentration an important option in sustainable energy generation in the future.

II .2. Concentrated Solar Power (CSP) Systems and Heat Transfer Fluids

II .2.1 Concentrated Solar Power Systems

Concentrated solar power systems utilize optical systems (such as parabolic or cylindro-parabolic mirrors, Fresnel lenses, and heliostats) to concentrate solar light onto a specific area, achieving higher temperatures where it is more efficient to extract energy. This can involve thermodynamic extraction, wherein the central area is heated by concentrated sunlight, and the heat is then transported using a heat transfer fluid and converted into electricity. In this chapter, we will delve into the details of cylindro-parabolic concentrators.

II .1.1.2 Heat Transfer Fluids[06]

The thermal energy collected from solar radiation is converted using a heat transfer fluid and then a thermodynamic fluid. In some cases, the heat transfer fluid is directly used as the thermodynamic fluid. The choice of heat transfer fluid determines the maximum allowable temperature, guides the selection of technology and receiver materials, and influences the feasibility and convenience of storage.

- Oils are single-phase fluids with a good heat exchange coefficient. Their temperature range is limited to around 400°C. They are the most commonly used fluid in cylindro-parabolic collector power plants.
- Molten salts based on sodium and potassium nitrates offer a good heat exchange coefficient and have a high density. Therefore, they are also excellent storage fluids. Their outlet temperature can reach 650°C. When combined with a tower concentrator, they provide better efficiency.
- Gases such as hydrogen or helium can be used as thermodynamic fluids to drive Stirling engines associated with parabolic collectors.

II .2.2 Different concentration technologies

High temperature solar designs require concentrating systems, such as parabolic reflector systems. Solar thermal power plants equipped with concentrating technologies are important candidates for providing solar energy in quantity needed over the coming decades.

This involves concentrating solar radiation and a wide variety of configurations are possible. Four concentrated solar power technologies are being developed and can be classified into two categories:

- Linear concentration systems: cylindrical-parabolic, Fresnel mirror,
- Point concentration systems: central receiver (tower), Stirling dish.

These technologies, which only use the direct component of solar radiation, and are equipped with devices for tracking the trajectory of the sun and mirrors to concentrate its rays.

II .2.2.1 Definition Solar thermal collectors

Solar thermal collectors are a technology used to extract thermal energy from sunlight and convert it into various uses, such as heating hot water for domestic or industrial use, providing energy for heating purposes, and generating electrical power. Solar thermal collectors typically consist of solar panels designed to absorb light and convert it into heat, which can be used in a variety of applications.

The history of the use of solar energy goes back many centuries. Since ancient times, humans have used solar energy to heat water and dry materials. As technology advanced, researchers began developing modern solar thermal collectors in the twentieth century. In 1767, Swiss scientist Horace Benton invented the first solar thermal collector, and his technology was based on concentrating sunlight using curved mirrors.

Since then, solar thermal collector technology has undergone continuous developments, with multiple applications and improvements in their efficiency and cost. In recent decades, the solar energy industry has witnessed a significant boom, with solar thermal collectors becoming an important part of the renewable energy field,[06] contributing significantly to reducing harmful emissions to the environment and promoting environmental sustainability.

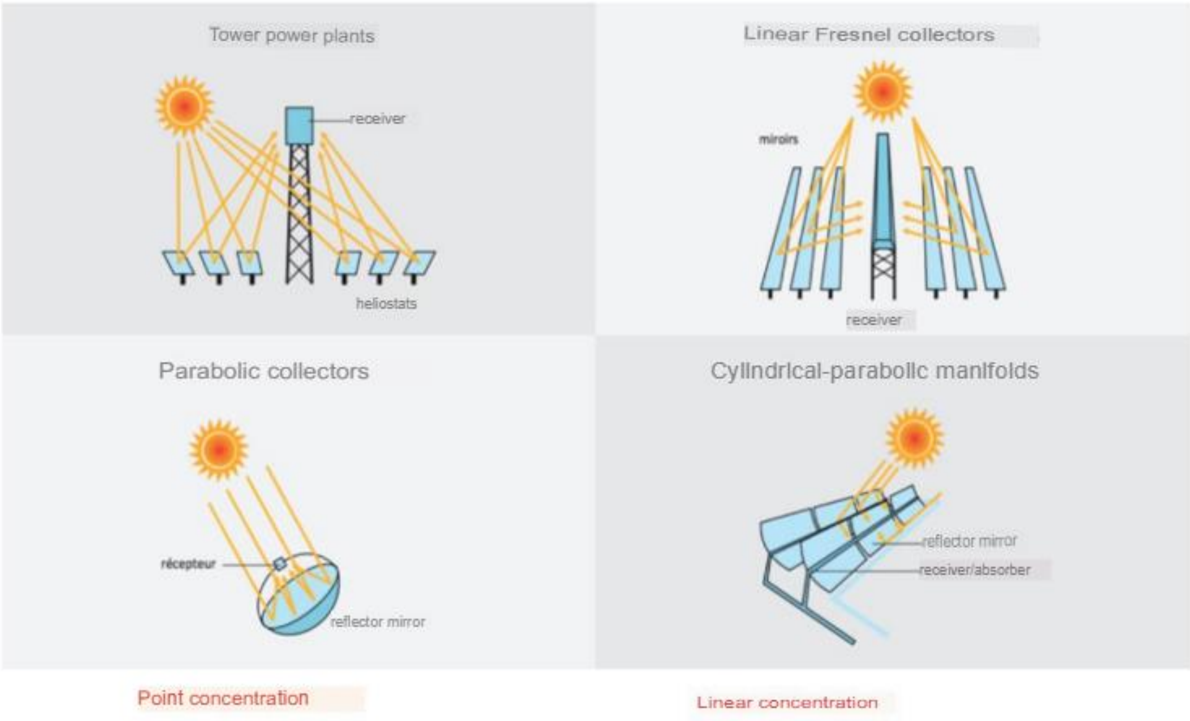


Figure II 1 : Concentrated solar power plants

II .2.3 Fresnel mirror solar power plants

II .A :History

Invented by the French physicist Augustin Fresnel, the Fresnel lens was designed to equip the optical system of marine signaling lighthouses. The system is now widely used on a large scale to concentrate solar radiation onto a horizontal tube.

II .2.3:1Fresnel technology

Fresnel technology is simple and inexpensive. The collectors consist of parallel strips of mirrors arranged flat and close to the ground, concentrating the sunlight onto fixed receiver tubes. Water, raised to 100 bars and 500°C, is used as both the heat transfer fluid and the working fluid to drive a turbine/electric generator. This technology is still in the demonstration stage. Its principle is similar to that of the cylindro-parabolic trough technology, but it uses flat or slightly curved mirrors that are cheaper than parabolic reflectors. This technology has the lowest optical performance and the lowest net annual solar-to-electric efficiency (10%), but its land footprint is 1.5 hectares per megawatt, which is less than 60% compared to cylindro-parabolic collector plants.

II .2.3.2: Operating Plant

Located in the only desert area in Western Europe, the research and development site Plataforma Solar de Almería, in Tabernas, Andalusia, hosts the German research area Fresdemo.

II .2.3.3:Advantages

- The main advantage of this technology is that flat mirrors are much cheaper than parabolic mirrors.
- Flat mirrors are simpler and cheaper to manufacture than parabolic and cylindro-parabolic mirrors.
- They have less wind exposure and require less infrastructure compared to a cylindro-parabolic collector power plant.

II .2.3.4: Disadvantage

- Optical performance approximately 30% lower than reflectors parabolic and parabolic cylindrical

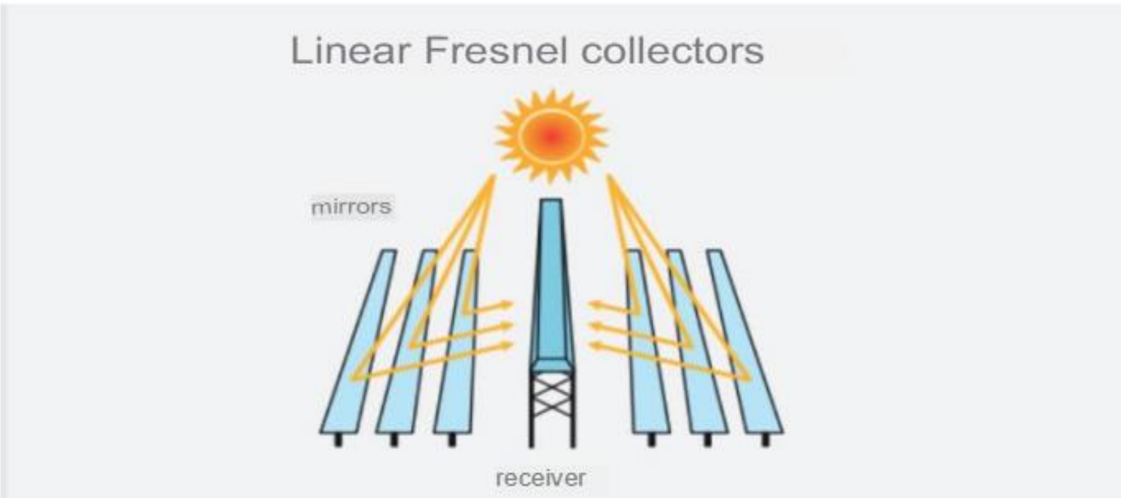


Figure II 2: Schematic diagram of Fresnel mirrors

II .2.4: solar towers

Solar towers represent the most versatile technology. Significant cost reductions are expected. There are two main technologies: direct steam production, which is less expensive, and the use of molten salts that can serve as both the heat transfer fluid and the thermal storage medium. Storage efficiency is three times greater than with cylindro-parabolic trough technology.

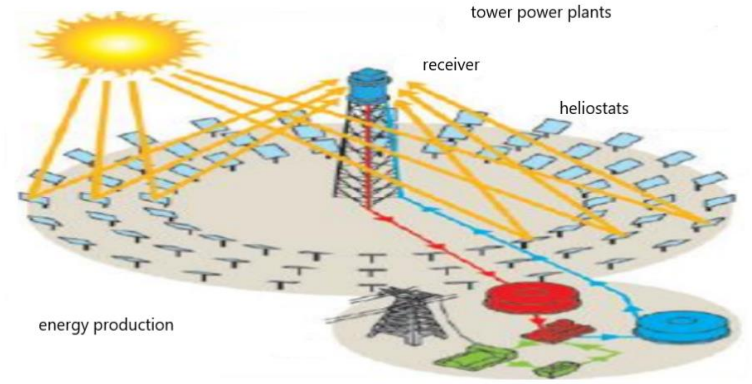


Figure II 3: diagram of a tower plant

The uniformly distributed mirrors are called heliostats. Each heliostat individually tracks the sun and reflects its light towards a receiver located at the top of the solar tower. The concentration factor varies from 600 to several thousand, allowing for significant temperatures ranging from 800°C to 1000°C. The maximum efficiency of Rankine cycle solar tower plants is around 22%, with a net annual efficiency of approximately 16%.

The advantage of solar towers over cylindro-parabolic collectors is that the losses to the surroundings are lower because the exposed surface area is limited. The land footprint without storage is around 4 hectares per megawatt. Heliostats can accommodate sloped terrain. [06]

II .2.4.1 Operating Plant

A new project on the same site emerged in 2006. Out of the 201 heliostats, half will be equipped with photovoltaic cells for electricity production. The other half will be dedicated to the "Pégase" research project led by the Promes laboratory of CNRS. Pégase is a new concept thermal solar power plant. The uniqueness of the project lies in heating compressed air (at a pressure of about 10 atmospheres). This air will then be expanded in a turbine, following the principle of gas turbines. Starting from 2013, Thémis could become a prototype for a solar power plant once again.

II .2.4.2Advantages

- The energy source is clean and free.
- Modest power plants can be built.
- Construction and operating costs are low.
- Continuous production during the night.
- Cheaper than current photovoltaic solar power.

II .2.4.3Disadvantages

- Very bulky power plant and reserved for desert areas.
- Cannot compete with nuclear power in terms of power.
- More expensive than coal (and nuclear power).

II .2.5 parabolic collector plants

II .2.5.1 History

Towards the end of the 1970s, Omnium-G, Inc. designed a parabolic system that powered a steam engine. The parabolic dish was 6 meters in diameter and was constructed from panels of polyurethane foam with a reflective surface of anodized aluminum.

II .2.5.2 parabolic trough systems

Parabolic trough systems operate autonomously. They track the sun along 2 axes to concentrate solar radiation onto the focal point of the reflective parabola. The concentration ratio is often greater than 2000, resulting in temperatures of around 750°C.

Among all solar technologies, parabolic trough systems have demonstrated the highest solar-to-electricity efficiencies, reaching around 29.4%. One of their main advantages is that they can be installed in remote locations, not connected to the electrical grid. Therefore, they also have significant potential for development, especially in sparsely populated regions of certain southern countries. Moreover, this technology remains the most expensive of all.

II .2.5.3 Concentrator

The solar concentrator consists of a reflective surface made of glass or plastic and focuses the incident radiation onto its focal point. Its size obviously depends on the required solar power. As a rough estimate, a concentrator with a diameter of 10 meters can provide up to 25 kW of electricity under an insolation of 1000 W/m². The concentrator has two degrees of freedom to effectively track the sun. This task is carried out entirely autonomously, unlike cylindro-parabolic collectors.

II .2.5.4 Receiver

The receiver absorbs the energy reflected by the concentrator and transfers it to the working fluid of the power cycle. The temperature of the hot source can be adjusted by placing the receiver closer or further from the collector's focal point. Two types of cycles can be used downstream of the receiver: the Stirling cycle or the Brayton cycle. In the case of the Stirling engine, the heat flow transmitted is intermittent, which poses problems of fatigue due to thermal expansion. To address this issue, an intermediate fluid (often sodium) is sometimes used between the receiver and the Stirling engine. The heat transfer efficiency reaches 90%. In the case of Brayton cycles, a technology similar to that of solar towers is used: solar radiation is absorbed by a porous substance, which heats the cycle's feed air. This method offers an efficiency of 80% .

II .2.5.5 The Operating Plant

In 2005, Stirling Energy Systems (SES) announced the signing of a contract with "San Diego Gas & Electric (SDG&E)" in Southern California for the construction of a power plant with a capacity of 300 to 900 MW, equivalent to 12,000 to 36,000 parabolic collectors. Another contract with "Southern California Edison" involves the construction of a solar power plant with a capacity of 500 MW (with an option to increase to 850 MW) on a 1,850-hectare site, located 110 km northeast of Los Angeles.

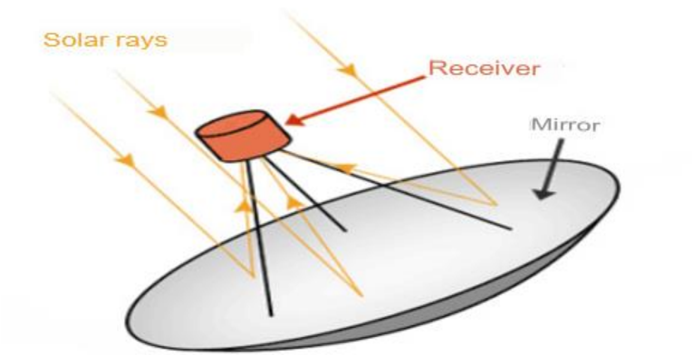


Figure II 4: Parabolic concentrator

II .2.5.6 Advantages:

- Solar energy source is unlimited and free.
- Using a Stirling engine brings several benefits: efficiency up to 40% and less pollution (no fossil fuel used, no smoke emissions). It's quieter and easier to maintain due to fewer moving parts.
- There is potential for networking of collectors to create an industrial-scale power plant.
- The use of gases (hydrogen or helium) with high heat absorption capacity increases efficiency.
- Production unit efficiency ranges between 20 to 25%, compared to approximately 15% for photovoltaic panels.

II .2.5.7 Disadvantages:

- The size of collectors is limited to enable two-axis rotation to track the sun's path.
- Intermittent operation.
- Currently, low power outputs compared to other thermodynamic solar power technologies (5 to 50 kW electric).
- Hydrogen easily diffuses into materials.
- Collectors are challenging to manufacture as they require double curvature to achieve the parabolic shape.
- High temperature differentials cause thermal expansion, limiting material choices.
- Investment costs remain high as commercialization is ongoing.

II .2.6 cylindro-parabolic trough

II .2.6.1 History

Nine Solar Energy Generating Systems (SEGS) were established in the Mojave Desert in California between 1984 and 1990. The first two SEGS plants (SEGS I and SEGS II) were built in Daggett, CA, between 1984 and 1985, with capacities of 14 MW and 30 MW, respectively. A power group of five SEGS plants, each rated at 30 MW, was assembled in Kramer Junction, CA, between 1986 and 1988. The final two SEGS plants (SEGS VIII and IX) are each rated at 80 MW and were built in Harper Lake, CA, between 1989 and 1990. All nine SEGS were designed, constructed, and sold by Luz International. The SEGS were made possible through substantial investment tax credits. All SEGS are still operational today, generating a total power of 354 MW.

II .2.6.2 Cylindro-parabolic trough technology

Cylindro-parabolic trough technology is by far the most mature. These systems use a series of long cylindrical reflectors shaped like a parabola. The parabola focuses light onto a receiver tube located along the focal line of the reflector. The concentrator tracks the sun's path by rotating on an axis. The heat transfer fluid, usually a synthetic oil, is heated as it passes through the tubes, circulating through a series of heat exchangers to produce superheated steam, with temperatures reaching up to 400°C, which drives a turbine/electric generator.

The maximum solar-to-electric efficiency is around 25% in optimal conditions, while the net annual efficiency is about 15%. The land footprint is approximately 3.25 hectares per megawatt for plants without storage.

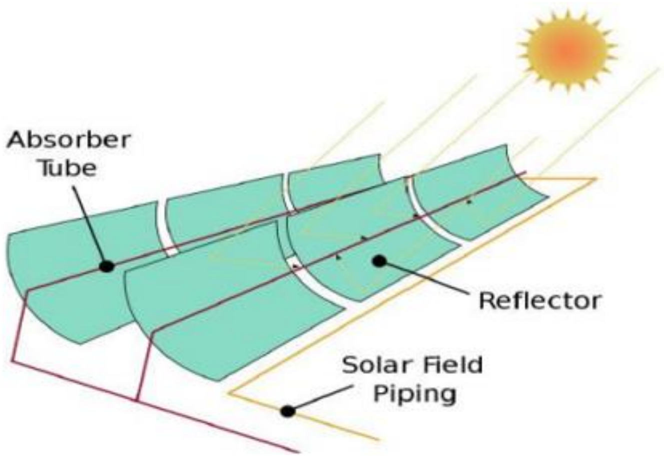


Figure II 5: Diagram of a parabolic cylindrical collector

II .2.6.3 Operating Plant

The Kramer Junction solar thermal power plant is the largest solar thermal power plant in the world. It is located in the Mojave Desert in California.

This plant uses the technology of cylindrical-parabolic collector power plants (CSP). It has 5 fields of 33 MW each (SEGS III to SEGS VII) for a total power of 165 MW. Operational since 1985, the plant is expected to remain functional for another fifteen years.

The plant primarily uses the sun to generate electricity, but also relies on natural gas to take over when days are overcast or at nightfall. However, the use of natural gas does not exceed 25% of electricity production. This plant is particularly useful as it provides more than 80% of its production during peak demand times. [07] Kramer Junction also has a thermal storage reservoir that allows the heat production to be stored for use when sunlight is insufficient.

II .2.6.4 Advantages:

- Few mechanical movements compared to other heat-based power plants.
- Less expensive than mirror concentration and Stirling parabolas.
- Good efficiency.

II .2.6.5 Disadvantages:

- Not suitable for small installations.
- Energy changes form multiple times: risk of energy loss.
- Always more expensive per watt compared to traditional photovoltaic panels.

Solar collectors are used in:

- Production of domestic hot water
- Domestic heating
- Steam production
- Electricity production
- Distillation of water
- Solar cooking.

The benefits of concentration

The use of concentrators allows:

- To increase the incident flow on the sensor
- To reduce the receiving surface
- To reduce thermal losses
- To increase the temperature of the receptor (the absorber).

II.3 conclusion

Solar concentration technology represents an innovative and effective solution for harnessing solar energy more efficiently and sustainably. By collecting sunlight from large areas and directing it towards a central point, this technology enables the production of thermal or electrical energy in an efficient and clean manner. Despite facing challenges such as costs and the impact of weather changes, recent advancements in this field indicate that solar concentration technology has the potential to be a fundamental part of the future of sustainable energy generation. Achieving progress in this field depends on continued investment in research and development, as well as support from government policies that promote the use of environmental and sustainable technologies.

Chapter III:

Presentation of the urban wastewater treatment plant of Hassi R'mel

III.1 Presentation of the urban wastewater treatment plant of HassiR'mel:

III .1.1 Introduction

Urban wastewater treatment is an essential part of sustainable urban development, ensuring the protection of water resources and reducing environmental impact. The urban wastewater treatment plant in Hassi R'mel plays a vital role in managing the wastewater generated by the local population and industrial activities in the region.

III .1.2 Geographic:

The study area (Hassi R'mel) is located in the Laghouat Province in the south of Algeria, 525 km south of Algiers, approximately 70 km west of Berriane, 120 km northwest of Ghardaia, and 120 km southeast of Laghouat. (Figure III 1)

Figure III 2: Geographic Location of the Study Area "Hassi R'mel" [3]

III .1.3 Historical Background:

The Hassi R'mel gas field has been developed since the 1960s and is operated solely by SONATRACH. It represents the largest gas processing facility in Algeria.

The major Hassi R'mel field was discovered in 1956, with the drilling of well HR01, revealing a wet gas field at a depth of 2132 meters. Since its discovery, the Hassi R'mel field has gone through several phases and development plans:

- 1957: Drilling of additional wells for structural reconnaissance.
- 1961: Operation of 2 gas treatment units with a capacity of 1.3 billion cubic meters per year.

- 1969: Operation of 4 additional units increasing capacity to 4 billion cubic meters per year.
- 1972-1974: Operation of 6 additional units increasing capacity to 14 billion cubic meters per year.
- 1975-1980: Capacity increased to 94 billion cubic meters per year, with maximum recovery of condensate and LPG.
- 1985: Construction and commissioning of a unit for flare gas recovery.
- 1987: Commissioning of a gas treatment center (Djebel Bissa).
- 1999: Commissioning of a station for recovery of associated gases from oil treatment centers.
- 2000: Commissioning of a gas treatment center HR South.
- 1980-2005: Drilling of additional wells.
- 2005: Commissioning of Boosting units.

III .1.4 Hydrogeology:

There are several aquifer complexes within the sedimentary sequence of the Saharan platform. The most important aquifers consist of limestone and sandstone sequences from the Mesozoic era.

Other aquifer layers exist in deeper formations, but they are less significant due to their low storage volumes (isolated and thin layers of fractured sandstone or limestone) or poor water quality (particularly near evaporite deposits). Several permeable units may contain brackish water, mostly consisting of water containing sodium chloride and calcium chloride.

At the Hassi R'mel site, SONATRACH exploits two aquifers: the Turonian aquifer and the Barrémian aquifer.

III .1.5 Climate:

The climate is characterized by low rainfall, with an average relative humidity of 19% in summer and 34% in winter. Temperatures generally range from -5°C in winter to +45°C in summer.

III .1.6 Industrial Zones:

The Hassi R'mel field is divided into 3 zones: North, South, and Center. The Center zone serves as the capital of the commune and the district of Hassi R'mel. These zones consist of modules (gas processing centers), compression stations, oil treatment centers, industrial effluent oil removal units, and a domestic wastewater treatment plant. [08]

III.2 Presentation of the wastewater treatment planthistory of Hassi R’mel:[09]

As part of the implementation of its policy, the National Hydrocarbon Transportation and Marketing Company (SONATRACH) through its regional directorate in Hassi R'mel, has undertaken an ambitious program aimed at eliminating or minimizing the nuisances caused by its activities and services. To achieve this, an urban wastewater treatment plant has been implemented.[09]

This plant was commissioned in 2001, designed for 15,000 equivalent inhabitants, and aims to achieve the following objectives:

- Prevent the proliferation of waterborne diseases,
- Protect the receiving environments,
- Comply with legislation and regulations regarding environmental protection,
- Reclaim treated water.

III 2.1- Basic data of the Hassi R'mel wastewater treatment plant:

The design of an urban wastewater treatment plant is determined through a comparative technical and economic calculation taking into account all aspects: structures, equipment, installations, economic costs, and processes; the latter is chosen in relation to the desired degree of treatment. [08] The basic data for the design of this treatment plant are:

➢ Population:

It is used to establish an equivalence relationship between different sources of pollution and the population. It is expressed in equivalent inhabitants (Eqha). Equivalent inhabitant is defined as the pollution generated per inhabitant per day. The equivalent population is 15,000.

➢ Potable water consumption

This is the quantity of conventional water consumed, expressed in cubic meters per day. It is estimated at 3750 cubic meters.

- Rejection coefficient

This is the ratio of potable water consumption to the average daily flow provided. It is expressed as a percentage (%) and is estimated at 80%.

- Average flow rate (daily or hourly) of wastewater

This is the average quantity of wastewater produced that flows at a certain point, expressed in cubic meters over a given time: it is estimated at 125 m3/h, or over 24 hours (average daily flow) at 3000 m3/day.

- Daily pollution load (BOD5 or TSS)

It is defined by the following relationship: Cx = BOD5 × Q where, Cy = TSS × Q

Where Cx: pollution load expressed in kilograms of BOD5 per day, which is approximately 810 kg BOD5/day at the Hassi R'mel treatment plant. Or Cy: pollution load expressed in kilograms of TSS per day, which is 1.05 kg/day.

Q: Average daily flow rate of wastewater is 3000 m^3.

- BOD5 concentration

This is the pollutant content determined by the five-day biological oxygen demand expressed in milligrams per liter, estimated at 270 mg/L.

- TSS concentration

This is the pollutant content of suspended solids expressed in milligrams per liter, estimated at 350 mg/L.

- Mass load

This is the ratio of pollution brought in by unit mass of sludge, estimated at 0.1 kg BOD5/kgVS/day.

- Volumetric load

This is the ratio of incoming pollution per unit volume of the basin, estimated at 0.351 kg/DBO5/m3.

III 2.2 Treatment process of the Hassi R'mel plant:

The goal of treatment is to obtain a purified effluent where pollution is limited to a degree that the discharge does not create any nuisance to the fauna or flora of the receiving environment. [09]

The Hassi R'mel wastewater treatment plant, which treats urban domestic wastewater from the central region, is a low-load activated sludge treatment plant with extended aeration. It is essentially the reproduction of the natural self-purification phenomenon of watercourses on a basin scale, involving the degradation of organic pollutants under the action of microorganisms, requiring a quantity of oxygen, called BOD5, expressed in mg of O2/L.

The activated sludge processes essentially involve a phase of water contact with bacterial floc in the presence of O2 (aeration), followed by a phase of separating this floc. Wastewater generally contains a diverse natural microbial population.

III 2.3 Treatment stages:

III 2.3.1 Pretreatment:

By (physical pretreatment), it refers to a series of operations aimed at removing the coarsest fraction of carried particles and removing from the effluent the materials likely to hinder subsequent treatments.[08]

a) Arrival of raw water:

Raw water is dispatched from two main pumping stations (Hay Ezouhour and OPGI), conveyed to the treatment plant by two main collectors, and pumped at the entrance of the plant.

b) Screening:

From the pumping station, raw water is pumped to the screening facility, which allows the removal of large solid bodies that may interfere with subsequent treatments. This process is carried out in a channel 5 meters wide and consists of two stages:

- Course screening (manual cleaning): provided by a grid with a spacing of 5 cm between bars.

- Fine screening (automatic cleaning): provided by a rotary automatic grid with a passage of 1.5 mm, with a hydraulic capacity of 430 m3/h, and powered by a 0.55 kW motor.

-The screenings from the grids are manually removed and disposed of in a landfill.

c) Grit and Grease Removal:

There is always a concern about the significant presence of sand, suspended mineral matter, and oil that could hinder or even impede the operation of the installation. This pretreatment phase is carried out in a rectangular channel with a height of 3.61 meters and a volume of 45.8 m3; the flow velocity is maintained at approximately 0.3 m/s.

The water is aerated by insufflation, allowing easy separation of sand from water, which settles at the bottom and is then lifted to the hopper and finally to the drying beds. Additionally, it promotes the accumulation of fats and oils on the surface, which are collected in a tranquilization zone and discharged into a grease sump to be pumped to the drying beds.

III 2.3.2 Biological Treatment:

A large number of microorganisms are capable of metabolizing organic matter and, consequently, promoting the purification of wastewater loaded with biodegradable organic matter.

Microorganisms can be classified as aerobic, facultative, and anaerobic. The majority of microorganisms present in biological treatment are facultative types (aerobic metabolism in the presence of oxygen and anaerobic metabolism in the absence of oxygen).

Biological treatment involves reducing pollution through the action of bacterial masses and is carried out in a complete system comprising:

- Aeration tank,
- Clarification tank,
- Recirculation station.

a) Aeration Tank:

Pre-treated water is gravitationally discharged to the wastewater pumping station, where it is lifted to the aeration tank.

The aeration tank is circular with a diameter of 28 meters, covering an area of 615.44 m2. The anticipated water depth is 3.6 meters. It is equipped with three surface aerators, which introduce air into the water to promote the growth of aerobic bacteria and the degradation of organic pollutants.

The biological treatment ensures the reduction of pollution through the action of a bacterial mass and is conducted in a comprehensive system that includes:

Pre-treated water is gravitationally discharged to the wastewater pumping station, where it is then lifted to the aeration tank. The aeration tank, which is circular with a diameter of 28 meters and covers an area of 615.44 m2, has a planned water depth of 3.6 meters. It is equipped with three surface aerators, each with a vertical-axis turbine resting on a metal walkway. An oxygen meter, or "oxygen probe," continuously measures the oxygen content of the wastewater-sludge mixture, thereby regulating the speed of the aerators. The oxygen concentration in the tank varies from 1 to 5 mg/L, depending on the season. Pollution removal is ensured at the wastewater treatment plant (WWTP) in this tank by maintaining a high concentration of microorganisms and prolonged aeration using the three two-speed aerators, thereby ensuring a satisfactory oxygen content for bacteria. Each aerator has a power of 35 kW, and the aerators' performance is 92%. The aerator's role is to supply oxygen to the bacteria and induce intense turbulence, which both maintains the suspension of activated sludge and enhances the intimate contact between raw water and bacteria.

b) Clarification Tank:

The performance of biological treatment results from the combined action of aeration and clarification, which form a single technical unit. The secondary settling tank is circular with a diameter of 20.5 meters, covering an area of 330 m2, and has a volume of 977 m3. The planned water depth is 2.96 meters. The mixed liquor maintained in suspension in the aeration tank passes into a clarification tank for clarification. Feed is accomplished through a siphon pipe surmounted at the center of the tank, with a repair skirt. The floc separates from the interstitial water and settles on the bottom of the clarification tank, while the clarified water is evacuated by overflow into a peripheral trough.

c) Sludge Recirculation and Extraction Station:

The sludge collected at the center of the settler is transferred by gravity to the sludge recirculation and extraction station to be recirculated or directed to sludge treatment based on the intended use of the produced sludge.

- Recirculated Sludge:

The effectiveness of activated sludge biological treatment processes relies on significant recirculation of sludge from the secondary settling tank. The required concentration of activated sludge in the aeration tank is ensured by two groups of centrifugal pumps with a flow rate of 125 m3/h each.

Recycling the sludge maintains a necessary concentration of microorganisms to ensure the level of biological treatment and, on the other hand, prevents sludge clogging in the settling tank.

- Excess Sludge:

Excess sludge is extracted from the pumping station with an average dry matter content of 8 g/l by a pump with a flow rate of 125 m3/h, resulting in a daily volume of 96 m3. They are directed to the sludge treatment process.

III 2.3.3 Disinfection of Water:

Further use of the purified effluent requires more advanced treatment to eliminate pathogenic germs and unpleasant odors. The settled water is introduced into a sterilization tank where disinfection occurs by injecting sodium hypochlorite at 47°, sourced from a chlorination unit consisting of a dosing group with two dosing pumps and storage tanks located in a separate room. The disinfectant concentration is 1.2 mg/l.

III 2.3.4 Sludge Treatment Process:

Sludge treatment aims to transform sludge into a product suitable for transportation or drying without causing harm to the environment. The sludge treatment operation at the WWTP is intended to reduce the volume of materials to handle by removing some of the water. The steps in the sludge treatment process are as follows:

a) Thickening:

This is the first and simplest stage, which involves reducing the volume of sludge without significant energy expenditure. The thickener is designed to concentrate the sludge before it is pumped to the drying beds. The slurry suspension is introduced into a thickener equipped with a scraper. The residence time is 23 hours to promote sludge compaction. Their evacuation is then carried out. [10].

The evacuation of sludge is done by gravity through the bottom towards the drying beds, while the interstitial liquid is evacuated from the top, returning to the wastewater pumping station. The structure is cylindrical with a conical bottom and a low slope, with a diameter of 5.5 meters and a height of 3.80 meters. Its surface area is 32.75 m2, and its volume is 91.7 m3.

b) Natural Drying:

The thickened sludge (with an average concentration of 30 g/L) is extracted from the thickener and directed to the drying beds where it will be spread to naturally dehydrate. There are 8 drying beds with a unit surface area of 160 m2 each.

- Annual sludge production: 936 m3/year.
- Height of the sludge bed: 0.4 m.
- Sludge drying duration: 20 days.
- Number of annual rotations of the drying beds: 18.

The wastewater treatment plant can be remotely controlled from the control room, equipped with a PC with remote control software featuring monitoring and control parameters, as well as process diagrams for the proper operation of the treatment plant.

III .2.4 Specificity of the Hassi R'mel Wastewater Treatment Plant:

Similar to other existing wastewater treatment plants in Algeria that use a low-load activated sludge biological treatment process, the Hassi R'mel plant complies with the standards recommended by the World Health Organization (WHO). It distinguishes itself from other plants through its modernized facilities and structures, analysis methods, and process automation. Indeed, it is equipped with a computer-assisted management system (maintenance and operation) through a programmable logic controller and computer software. Figure No. 2 schematically represents the Hassi R'mel wastewater treatment plant.

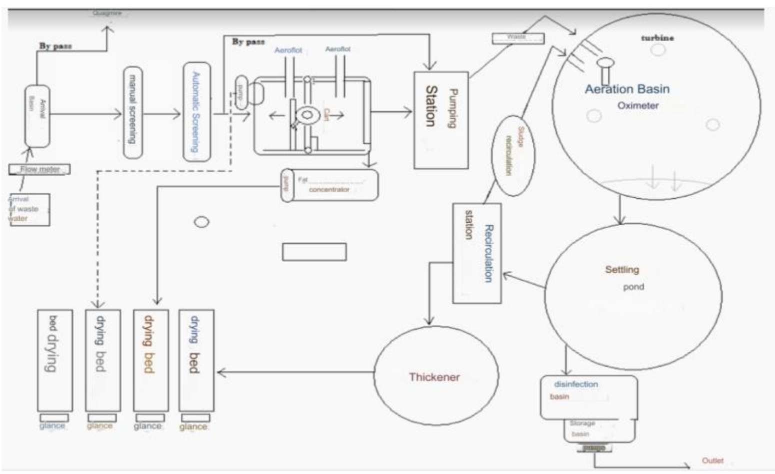


Figure III 3: Schematic representation of the wastewater treatment plant of Hassi R'mel.

III 2.5 Measurement Parameters:

For an assessment of wastewater composition, the following pollution criteria have been measured: water temperature, pH, electrical conductivity, suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrogen, phosphorus, and other criteria such as germs and viruses, fat content, detergents, and heavy metals, which can represent potential nuisance. [12].

III 2.5.1 Physico-Chemical Parameters:

a) Temperature:

It is a parameter often overlooked in urban sewers but should be measured more frequently, especially in the case of industrial discharges. The operation of certain treatment facilities is highly sensitive to temperature, and thus any discharge should be below 30°C. [11].

b) PH:

It is a parameter that expresses the acidity level of wastewater. Its measurement is crucial for assessing the proper functioning of a treatment stage.

c) Conductivity:

It provides a precise indication of the total concentration of dissolved salts. By comparing it with the conductivity of drinking water, it is possible to quickly determine if significant inputs, especially industrial ones, are occurring in the sewer network. [11]

d) Turbidity: It is the property of water to appear cloudy. Its measurement provides an indication of the content of suspended solids.

e) Total Suspended Solids (TSS): They represent materials that are neither soluble nor colloidal, thus retained by a filter. TSS, comprising organic and mineral materials, are an important parameter that clearly indicates the degree of pollution in urban or even industrial effluent.

f) Volatile Suspended Solids (VSS): They represent the organic fraction of suspended solids and are measured by calcination at 620°C of a sample, the TSS content of which is already known. They constitute approximately 70%-80% of TSS. [13].

g) Mineral Matter (MM): It represents the result of total evaporation of water, known as the "dry residue," comprising both suspended mineral matter and soluble substances (chlorides, phosphates, etc.).

h) Chemical Oxygen Demand (COD): It is the amount of oxygen consumed by substances present in water under defined operating conditions. [14].

i) Biochemical Oxygen Demand (BOD): It represents the amount of oxygen consumed by chemical oxidation phenomena on one hand and the degradation of organic matter via aerobic pathways necessary for the destruction of organic compounds on the other hand. In complex effluents, both types of oxidation overlap, hence the term "biochemical." Note that in domestic wastewater, biological phenomena predominate. BOD measurement remains the most commonly used parameter in the water sector. The ratio of COD to BOD5 provides information on the quality of biodegradation, with a COD/BOD5 ratio below 2.5 indicating good biodegradability.

III 2.5.2 Chemical Parameters (Pollution Indicators):

a) Nitrogen: Nitrogen is measured in various forms. The types of analyses depend on the chemical forms being sought. They can be divided into two major categories (in terms of purification): reduced nitrogen and oxidized nitrogen. The former corresponds to organic nitrogen found in wastewater, especially from human metabolic waste (proteins, urea). Oxidized nitrogen is found marginally in wastewater and includes nitrites (NO_2^-) and nitrates (NO_3^-), which are products of the chemical transformation (oxidation) of reduced nitrogen.

b) Phosphorus: It can exist in mineral or organic forms. These different compounds are either dissolved in the liquid phase or fixed on suspended and colloidal matter. In urban wastewater, phosphorus comes from metabolism and detergents, but the latter origin tends to decrease due to the reduction of phosphorus compounds in detergents. [15]. [16].

III 2.5.3 Biological Parameters:

In activated sludge, bacteria are the predominant group responsible for both pollution removal and floc formation. Numerous species of bacteria can contribute to the formation of activated sludge. The nature of the organic compounds constituting the pollution influences the dominant genus as well as the environmental conditions such as pH, temperature, dissolved oxygen, etc.

b) Protozoa: These are microscopic metazoans commonly found in freshwater plankton.

c) Nematodes: These are non-segmented, thread-like worms covered with a transparent chitinous layer.

III .3 Conclusion

The establishment of an urban wastewater treatment plant in Hassi R'mel holds significant importance in improving public health and the environment in the region. This plant represents a step towards environmental sustainability and the preservation of water resources, as it efficiently treats wastewater and reduces pollution from discharges into natural water bodies. Additionally, the plant contributes to achieving environmental goals such as reducing water consumption and maintaining the quality of groundwater and surface water.

Providing a wastewater treatment plant contributes to enhancing the quality of life for the local community, as it reduces the spread of infectious diseases and improves the health and environmental conditions for local residents. Moreover, it helps provide clean and healthy water sources for various uses such as drinking, agriculture, and industry.

By relying on advanced technologies and environmentally friendly practices, the urban wastewater treatment plant in Hassi R'mel can be a successful model for sustainable development and environmental stewardship in the region. Achieving sustainability in treatment and operation processes requires a continuous commitment to quality, efficiency, social responsibility, and environmental stewardship.

This step reflects the efforts made to achieve sustainable development and comprehensive well-being for the community, and it represents a significant contribution to building a better future for current and future generations.

Chapter IV Description of the Hassi R'Mel hybrid power plant SPP 01

IV.1 Introduction

Owned by "SPP" company, located in the Hassi R'Mel region, this station has a production capacity of 150 megawatts. The name "SPP" was chosen in reference to the manufacturing company, "One Solar Power Station." The first hybrid power station operating on solar and gas in Algeria was inaugurated on July 14, 2011. The main contributors to this project are Abener, Nile, Cofides, and Sonatrach.

The primary goal of this project is to generate electricity using clean and sustainable energy sources, thereby reducing harmful environmental emissions and improving air quality. Additionally, in this presentation, we will explain the significant role played by the Rankine cycle with reheat in achieving the project's objectives in terms of efficiency.

This project represents an important initiative in directing the energy sector towards sustainability and diversity, and it signifies a crucial step towards achieving environmental and climate change goals.

IV.2 PRESENTATION OF THE PROJECT:

The construction of the hybrid gas-solar power plant in Hassi R'Mel is a large-scale project, spanning an area of 150 hectares and costing 315 million Euros. Construction of this plant was initiated on November 3, 2007. Its shareholders are NEAL (34%) and ABENER (66%), and the construction was carried out by Solar Power Plant One (SPPI).

IV.2.1 New Energy Algeria (NEAL): [17]

New Energy Algeria is a joint-stock company (NEAL spa), with its share capital owned by three shareholders: SONATRACH at 45%, SONELGAZ at 45%, and the private group SIM at 10%. Established in July 2002, its objectives include promoting and developing renewable energies, implementing projects related to renewable energies, constructing a solar research center, and managing and marketing renewable energies in Algeria and abroad. Currently, it is planning the feasibility study of a hybrid gas-solar power plant with brackish water desalination in El Oued (Meghaïer). [17]

IV.2.2 ABENER:

ABENER is a Spanish company established in 1994, operating in the engineering and industrial construction of solar thermal power plants, the installation of conventional electricity production plants, and biofuel factories. Its revenue was estimated at 693 million Euros in 2008, compared to 353 million Euros in 2007 and 168 million Euros in 2006. ABENER operates in Poland, Mexico, the United States, India, Brazil, Morocco, France, the Netherlands, Germany, the United Kingdom, and Algeria.

IV.2.3 Solar Power Plant One (SPPI)[17]

Solar Power Plant One is the implementing company for the hybrid gas-solar power plant project in Hassi R'Mel. Its shareholders are:

- ABENER with a stake of 51%,

- COFIDES (a Spanish company financing projects in developing countries) with a stake of 15%,

- NEAL (New Energy Algeria) with a stake of 20%,

- SONATRACH with a stake of 14%.

Its subcontractors are UTE ABENER Construction for the construction phase and UTE ABENER Operation for the operational phase. Its financing comes from a consortium of Algerian banks: BEA, CPA, and BDL, with BEA as the lead bank. SONELGAZ is the electricity supplier during the construction and commissioning period, and SONATRACH will be the natural gas supplier, the electricity buyer (client), and the water supplier. [17]

IV.3 LOCATION OF THE POWER PLANT (HASSI R'MEL SITE):

The SPP1 power plant is located 494.5 km south of the capital, Algiers, at the southern boundary of the Laghouat province (Figure 28). It is situated on a plot of land covering an area of 130 hectares. Access to it is provided via National Road N1.

Figure IV 1: location (Hassi R'Me)

The power plant is located near the natural gas field of Hassi R'Mel, at a latitude of 33.074° and a longitude of 3.214°.

The site selection was based on several criteria that are essential for the proper functioning of the power plant:

IV.3.1 Solar irradiation:

Hassi R'Mel benefits from good solar coverage with an average of 3500 hours of sunshine per year (40% of the entire year) and an average energy received of 2650 kWh/m²/year. [18]

IV.3.2 Flat ground:

Hassi R'Mel has flat terrain, which is necessary for the layout of the solar field to ensure there are no obstacles between the sun and the collectors, such as mountains or hills.

IV.3.3 Availability of gas and water:

Hassi R'Mel has very significant quantities of natural gas, which ensures the supply of components operating with gas (turbines, recovery boilers, auxiliary boilers). Water will be sourced from the SONATRACH base, which is in close proximity to the power plant.

IV.3.4 Accessibility to the national network:

Indeed, the power plant site is located near the electricity production plant of "Tilghemt," which is connected to the national grid with an electrical network along the RN1

IV.4 DESCRIPTION OF THE HASSI R'MEL HYBRID POWER PLANT:

IV.4.1General Description of the WTP (Water Treatment Plant):

The WTP aims to treat raw water from the WWTP (Wastewater Treatment Plant). This water goes through several stages (six stages) to obtain purified high-quality water (demineralized water).

Settler Treated water from the raw water tank (captured by the WWTP) drives the process through two horizontal centrifugal pumps, one on standby, designed to provide a flow rate of 45-50m3/h for the physico-chemical system. In the mixing coil, sodium hypochlorite and the coagulant and flocculant are also dosed for further treatment.

- Biocide Dosing (Sodium Hypochlorite): Two dosing pumps

- Coagulant Dosing: Same installation as the biocide

- Flocculant Dosing: Same installation as the biocide

The role of the bypass: A bypass is installed before the coil. In case the water is of good chemical quality (good turbidity less than 01NTU), the chemical injection is bypassed, and the water passes directly to the filtered water tank. The mixed water is distributed between two lamellar settling lines sized for 60% of the total flow rate, so each line has a working flow rate of 22.5 to 25 m3/h. Each compartment of the settler has dimensions of 11'10 x 2'34 m x 3'00, separated by a clarified water part that will feed the filtration by two pumps, one in operation and the other on standby, and a part which is the sludge extraction and recirculation system.

Sludge extraction and recirculation system: The deposition of solid materials in the settlers produces sludge at the bottom of the settlers. The sludge can be used to promote circulation through the formation of flocs in the raw water. For this purpose, there is a recirculation system consisting of two pumps and three pinch valves located in each of the settlers. There is also a sleeve valve that allows the passage of sludge into the settler.

Figure IV 2: Recirculation system

Figure IV 3: Pinch valves

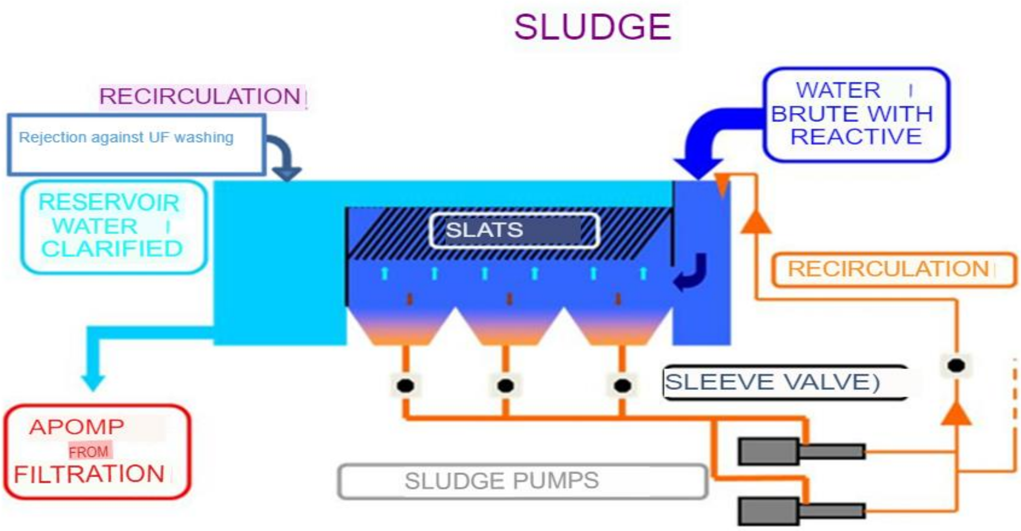


Figure IV 4: Sludge recirculation

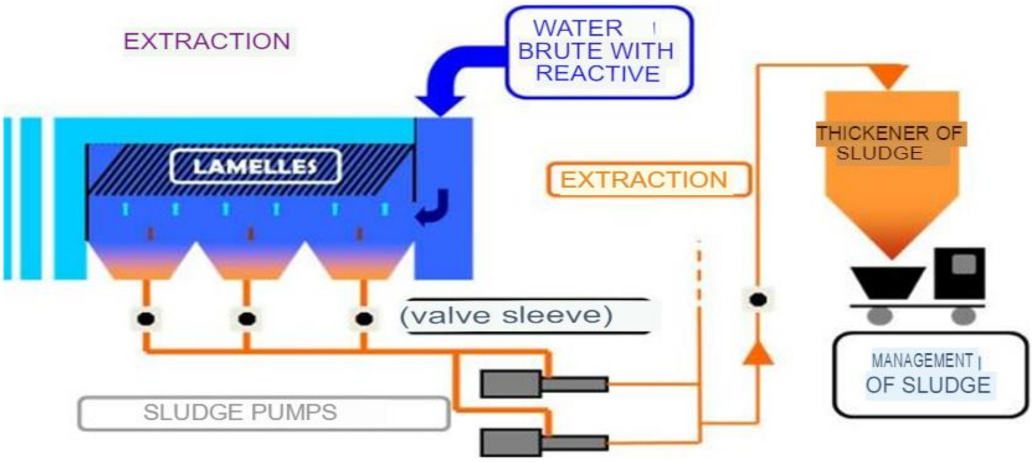


Figure IV 5: Sludge recirculation

IV.4.1.1 Sand-Anthracite Filters:

Filtration is a method used to remove impurities from water by passing it through a filtering media (sand-anthracite). The filtration system consists of two parallel filters filled with sand-anthracite, controlled by a pneumatic valve system for automatic operation. Two flow meters are installed at the inlet of each filter.

The pressure difference between the inlet and outlet of the raw water in the filter is monitored by a pressure differential gauge (ΔP), and the quality of the filtered water is checked using a turbidity probe. A set point is established based on the pressure difference between the inlet and outlet of 1 bar, indicating the start of the filtration washing process, or by a cumulative production flow set point of 1500m3.

IV.4.1.1.1 Sand Filters Washing System:

The causes for washing a filter may include:

- Completion of production cycle, exceeding 1500 m3 of production.
- Differential pressure alarm in the filters.
- Initiated by the operator.

The status of the two filters will be continuously displayed on the screen, indicating the corresponding phase for each. The sequences of the four phases explained below occur after the automatic startup of the entire system, using a button on the screen to initiate.

The washing of the two filters is carried out in four steps:

- 1st Step: Partial draining of water inside the filters.
- 2nd Step: Bed sponging using air from two blowers.
- 3rd Step: Backwashing with water.
- 4th Step: Refilling and ventilating the filter to make it available.

Note: Two filters cannot be washed simultaneously. If they coincide, one will be washed while the other remains on standby.

Figure IV 6: Sand-Anthracite Filters

IV.4.1.2 Ultrafiltration:

Due to the deterioration in the quality of incoming water, the water needed for the reverse osmosis demineralization process must be pretreated using ultrafiltration to remove suspended solids, colloids, and microorganisms it may contain.

The water from the sand filter is sent to ultrafiltration after passing through self-cleaning slotted filters with a mesh size of 300 microns installed at the ultrafiltration inlet to protect the ultrafiltration cartridges. Cleaning is performed by pressure sensors installed on each filter. After prefiltration, the water is sent to the ultrafiltration modules (3 racks). Each of these modules is designed to treat 50% of the flow, ensuring that all 3 units are in operation, and during the chemical cleaning or backwashing sequence, one rack is out of service. Each module consists of pressure membranes formed by fibers.

Once the water has been treated, it accumulates in the two ultrafiltration permeate tanks, each with a capacity of 10 m3. These tanks have sufficient capacity for module chemical cleaning, which is ensured by two redundant pumps (1 + 1 R), capable of providing a maximum flow rate of 70 m3/h for chemical cleaning and 140 m3/h for backwashing flow of the racks.

The ultrafiltered water will be pumped into the filtered water storage tank by two redundant pumps (1+ 1 R) capable of providing a flow rate of 50 m3/h. The collector at the common outlet of the pumps is equipped with an electromagnetic flow meter, a turbidity meter, chlorine measurement, pH measurement, temperature measurement, and conductivity measurement.

IV.4.1.2.1 Countercurrent Backwashing (without chemical):

A countercurrent backwash is performed approximately every 60 minutes for about 60 seconds with water accumulated in the ultrafiltered water tanks, which is pumped to the ultrafiltration modules through countercurrent washing pumps (max 140m3/h). This flow is then recovered at the outlet of the clarifier.

IV.4.1.2.2Chemical Cleaning of Ultrafiltration:

(Programmed every 12 hours) The sequence of chemical cleaning is performed in turn through the three racks of the system, controlled by logic. The reject flow from chemical backwashing is not recovered. During ultrafiltration cleaning with chemicals, the addition of sodium hydroxide, sodium hypochlorite, and sulfuric acid is necessary (availability of skids for dosing the three products).

- Sodium hydroxide dosing: Two dosing pumps.
- Sodium hypochlorite dosing: Two dosing pumps.
- Sulfuric acid dosing: Two dosing pumps.

Figure IV 7: Ultrafiltration

IV.4.1.3Reverse Osmosis

The installation consists of two lines of reverse osmosis water treatment (one primary and one redundant).

Each line consists of two stages that work in series. The first stage is designed to produce 34 m^3/h of osmosis water, and the second stage is designed to produce 23 m3/h. The water from the first stage is stored in a water tank that can supply several services in the plant or proceed to the treatment of the second stage.

Reverse osmosis is a water purification system that removes dissolved solids from water through a very fine filtering system that only allows water molecules to pass through.

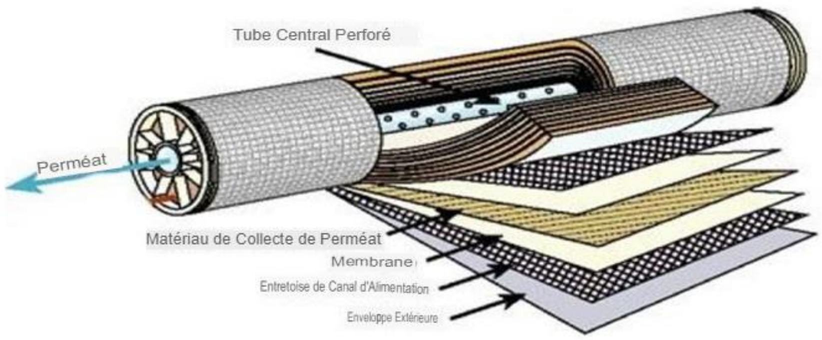


Figure IV 8: membrane

In practice, raw water is pumped into a pressurized tube containing a spiral membrane or a set of semi-permeable hollow fibers. The purified water passes through the membrane, forming the "Permeate." Contaminants accumulate in the residual water, called the "Concentrate," which is continuously discharged into the sewer.

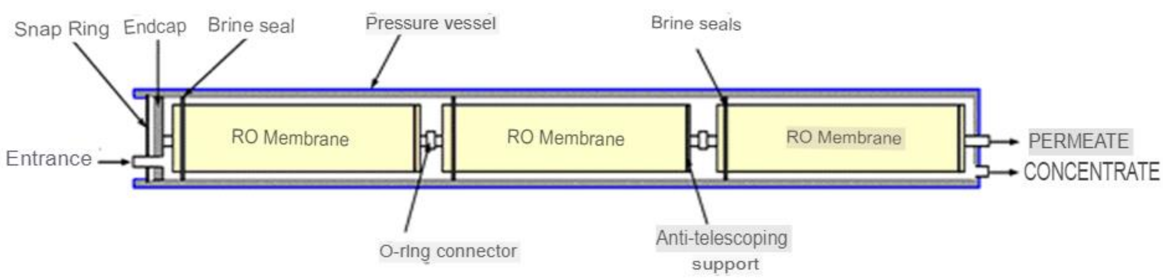


Figure IV 9: the placement of the three membranes in RO line

Osmosis is based on the fundamental principle of equilibrium. When two liquids containing different concentrations of dissolved solids are brought into contact, they mix until the concentrations become uniform. When these two liquids are separated by a semi-permeable membrane (which allows liquids to pass through while retaining dissolved solids in their compartment), the liquid with the lower concentration of dissolved solids will pass through the membrane into the liquid with the higher concentration of dissolved solids.

After a given time, the water level will be higher on one side of the membrane. The difference in height is called osmotic pressure.

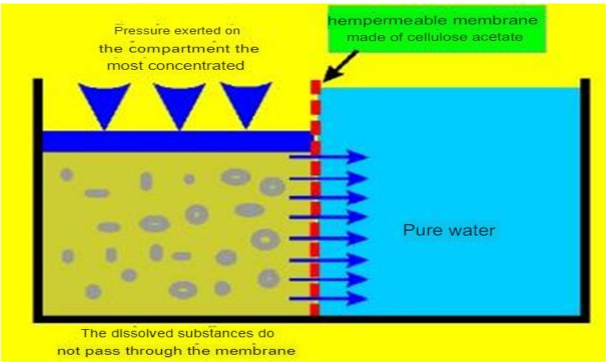


Figure IV 10: Principe of reverse osmosis

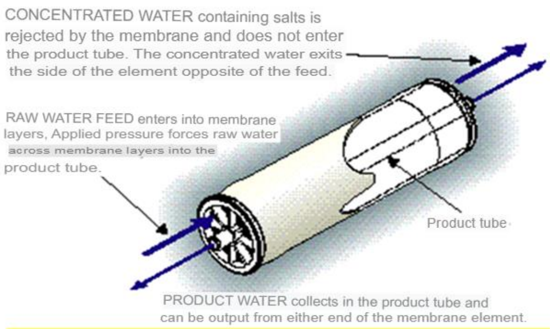


Figure IV 11: the flow water in the membrane

IV.4.1.4 Reverse Osmosis First Stage (RO1)

The installation is designed for treating filtered water to produce osmosed water from the filtered water tank. The osmosed water is pumped using two redundant pumps with a flow rate of 50 m^3/h and a pressure of 9.7 bars to the unit.

At the entrance of this unit, there are three chemical injections (bisulfite dosage, anti-scale dosage, and HCL acid dosage), along with two redundant parallel cartridge filters that feed into a collector. From this collector, two suction lines are distinguished. Each line consists of two high-pressure pumps that operate alternately. Each line feeds a reverse osmosis module, which contains 48 spiral membranes (5*6 and 3*6) with a production capacity of 34 m³/h of permeate.

The permeate is directed to the osmosed water tank, and the concentrate is directed to waste.

The installation includes four pressure pumps (02*50%), with two reserved for each, with a unit flow rate of 34 m3/h at a pressure of 14 bars.

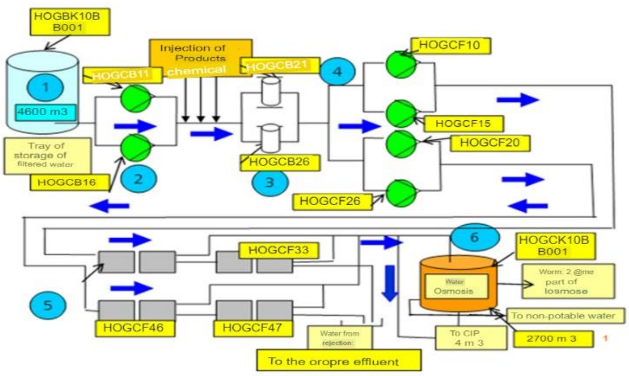


Figure IV 12: reverse osmosis first stage R01

IV.4.1.5Reverse Osmosis Second Stage (RO2)

From the osmosis water tank, two low-pressure alternating pumps feed the second reverse osmosis module, with a flow rate of 27.5 m³/h at a pressure of 10.2 bars. Injection of caustic soda is essential at the inlet (to neutralize the pH and CO_2 from the products injected in the first stage). The water is sent to two cartridge filters in parallel until the collector, which is connected to 3 high-pressure pumps (3*50%) with a pressure of 14 bars and a flow rate of 27.5 m³/h.

The unit consists of two redundant lines designed to produce 100% of the required flow rate, with a treatment capacity of 23 m³/h of permeate. Each line has 18 membranes distributed across 2 racks in parallel and one in the second phase.

The permeate is directed to the breather tank and the reject is directed to the UF permeate tank to be recovered in the filtered water tank.

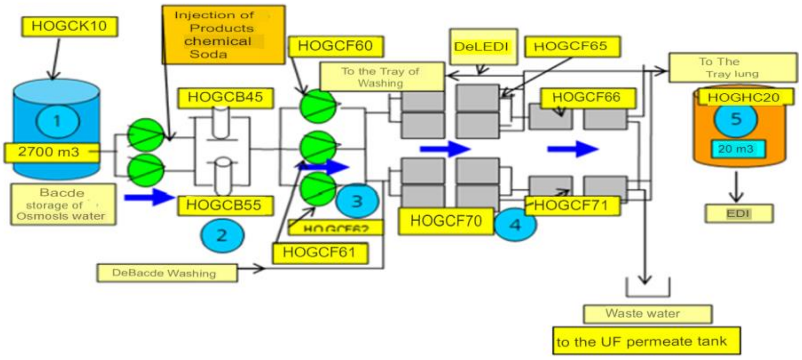


Figure IV 13: Reverse osmosis second stage R02

IV.4.1.6Continuous Electrode ionization cedi

CEDI is a process that combines a semi-permeable membrane technology with an ion exchange media to provide a highly efficient demineralization process. Electro dialysis employs electric current, specially prepared membranes that are semi-permeable to ions based on their charge, and the ability to reduce ions based on their charges. Through electro dialysis, an electrical potential transports and isolates charged aqueous species. The electric current is charged to continuously regenerate the resin, eliminating the need for periodic regeneration.

The CEDI process produces industrial process water with high purity, using less than 95% of the chemicals used in conventional ion exchange processes. With the CEDI system, membranes and electricity replace the thousands of cubic meters of acidic and caustic chemicals that were required daily in old processes.

The CEDI installation consists of 2 redundant operational production lines with a capacity of (20 m^3/h). The installation contains a 20 m^3 tank, 2 centrifugal pumps (1*100%), and 2 cartridge filters (1*100%). The CEDI is composed of 2 parallel lines (1*100%), each line is composed of 2 modules in parallel (2*50%). The product is directed to the demineralized water tank, and the concentrate is directed to the UF permeate tank to be recovered in the filtered water tank.

Figure IV 14: CEDI (Continuous Electrodeionization)

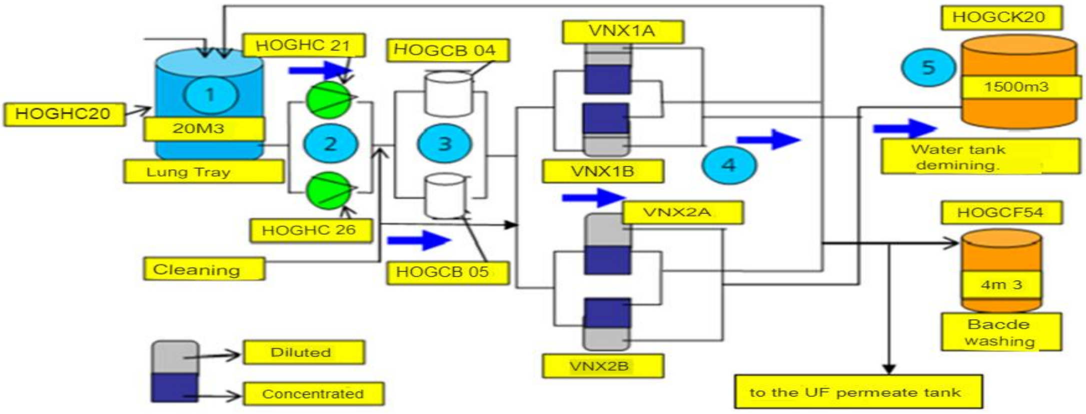


Figure IV 15: CEDI (Ionization Electrode)

IV.4.1.7. Non-potable Water:

From the osmosis water tank, two redundant centrifugal pumps with a flow rate of 2 m³/h and a pressure of 3 bars are supplied. Through two parallel activated carbon filters at the outlet, there are two chemical injections (remineralization and Hypochlorite) to maintain a residuallevel of chlorine in the waterwhile controlling its pH, which is done in the 5 m³

reservoir.

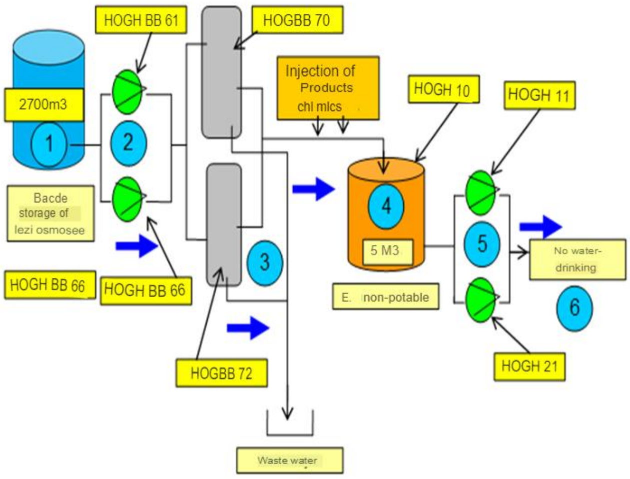


Figure IV 16: Non-potable Water

Figure IV 17: Non-potable Water Tank

IV.4.2. the solar field

The capture surface, which is 183,120 m², is divided into two solar fields, one located to the north of the plant and the other to the south. They consist of a total of 2688 concentrators, with each 12 concentrators arranged in series forming a "ET 150" collector, resulting in 224 collectors. The assembly of 4 collectors constitutes what is called "a solar loop." The two solar fields cover an area of 90 hectares. The configuration used for the solar field is that of a centrally powered installation, meaning that our basic element is the solar loop, which has an inlet and an outlet to ensure an increase in fluid temperature.

The heat transfer fluid reaches around 100°C. This configuration has the advantage of minimizing the total length of piping (cost), but it requires the use of adjustment valves to compensate for pressure losses. [17] [18].

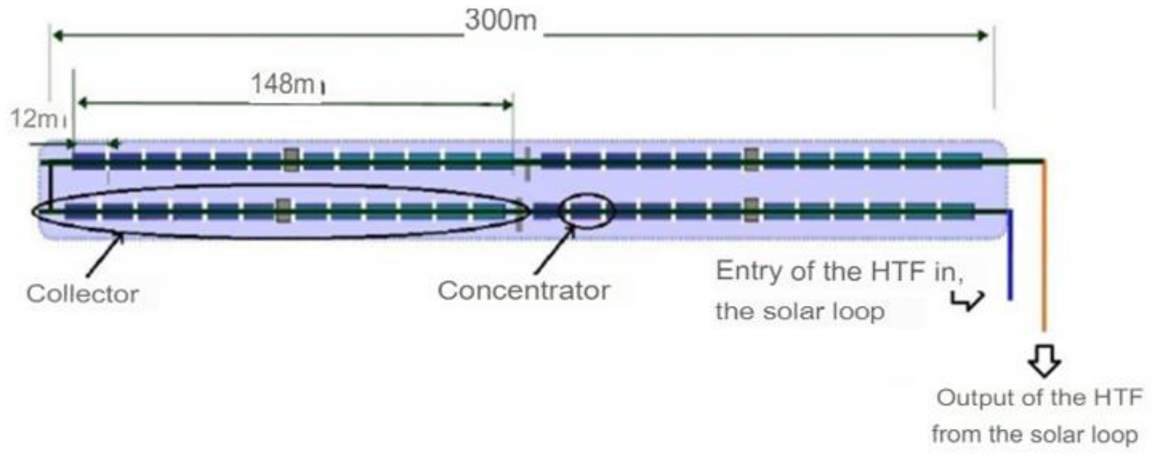


Figure IV 18: Schematic of the solar ring

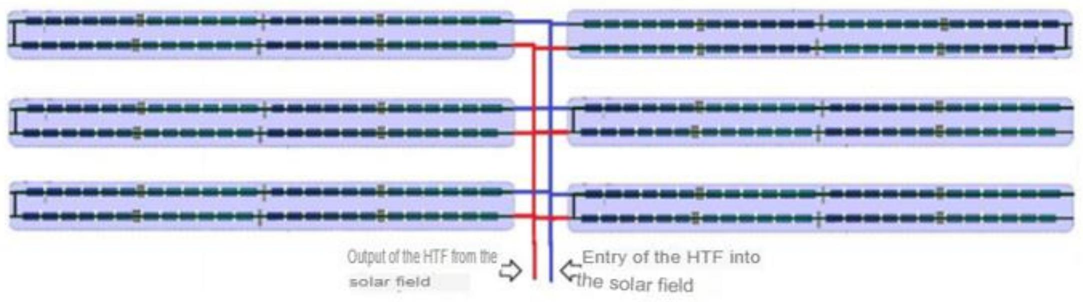


Figure IV 19: Central configuration of the solar field of a power plant

IV.4.2.1. Cylindrical-parabolic concentrator:

The collector module ET 150 is a concentrator composed of 28 segments (4 × 7) of curved mirrors manufactured by the glassmaker Rio Glass, mounted on a metal structure. The mirror is made of high reflectivity crystal glass (98%), on its lower part, it is coated with a layer of silver, copper, a protective layer, and a ceramic layer.

IV.4.2.2. Receiver tube (SCHOTT PTR 70

It is a 4-meter long tube placed at the focal line of the mirrors. The receiver consists of two nested tubes, the outer tube is made of borosilicate glass with an optical coating, it has high

Table IV 8: Characteristics of the ET 150 Collector of the Plant

Width of opening surface [m]	5.75
Opening surface [m²]	817.5
Collector length [m]	148.5
Number of modules per tracking system (collector)	12
Number of glass facets (collector)	336
Number of absorber tubes (4.1m)	36
Concentrator reflectivity [%]	94
Optical efficiency [%]	80
Average annual collector yield [%]	43.5

Transparency and mechanical resistance. It features an innovative anti-reflective coating characterized by durable resistance to abrasion while allowing 96% of solar radiation to pass through. The outer tube is coated to achieve 95% absorption. A vacuum is maintained

between the two tubes to prevent convection losses. The tubes are connected in series by glass-metal seals that compensate for the different expansion effects of glass and metal.

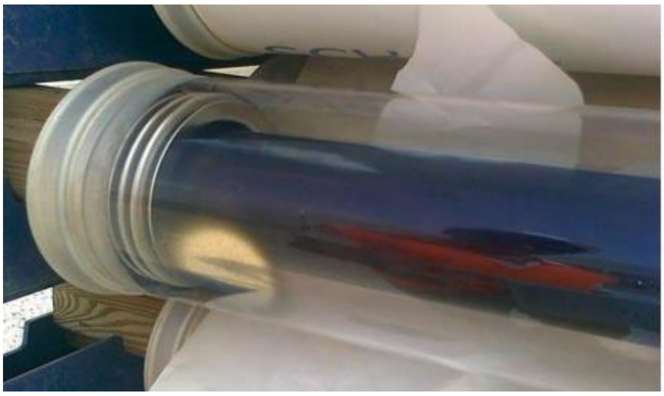


Figure IV 20: Tube receiver SCHOTT PTR 70 from the central

IV.4.2.3. Metal structure and solar tracking system:

The role of the metal structure is to provide rigidity to all the components of the cylindro-parabolic concentrator. Metal supports and pillars, fixed on concrete foundations, support the structure. A tracking system equips each 148 m long collector with two hydraulic cylinders powered by a motor pump. They rotate the structure on its single axis of rotation for solar tracking from East to West. Each system consists of the following elements: Double-acting cylinder, Control valves, Filters, Oil tank, Motor, and Hydraulic fluid.

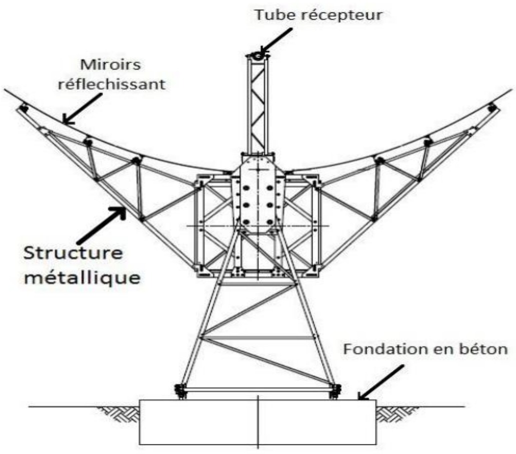


Figure IV 21: Metallic structure of the ET 150

IV.4.2.4. Operation of the solar field:

Sun rays are reflected by the cylindro-parabolic concentrators towards the receiver tube, where the heat transfer fluid circulates, carrying the collected heat through the piping to the solar field outlet. At the first appearance of solar irradiation at sunrise, and once it reaches a minimum value called the irradiation threshold, the pulse pumps start circulating the oil through the field of cylindro-parabolic collectors at an initial flow rate. This flow rate is just sufficient to create turbulence in the absorber tubes. This way, the oil gradually heats up at the solar field outlet. When the oil reaches a temperature of 391°C at the outlet with minimal flow rate, heat exchange begins in the HTF-water heat exchanger (solar steam generator). As the energy becomes more significant in the solar field, the flow rate will increase to always maintain 391°C at the outlet. Thus, throughout the day, the flow rate will vary depending on the useful energy captured by the solar field at any given time. This flow rate will vary between a minimum value and a maximum value while maintaining the outlet temperature at 391°C. At dusk, the levels of useful energy will decrease, and the oil flow rate will decrease to its minimum value. Once this minimal flow rate no longer maintains 391°C at the outlet, circulation is interrupted until a new nighttime period begins.

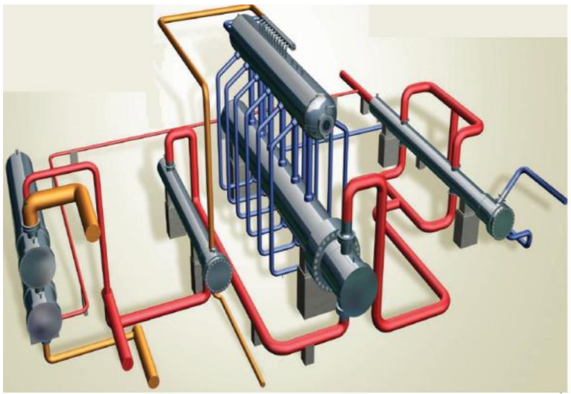
IV.4.3. HTF zone (Heat Transfer Fluid)

IV.4.3.1. Heat transfer fluid (THERMINOL VP-1)

The heat transfer fluid used in the solar circuit is the synthetic oil composed of Biphenyl-Diphenyl Oxide known commercially as THERMINOL VP-1. This oil was chosen for its good thermal stability, affordable cost, and its ability to work at temperatures close to 400°C.

IV.4.3.2. Solar steam generator (SSG):

The function of the steam generator is to produce steam before passing through the Heat Recovery Steam Generators (HRSG) to supply the steam turbine. It is considered the point of connection between the combined cycle and the solar field, known as "solar integration." The steam generator consists of four heat exchangers: a preheater (economizer), two evaporators, and a superheater. The exchange occurs between the heat transfer fluid from the solar field and the water from the HRSG economizers. The heat transfer fluid arrives at the solar steam generator at very high temperature to first pass through the superheater, then through the two evaporators, and finally through the preheater. The water circuit operates in the opposite direction, meaning it first passes through the preheater before ending in the superheater and then returning to the HRSG. This configuration (counter-current heat exchange) allows for better performance.



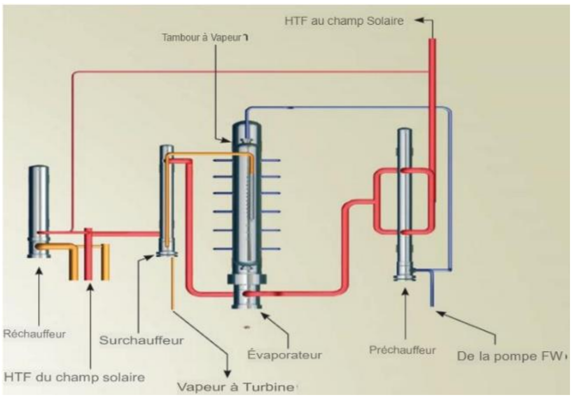


Figure IV 22: Operating diagram of the solar steam generator [19]

IV.4.3.3. HTF boiler (Heat Transfer fluid):

The THERMINOL VP-1 has the property of working at very high temperatures while preserving its characteristics, but it has the disadvantage of crystallizing at ambient temperatures (12°C). To overcome this problem, a boiler is provided to maintain the heat transfer fluid, at night, at a temperature above 50°C [22].

The model used in the Hassi R'Mel plant is the FT - Horizontal model, which is a Horizontal Thermal Fluid generator, with three paths of smoke in double helical serpentine, concentric, and unified by a collector. It has high thermal efficiency. The FT boiler has a homogeneous and stable temperature resulting in a long life for the heat transfer fluid

Figure IV 23: central HTF boiler [22]

IV.4.4. Gas turbine unit

The Hassi R'Mel hybrid power plant features a group of two identical gas turbines, which are of the SIEMENS SGT-800 type. This group consists of gas turbines, alternators, and auxiliary systems. The gas turbine group independently produces electricity and contributes to the operation of the combined cycle by utilizing its exhaust gases. The SGT-800 gas turbine operates according to the process of a conventional gas turbine, as defined previously in Chapter I (Electricity Production Plant)[21].

IV.4.4.1. SIEMENS SGT-800 gas turbine:

The SIEMENS SGT-800 gas turbine is designed for electricity production. Equipped with the latest technologies, it achieves an efficiency of 37.5% and a power output of 47 MW under ISO conditions with low NOx emissions. Due to the high temperature of its exhaust gases, the SGT-800 gas turbine is particularly suitable for cogeneration or combined cycle power plants.

Technical specifications of the SGT-800 Gas Turbine:

- Electricity production: 47 MWe.

- Electrical efficiency: 37.5%.

- Heat consumption: 9,597 KJ/KWh.

- Rotational speed: 6,608 rpm.

- Exhaust gas flow rate: 131.5 Kg/s.

- Exhaust gas temperature: 544°C.

- NOx emissions: ≤ 15 ppm.

IV.4.4.1.1. Compressor:

The compressor of the SGT-800 Gas Turbine is an axial compressor with 15 stages of compression. Its compression ratio is 19, and its blades are coated with chromium steel.

IV.4.4.1.2. Combustion Chamber:

It is an annular chamber equipped with 30 DLE (Dry Low Emissions) burners that can operate on dual fuel (gas, fuel) with low emissions. Ignition is achieved using an ignition system with spark plugs and UV flame detectors.

IV.4.4.1.3. Turbine:

It is a single-module turbine with 3 expansion stages that are air-cooled.

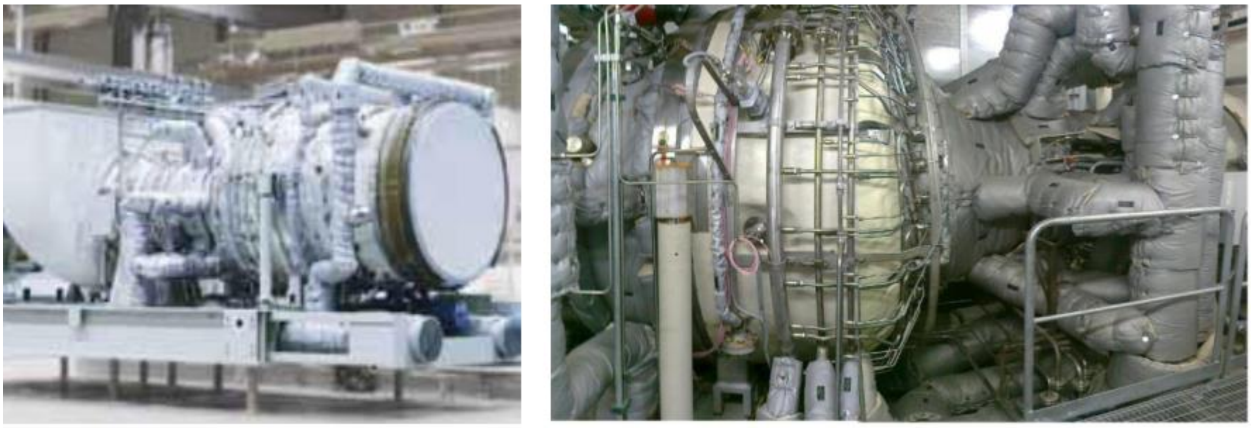


Figure IV 24: SIEMENS SGT-800 gaz turbine power plant

IV.4.4.2. Generator:

The generator is coupled with the SGT-800 and can produce electricity at 50 Hz with an output voltage of 11.0 kV. Its nominal apparent power is 53.6 MVA, the nominal active power is 42.88 MW, the power factor is 0.80, and its excitation force is of the PMG type. It is separately cooled by two horizontally mounted duplex refrigerators located in the upper part of the generator. The cooling temperature is -6.66°C.

IV.4.4.3. SGT-800 Systems:

The SGT-800 gas turbine is equipped with several auxiliary systems to ensure its proper operation, including:

IV.4.4.3.1. Lubrication System:

This circuit supplies lubrication oil to the bearings of the SGT-800 and the generator. The main lubricating oil pump delivers oil from the tank to the feed piping through the temperature control valve refrigerant and the dual filter. Oil is supplied to the various consumers before returning to the tank without pressure. Its flow rate is controlled by diaphragms located at the entrance of the consumers.

IV.4.4.3.2. Fuel Circuit:

For gaseous fuel: This circuit delivers gas to the annular combustion chamber, modulating the flow according to the specific needs during startup and shutdown. It interrupts the fuel supply to the gas turbine under certain operating conditions as dictated by protective measures. The gas must be dry and clean upon admission to the circuit to avoid damage to the burners. Hybrid burners help minimize NOx and CO emissions in the exhaust gases.

For liquid fuel, it consists of two subsystems (diffusion and premixing). It delivers fuel to the combustion chamber, modulating the flow according to the startup, operation, and shutdown requirements. It can interrupt the fuel supply under certain operating conditions.

IV.4.4.3.3. Starting System:

The starting process is facilitated by an electric motor connected to the speed reducer (Gearbox). The gearbox ensures a speed of 3000 rpm at the output (generator input) for a 50Hz grid and 3600 rpm for a 60Hz grid.

IV.4.5. Recovery boilers (HRSG) :

The Heat Recovery Steam Generator (HRSG) is an essential component in combined cycle installations, serving as the link between the gas cycle (gas turbine) and the steam cycle (steam turbine). Its role is to recover the remaining heat from the gas turbine exhaust gases to generate steam required for the steam cycle. Heat transfer between the burned gases and the water (liquid or steam) occurs through several heat exchangers. The Hassi R'Mel hybrid power plant has two HRSGs (one for each gas turbine) of the THERMAX INDIA type. They are horizontally natural circulation, single-pressure level (maximum pressure 92.12 Bars), and temperature of 562°C according to the technique used. With a capacity of 135 tons of steam per hour, they can produce the required steam flow rate for full-load operation of the steam turbine. For steam production, they contain three types of exchangers [19].

IV.4.5.1. Super heater:

This is the first exchanger encountered by the exhaust gases at the inlet of the heat recovery steam generators, exploiting their very high temperature to produce superheated steam (it is the last exchanger the water vapor passes through before being sent to the steam turbine).

IV.4.5.2. Evaporator:

The evaporator is the heat exchanger responsible for steam production, equipped with a separator vessel where the saturated liquid-vapor mixture is located. Its role is to transport the saturated steam to the superheater and to re-pass the saturated liquid through its tubes to vaporize it.

IV.4.5.3. Economizer (preheater):

The liquid water is heated, using the exhaust gases before their exit from the main chimneys, up to the approach temperature which is a few degrees below saturation. This temperature difference is a safety measure to prevent vaporization inside the tubes. Then the water is directed to the separator vessel of the evaporator.

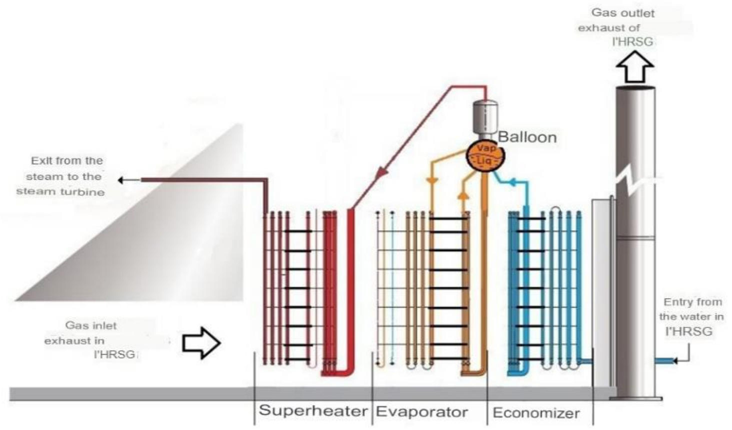


Figure IV 25: Operation diagram of recovery boilers [19]

IV.4.6. Steam turbine unit:

The steam turbine represents the connection point between the combined cycle (exhaust gas recovery) and solar integration. The steam produced by heat exchange at the solar steam generator and the heat recovery steam generators (HRSG) is expanded in the steam turbine, and this steam is then condensed at the air condenser. For a combined cycle, the best combination with SGT-800 gas turbines is the SST-900 steam turbine (SIEMEMS Technology) [21].

IV.4.6.1. SIEMENS SST-900 steam turbine:

The SST-900 steam turbine is a two-pole turbine designed for electricity production and industrial applications. It can be used for single-stage expansion without reheating or for double-stage (HP, LP) expansion with reheating. It has the following characteristics:

Single pressure level:

- Nominal power: 140 MW

- Rotation speed: 3000 rpm for 50Hz and 3600 rpm for 60 Hz.

- Maximum temperature: 560°C

- Maximum pressure: 140 Bars

Double pressure level:

- Nominal power: 250 MW

- Rotation speed: 3000 rpm for 50Hz and 3600 rpm for 60 Hz.

- Maximum temperature: 585°C

- Maximum pressure: 165 Bars

The Hassi R'Mel power plant has an SST-900 steam turbine at a single expansion level, and the maximum pressure that the heat recovery steam generators can provide is 92.12 Bars [11].

IV.4.6.2. Generator:

The generator coupled with the SST-900 can produce electricity at 50 Hz with an output voltage of 11.0 kV. Its nominal apparent power is 102 MVA, the nominal active power is 81.6 MW, and the power factor is 0.80. It is separately cooled by two horizontally mounted duplex refrigerators located in the upper part of the generator.

IV.4.7. Air Condenser:

Air condensers condense the exhaust steam from the steam turbine and return the condensate to the boiler. They are commonly used in power plants and energy production plants of various sizes. Unlike conventional condensers that use a cold fluid (river, stream, etc.), the air condenser uses air circulated by fans for cooling.

SPX air condensers are characterized by long-term mechanical and thermal integrity, excellent resistance to corrosion and freezing, low fan power consumption, reliable operation, and low maintenance. They consist of modules arranged in parallel rows. Each module contains a certain number of finned tube bundles. An axial forced draft fan located in each module forces cooling air through the heat exchange area of the finned tubes.

An air condenser installation typically includes the supporting structure, steam pipes from the steam turbine, auxiliary elements such as condensate and purge tanks, air extraction units and associated piping, as well as instrumentation. Finned tubes are the primary technology used in air condensers:

- Single Row Condensers (SRC™): elongated flat tubes with aluminum brazed fins.

- Multi-Row Condensers (MRC): oval tubes with hot-dip galvanized steel fins.

The Hassi R'Mel power plant is equipped with an SPX Air Condenser due to the absence of a cold source and unfavorable weather conditions for cooling (ambient temperature can reach 50°C).

This SPX air condenser consists of a set of three finned tube heat exchangers shaped like a V-roof, and the assembly is equipped with 15 fans driven by electric motors.

Figure IV 26: The SPX air condenser of the power plant [20]

IV.4.8. Auxiliary systems:

IV.4.8.1. Transformers:

Each generator of the three turbines (two gas turbines and one steam turbine) is connected to a main transformer with the following characteristics:

Transformers for the gas turbine group:

- Power: 40 / 52 MVA

- Cooling: ONAN / ONAF - HV / LV: 220 / 11 kV

- Load regulation: ± 10 x 1%

- Direct impedance voltage: 12.5% (ONAF power base)

Transformer for the steam turbine group:

- Power: 80 / 102 MVA

- Cooling: ONAN / ONAF - HV / LV: 220 / 11 kV

- Load regulation: ± 10 x 1%

- Direct impedance voltage: 12.5% (ONAF power base)

IV.4.8.2. Compressed air system:

Compressed air used for pneumatic controls (valves, solenoid valves, etc.) is supplied by a compressed air station. The air is compressed using an electric compressor, then cooled to the dew point. The internal separation system removes condensation water droplets as well as solid impurities from the outgoing compressed air flow.

IV.4.8.3. Cooling system (Chillers):

The chillers are responsible for cooling the air at the inlet of the gas turbine compressors due to the high ambient temperatures at Hassi R’Mel. These high temperatures affect the performance of the gas turbines, as shown by the characteristic curve, which illustrates the evolution of the generator power and heat consumption based on the inlet temperature of the SGT-800.

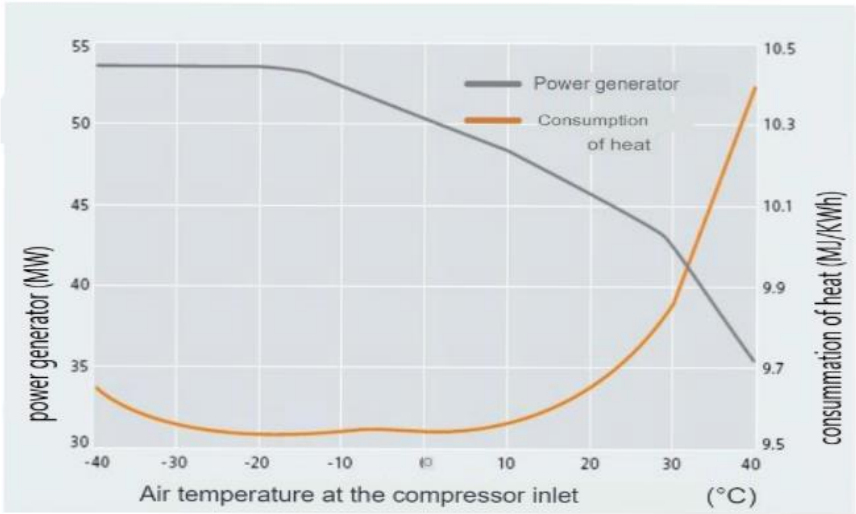


Figure IV 27: Generator power and heat consumption in Function of the inlet temperature of the SGT-800

Based on these characteristic curves of the SGT-800, it can be observed that the generator power reaches its maximum value for inlet temperatures below -15°C. Beyond this temperature, the generator power decreases, while the heat consumption is minimal within this same range. It is also evident that the ideal range for optimal operation of the SGT-800 lies within inlet temperatures ranging from -30°C to -15°C, highlighting the necessity of using chillers.

IV.4.9. Command and control room:

The power plant is equipped with a control room where the management and control of the various components involved in the electricity production process (gas turbines, steam turbine, solar field, air condenser, etc.) and auxiliary systems (auxiliary boiler, chillers, compressed air station, fire suppression system, etc.) take place.

The management of these equipment is facilitated by the Distributed Control System (DCS), which handles the startup, shutdown, and monitoring of plant operations without direct intervention from operators. Two individuals are typically sufficient to manage the control room, which is equipped with a computer system that manages programmable logic controllers (PLCs) and electronic circuits. These systems are responsible for:

- Triggering an alarm in less than 20 ms in the event of risks or incidents.

- Monitoring and recording various operating parameters (pressures, temperatures, flow rates, etc.).

- Calculating the performance of different installations.

IV.5. OPERATION OF THE POWER PLANT:

The Hassi R'Mel hybrid power plant operates according to the ISCC system, meaning it combines a combined cycle with solar integration. The gas turbine group produces electricity independently, which is why this group is started first during the power plant startup process. The exhaust gases from the two turbines are recovered in two heat recovery steam generators (HRSGs) to utilize the heat contained in these gases to produce steam for the steam turbine. The heat recovery boilers are supplemented by input from the solar field, with the exchange taking place at the solar steam generator.

Water is sourced from the air condenser at a temperature of 52°C for the initial passage through the heat recovery boilers (in the economizer), where its temperature increases to reach 220°C before passing through the solar steam generator to recover the heat contained in the heat transfer fluid from the solar field at a temperature of 391°C. Following this exchange, the water temperature increases to 383°C, and the heat transfer fluid returns to the solar field at a temperature of 293°C. After this exchange, the steam is redirected to the heat recovery boilers for a second passage to be superheated before impinging on the blades of the steam turbine at a temperature of 560°C. In our current case, the temperature increases to around 500°C because the steam turbine is only used to produce approximately 80 MW.

In the absence of input from the solar field (at night or in case of anomalies), the heat recovery boilers are equipped with auxiliary boilers operating with gas to partially compensate for this input [23].

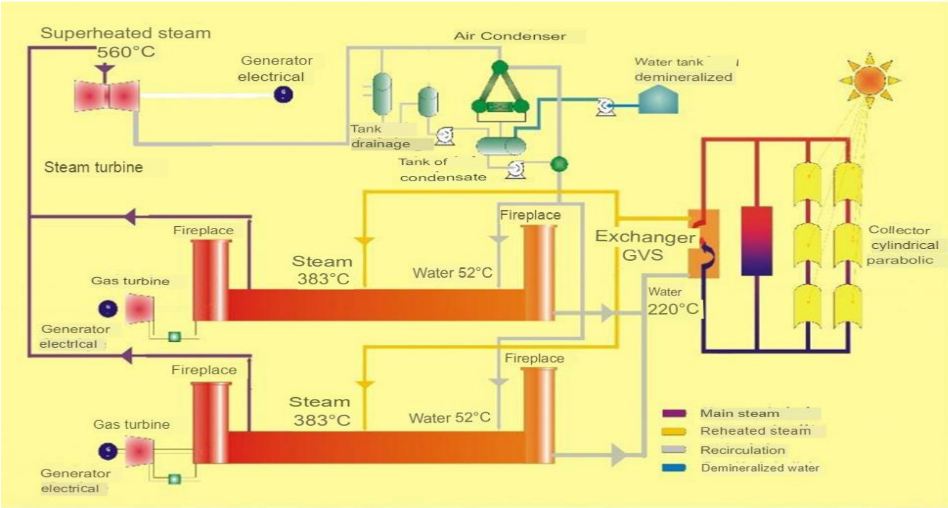


Figure IV 28: Operational diagram of the Hassi hybrid power plant R'Mel

IV.6. Energy calculations of the STEAM turbine:

IV.6.1. EES program definition:

There are several major differences between EES and other equation-solving programs. First, EES allows equations to be entered in any order with unknown variables placed anywhere in the equations; EES automatically reorders the equations for efficient solution. Second, EES provides many built-in mathematical and thermophysical property functions useful for engineering calculations. For example, the high accuracy steam tables are implemented such that any thermodynamic property can be obtained from a built-in function call in terms of any two other properties. Similar capability is provided for most refrigerants, ammonia, methane, carbon dioxide and many other fluids. Air tables are built-in, as are psychrometric functions, JANAF data for over 1200 substances, and property data for hundreds incompressible solids and liquids including heat transfer fluids and brine solutions. Transport properties are also provided for all substances.

An extensive heat transfer library, developed in conjunction with the book Heat Transfer is provided in addition to the built-in library of mathematical and thermophysical property functions. EES also allows the user to add functions in three ways. First, a facility for entering and interpolating tabular data is provided so that tabular data can be directly used in the solution of the equation set. Second, the EES language supports user-written functions, procedures, modules and subprograms. Functions and procedures are similar to those in Pascal and FORTRAN in which assignment statements rather than equalities are employed. EES modules and subprograms are callable EES routines that use equalities. Functions, procedures, modules, and subprograms can be saved in library files that are automatically read in when EES is started. Third, compiled functions and procedures, written in a high-level language such as Pascal, C, or FORTRAN, can be dynamically-linked with EES. These three methods of adding functional relationships provide very powerful means of extending the capabilities of EES.

EES is particularly useful for design problems in which the effects of one or more parameters need to be determined. The program provides this capability with its Parametric Table, which is similar to a spreadsheet. The user identifies the variables which are independent by entering their values in the table cells. EES will calculate the values of the dependent variables in the table. Plotting capability is provided to display the relationship between any two variables in the table.

With EES, it is no more difficult to do design problems than it is to solve a problem for a fixed set of independent variables. EES offers the advantages of a simple set of intuitive commands which a novice can quickly learn to use for solving complex problems. The large data bank of thermodynamic and transport properties built into EES is helpful in solving problems in thermodynamics, fluid mechanics, and heat transfer. The convection and heat exchanger library functions greatly reduce the effort and possibility of errors in the calculations needed to analyze and design heat exchange equipment. EES can be used for many engineering applications; it is ideally suited for instruction in mechanical engineering courses and for the practicing engineer faced with the need for solving practical problems.

IV .6.2. Thermodynamic Analysis of the Steam Reheat Cycle Theory

The Rankine cycle and the reheat cycle are both thermodynamic cycles used to convert heat into mechanical work, typically in power plants. Here's an explanation of the differences between these two cycles:

IV.6.3. Simple Rankine Cycle:

The Rankine cycle is a basic thermodynamic cycle for steam-based power generation and consists of four main components:

- Boiler: Water is heated to produce high-pressure steam.
- Turbine: The high-pressure steam expands through a turbine, producing mechanical work and reducing steam pressure.

- Condenser: The low-pressure steam is condensed back into water by removing heat.
- Pump: The condensed water is pumped back to the boiler at high pressure.

The Ideal Rankine cycle:

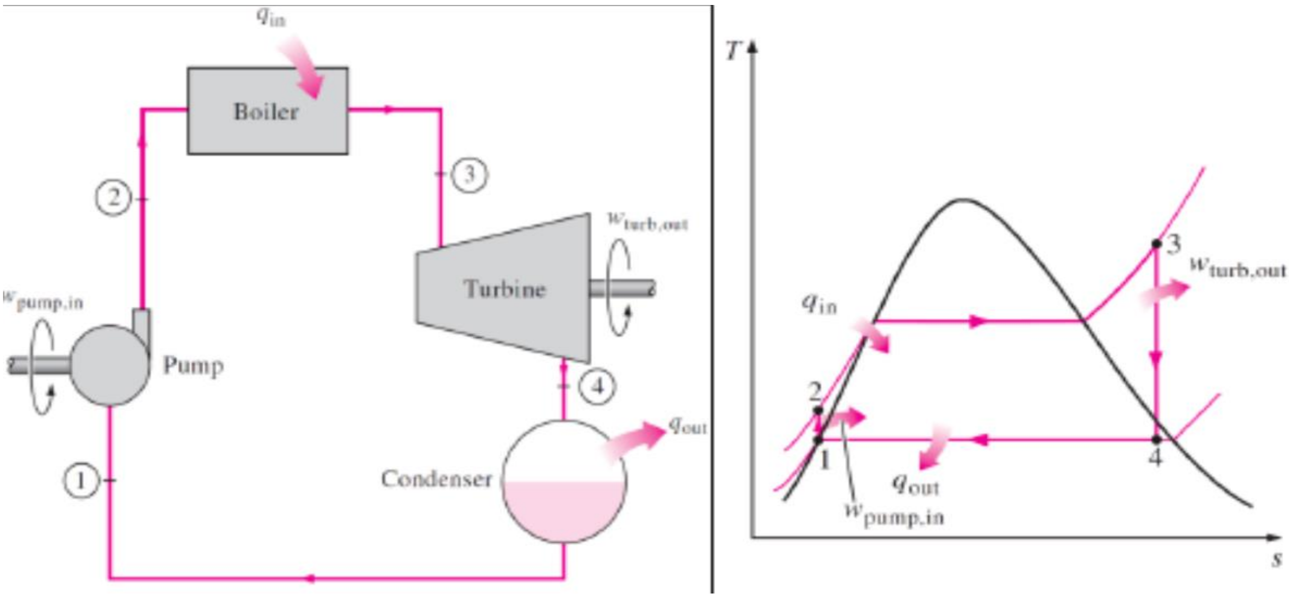


Figure IV 29: Ideal Rankine cycle diagram

IV.6.4. Reheat Cycle:

The reheat cycle is a modification of the simple Rankine cycle aimed at improving efficiency and reducing moisture content in the low-pressure stages of the turbine. It introduces an additional reheating process:

- Boiler: Water is heated to produce high-pressure steam.
- High-Pressure Turbine: The high-pressure steam expands through a high-pressure turbine, producing work.
- Reheater: The partially expanded steam is sent back to the boiler and reheated to a higher temperature.
- Low-Pressure Turbine:The reheated steam then expands through a low-pressure turbine, producing additional work.
- Condenser: The steam is condensed back into water.
- Pump: The condensed water is pumped back to the boiler.

The ideal reheat Rankine cycle :

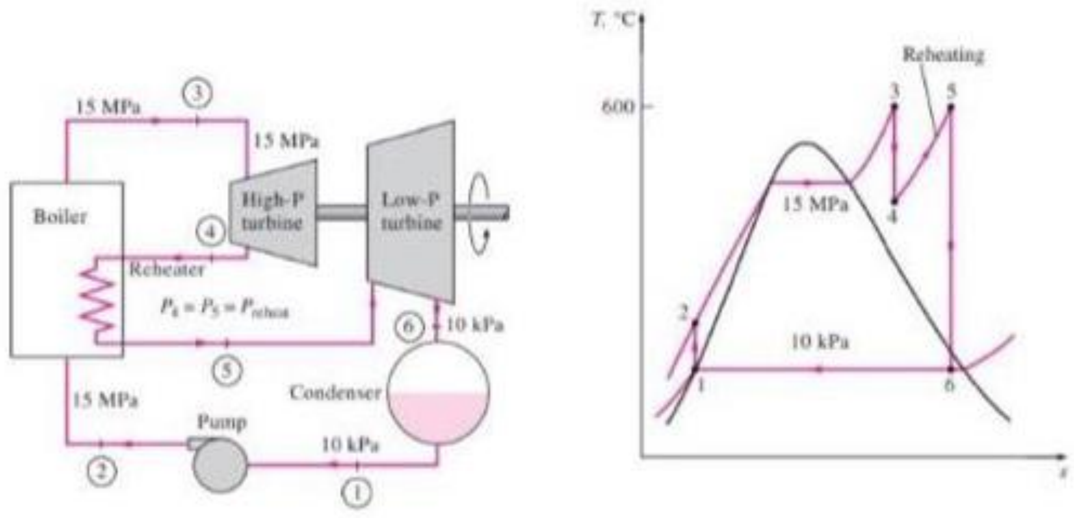


Figure IV 30: Ideal reheat Rankine cycle

IV.6.5. Efficiency:

- Simple Rankine Cycle:This cycle is less efficient because it has a single expansion stage, and the steam exiting the turbine can have a high moisture content, which reduces the turbine efficiency
- Reheat Cycle: By reheating the steam after partial expansion, the reheat cycle improves thermal
- Efficiency and reduces moisture content in the later stages of the turbine, which enhances turbine efficiency and longevity.

IV.6.5.1. Moisture Content:

- Simple Rankine Cycle: The steam at the turbine exhaust can become very wet (high moisture content), causing erosion of turbine blades and reducing efficiency.
- Reheat Cycle: The reheat cycle reduces the moisture content of the steam entering the low-pressure turbine, minimizing blade erosion and improving efficiency.

IV.6.5.2. Complexity and Cost:

- Simple Rankine Cycle: Simpler in design and less costly to implement since it involves fewer components.

- Reheat Cycle: More complex and expensive due to the additional reheater and associated piping, but the benefits in efficiency and turbine longevity often justify the added complexity and cost.

IV.6.5.3. Thermal Efficiency:

The thermal efficiency of both cycles can be represented using the formula for Carnot efficiency, but the reheat cycle typically achieves a higher actual efficiency due to the reduced entropy generation and better utilization of high-temperature heat.

IV.6.5.3.1. Practical Implementation:

In practice, modern power plants often use multiple reheats (double or triple reheat cycles) to further improve efficiency, especially in large-scale electricity generation.

IV.6.5.4 .Summary:

The primary difference between the simple Rankine cycle and the reheat cycle lies in the addition of a reheating process in the latter, which improves thermal efficiency and reduces moisture content in the steam. This results in better performance and durability of the turbine in the reheat cycle compared to the simple Rankine cycle.

Mathematical modeling

Net work

Equation 1 $$W\ net = h3 - h4 + h5 - h6 - [h2 - h1] \quad (IV.01)$$

Efficiency

Equation 2 $$\eta th = \frac{w\ net}{q\ in} \quad (IV.02)$$

Equation 3 $$q\ in = h3 - h2 + h5 - h4 \quad (IV.03)$$

Mass flow rate

Equation 4 $$\dot{m} = \frac{Power}{w\ net} \quad (IV.04)$$

Data

Data introduced are as follows:

Stema turbine Power = 80000 [kW]

Boiler pressure Pb = 80 [bar]

Temperature at boiler exit T max= 500 [c]

The reheat pressure

Preheat= 10 [bar]

The reheat temperature

Treheat= 500 [c]

The condenser pressure

Pc = 0.12 [bar]

The turbine efficiency

ηTurbine= 0.9

The pump efficiency

ηPump= 0.95

The simulations are done using an EES code to find out the parameters at different points of the reheat cycle (Figure IV .31).

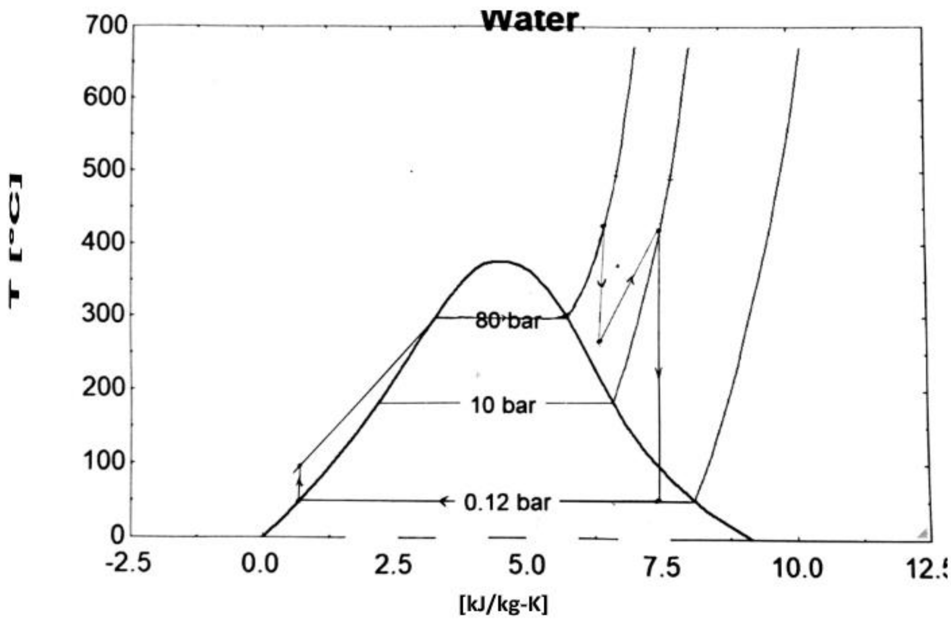


Figure IV 31: Diagram Rankine reheat cycle of Stem -Turbine

Outcomes

Heat absorbed from the boiler

qin = 3764

Net work

Wnet = 1385

Thermal efficiency

η_{th} = 0.3681

The thermal efficiency calculated is η_{th} = 0.3681 while that of the simple Rankine cycle is in the range of 0.3 which means an increase of about 20%.

IV .7 .Conclusion:

In thermal power generation stations like Hassi R'Mel Hybrid Station 01, a combination of solar and thermal technologies is used. The facility features solar units converting sunlight to electricity and thermal boilers fueled by natural gas. These boilers heat water to produce steam, which then drives turbines for electricity generation. Unlike standard cycles, the Rankine cycle with reheating, employed here, involves reheating steam at certain stages to improve heat utilization efficiency. This sets it apart from regular cycles, which lack this reheating process and rely solely on electricity generation and cooling

General conclusion

General conclusion:

Hassi R'Mel Hybrid Station SPP1 is a power generation facility that utilizes hybrid technology, combining both thermal power generation and solar power generation. The station comprises a set of solar units that convert sunlight into electrical energy, along with thermal boilers that use fuel such as natural gas to heat water and produce steam used to drive turbines for electricity generation.

The Rankine cycle with reheat is a process employed in thermal power generation stations, where the steam produced at a certain stage of electricity generation is reheated through heat exchange to enhance the efficiency of heat utilization.

The main difference between the regular cycle and the Rankine cycle with reheating lies in the latter's utilization of reheating process to enhance system efficiency, whereas the regular cycle relies on electricity generation and cooling processes without incorporating reheating.

Simulation has been made using EES code to calculate the network and efficiency of reheat Rankine cycle used in SPP1. Calculations have shown a thermal efficiency of $\eta_{th} = 0.3681$ while that of the simple Rankine cycle is in the range of 0.3 which means an increase of about 20%.

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