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ENERGY PLANNING FOR A RENEWABLE POWER PLANT SYSTEM (CSP) CONNECTED TO GRID

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So … …Thank You All For All

Summary:

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List of Abbreviations:

Abbreviations :

CSP	Concentrated Solar Power.
PV	Photovoltaic.
PTC	Parabolic Trough Collector.
RE	Renewable Energy.
PNERA	National Renewable Energy Programme in Algeria.
LCOE	Levelized Cost of Electricity.
SAM	System Advisor Model.
NREL	National Renewable Energy Laboratory.
NREP	National Renewable Energy Program
TRNSYS	Transient System Simulation Tool
LFC	Linear Fresnel Collector.
PACES	Power And Chemical Energy Systems.
HTF	Heat Transfer Fluid.
NSRD	National Solar Radiation Database.
DNI	Direct Normal Irradiance.
GHI	Global Horizontal Irradiance.
PVGIS	Photovoltaic Geographical Information System.
SM	Solar Multiple.
PPA	Power Purchase Agreement.
EQW	EQual Weighted.
AHP	Analytic Hierarchy Process.
BWM	Best Worst Method.
PAPG	Pole-Adrar- Power-Grid.
TES	Thermal Energy Storage.
TMY	Typical Meteorological Year.
MCDM	Multi-Criteria Decision Making.
GIS	Geographic Information System.
SCA	Solar Collector Assemblies.
Mtoe	Million or mega tonnes of oil equivalent.
NIR	National Interconnected Network
NEPG	National Electrical Power Grid

List of Abbreviations:

Symbole	Nomenclature	Unite
P_{ats}	Absorbed Power	W/m^2
δ	The declination angles	deg
N	The day number of the year	Day
ω	The hour angles	Deg
ST	Solar Time	hr
DST	Daylight Savings Time	hr
Lst	Standard meridian for the Local Time zone	deg
Lloc	The local meridian of the collector site	deg
E	Equation of time	min
ϕ	latitude location of the plant	deg
IAM	Incidence Angle Modifier	Deg
η_{opt}	The optical efficiency	/
ρ	The mirror reflectivity	%
γ	The interception factors	deg
τ	The absorbtivity of the absorber tube	%
α	Factor is the fraction of the solar field that is operable	deg
f	Factor is the tracking the Sun	m
L_C	Losses Collector	/
L_P	Losses piping	/
R_S	Row Shadow	/
SF_{Avail}	Solar field available	/
P_{therm}	The total thermal power delivered to the cycle	MW
η_{therm}	The thermal efficiency of the cycle	/
P_{oil}	The thermal power delivered by the oil	W
$\eta_{stem.ge}$	The efficiency of the steam generator	/
P_{mec}	The mechanical power available from the turbine	W
$P_{loss.el}$	Thermal loss from the tubes leading to the rings	W
P_{aux}	The electrical losses on the generator and on the transformer	MW
P_{net}	The electric power that can be delivered to the net	MW

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General introduction

General introduction

Energy is considered as one of the most important constituents of the world's economy. The energy demand is constantly rising due to the continuous growth in the world population, that is expected to increase from 7.5 billion in 2017 to 8.1 billion in 2025 [1]. Actually, around 80% of worldwide energy consumption is supplied with fossil fuels [2], which harms the environment as one of the major gas pollutant emissions sources that contribute to the global warming problem.

In Algeria, the energy demands are tremendously growing, and on the African continent it ranks among the countries with the highest energy consumption [3]. The final energy consumption reached 48.15 Mtoe in 2018, up to 7.84% from 2017, where final energy consumption is dominated by natural gas 33.3% followed by electricity 28.9% and the remaining share 37.8% correspondent to other final energy forms [2]. To counter its growing energy demand, the country is progressively adopting renewable energy technologies, although conventional energy technologies still play a central role in its electricity production [3].

The main renewable energy sources include solar, wind energy, hydropower, and this is one of the reasons pushing it to shine towards the demand for renewable energy. The huge solar energy potential in Algeria can be exploited and utilized to meet the country's growing energy demand with minimal greenhouse gas production.

Algeria is committed to the path of renewable energies in order to provide global and sustainable solutions to environmental challenges and to preserving conventional energy resources through the National Renewable Energies Program (PNER), adopted by the government in February 2011 and revised in May 2015 and identified as a national priority in February 2016 [4], the updated version of this program consists of installing energy from renewable sources in the order of 22 000 MW by 2030 for the national market. Significant capacities will be installed (in particular photovoltaics, wind power and in 3rd class Concentrating Solar Power (CSP) technology as part of the renewable energy program broken down by technology and by implementation period from 2015-2030.

This research focuses in particular on the Parabolic Cylindro Concentrators technology, which is considered as the best one in terms of concentrating solar energy among the four main types of solar concentrators (Parabolic Trough Collector Technology (PTC), Linear Fresnel

Collector Technology (LFC), Solar Power Tower or Technology Central receiver, parabolic dish or Stirling dish technology), [5, 6].

Algeria has built many solar power plants across the country, an example is the Hassi R'Mel plant, which contributes 30 MW of the renewable energy supply. CSP technologies are currently a proven technology for converting solar energy into electricity [7]. Where several progressive engineering performance models for CSP plants have been developed [8].

The aim of this research is to evaluate the electric power generation and the performance of PTC CSP technology at four preferred sites in Algeria using the System Advisor Mode (SAM) as free software developed by the National Renewable Energy Laboratory (NREL) which is a performance and financial model designed to facilitate decision making for people involved in the renewable energy. A CSP will be considered with top bearing capacity of 100 MW. The work presented here is organized into three chapters:

The first chapter presents CSP technology as one of the large capacities installed around the world, the renewable energy program in Algeria, as well as the objectives and the current situation in addition to the presentation of the electricity network in Algeria, the principle of operation and the option of thermal energy storage. In this chapter we refer to the components of CSP power stations and some characteristics of the station.

In the second chapter, we will address the presentation of the working methodology for modeling simulations of a 100 MW PTC station. The SAM simulation system will be defined for modeling simulations as the best program among others. He described a system and identified its potential for presenting data and areas of use. We will also consider how to identify the data sources and input required by a program for simulation, the four regions will be identified based on studies that illustrated the most important elements of the PTC and the criteria to be defined for modeling in the SAM program. And will be identified and some of the rates for the study will be modelled. and Determination of an electrical assessment methodology.

In the last chapter, we will presentation of the results on the concentrated solar power system, and the most important of these results is the production of electricity in the concentrated solar power plant and energy annually, the capacity factor of thermal energy storage. Furthermore, the performance comparison between CSP plants will be carried out for four sites (Bechar, Ouargla, Adrar and Tamanghasset) across Algeria. The study also discusses the possibility of application of CSP plants on the proposed region based on the analysis on different parameters such as the: (Electrical power generation (or electrical source - Power cycle) gross, net and losses at the first level, the capacity utilization factor, Annual water usage in the second level.

Chapter 1: PTC-CSP Technology approaches and potential.

1.1 Introduction:

Energy is the backbone of modern life, and the main engine of industrial progress in particular and economic progress in general, and this is given its important role in life, as modern economies among countries depend on energy with its various sources to transfer economic resources from its initial form to its final form, capable of satisfying needs and desires. They are numerous and varied, as they are also considered an important factor in achieving the economic and social well-being of the human being.

Man's discovery of energy and its use increases his knowledge, broadens his perceptions, and raises the level his control over nature, and accordingly, the human discovery of more new energy sources raises the level of his use of old and modern sources, and thus the subject of energy in its various forms and sources has become subject to continuous research and development, as energy is a necessary requirement for progress.

Where providing and securing access to energy has become an important issue worldwide, but this energy is characterized by relative scarcity in certain regions of the world and abundance in other regions, and here the role of renewable energy (RE) technology approach (especially solar energy) and the potential of concentrated solar energy appears. In this chapter, we will discuss and clarify the following points: The role of clean energy and its most widespread use, the technologies used and their advantages and the national renewable energy program in Algeria.

1.2 Renewable energy (RE):

Renewable energy is energy that is collected from renewable resources, which are naturally replenished, these resources are either limitless or replenish at a faster pace than they are consumed [9, 10]. Solar energy, wind, hydraulic, and geothermal heat are all examples of renewable energy sources that provide energy [10]. Although energy from fossil fuels remains available and will not disappear any time soon [5], the era of abundant low-cost energy will not last long, and addressing the environmental issues associated with energy sources has become necessary [11].

Energy produced and used in ways that support human development in all its social [12], economic and environmental dimensions is what is meant by sustainable energy, particularly clean energy, is increasing rapidly [5]. Different types of renewable energy sources are promising with the most interesting being solar energy [13]. As the most widely available renewable source [14], is among the most practical and affordable solutions to decelerate the rate of climate change and its unavoidable impacts [11]. Also, it is beneficial to enhance energy security and sustainability in the global market. Solar power plants or hybrid solar plants that use a combination of renewable and traditional energy sources can provide the power [12]. Concentrating Solar Power (CSP) and Photovoltaic panels (PV) are the two major categories of solar technologies [15]. Since solar energy is now widely available, it is possible to replace or reduce the use of traditional power plants such as natural gas and coal with solar power plants [11].

The status quo of global challenges regarding the threats of climate changes as well as the development of clean and sustainable energy clearly indicates an urgent need to hasten the utilization of renewable energy sources [11]. The objectives established by NEAL are focused on raising renewable energy production to 1 400 MW in 2030 and 7 500 MW at the beginning of 2050 [12]. Renewable energy production is projected to account for 50 % of power generation in the European Union by 2040, nearly 30 % in China and Japan, and over 25 % in the United States and India [5].

1.3 Solar energy:

The power sector has grown significantly over the last decade, with a large increase in global production [11]. The solar energy is one of the most used renewable energy in the word, due to the abundance of high solar radiation and, in particular, concentrated solar power and photovoltaic technologies [2]. The underlying advantage of solar energy is that the fuel is free, abundant and inexhaustible [14, 16]. Solar energy technology can provide approximately 7 % of the projected total electricity needs of the world by 2030, and 25 % by 2050 [5].

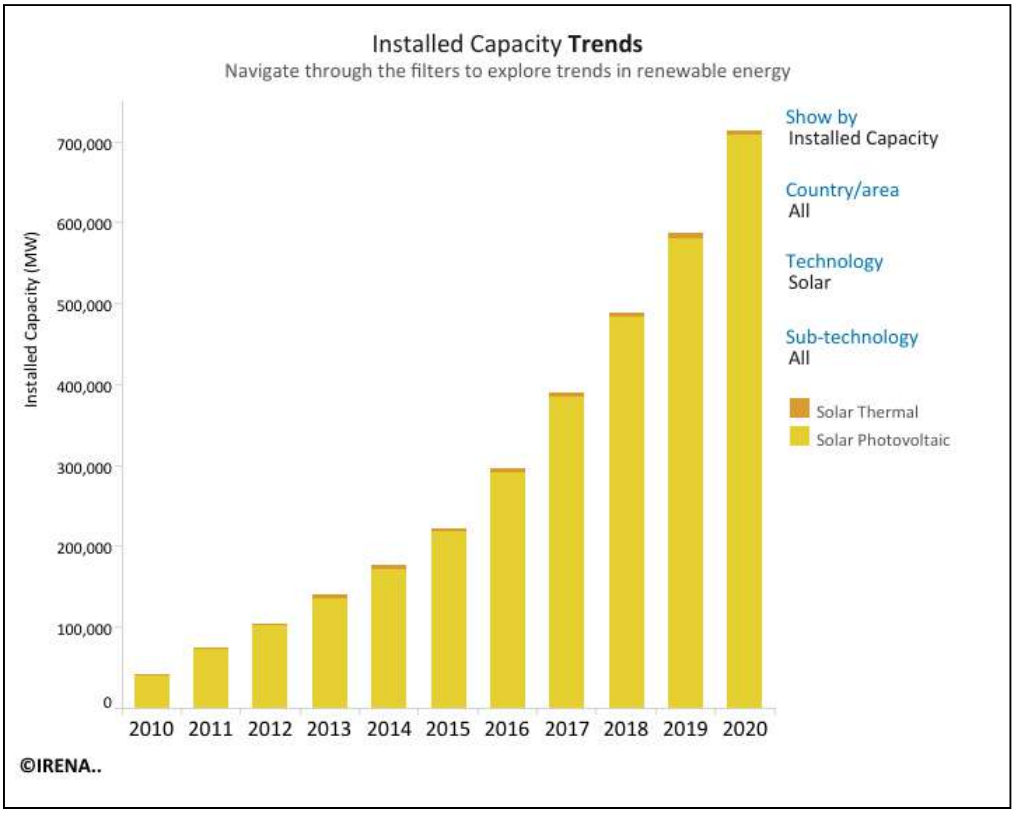


Figure 1.1: Installed capacity (MW) the Solar energy technologies (CSP end PV),[17].

Solar to electricity conversion can be achieved by different technologies (PV and CSP) The benefits of solar power are compelling: environmental protection, economic growth, job creation, diversity of fuel supply and rapid deployment, as well as the global potential for technology transfer and innovation [16, 17]. The cumulative amount of energy emitted by the sun to the earth's surface is sufficient to meet annual global energy demand 10 000 times over [16].

1.4 Overview of the CSP technologies:

The contribution of Renewable sources on the total energy mix in the word reached only 5 % [1]. The world is now looking forward to a revolutionary change in the development of sustainable alternative energy sources especially solar resources. CSP is one of the most promising solar energy technology that can reduce the fossil fuel consumption and CO_2 emissions [13].

CSP is a new technology that has a number of benefits, including built-in storage, high economic returns, and lower greenhouse gas emissions [14], and it has been shown to have significant potential to meet a considerable portion of the world’s energy demand [18, 14]. Are a viable option for sustainable power generation with a minimum adverse effect on the environment [1].

There are four main technologies of CSP technologies [18] named as Parabolic Trough Collector (PTC) technology, Linear Fresnel Collector (LFC) technology, solar tower or central receiver technology, and parabolic dish or Stirling dish technology [5, 6]. Parabolic Trough Collector is Among Concentrated solar power technologies more used and successful. See show figure 1.2.

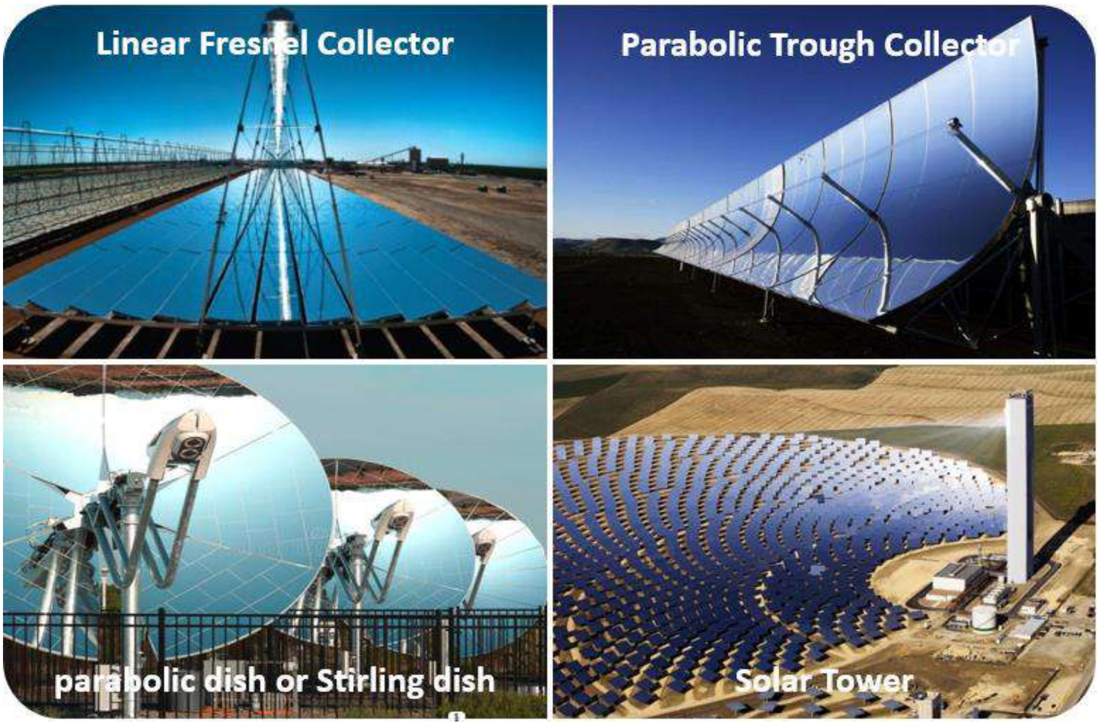


Figure 1.2: Concentrated Solair powerr (CSP) technologies.

1.5 Current and future status of the CSP sector in the world:

CSP is a widely used technology around the world [14]. And is an emerging technology offers significant advantages such as built-in storage capability, high economic returns and reduced greenhouse gas emissions [2]. Further growth of the CSP sector is a key factor for a global shift towards a 100 % renewable energy share by 2050 [11].

CSP technologies have the capability to be economically viable in the sunny regions around the globe. Well as in tense competition with other renewable energy technologies particularly PV. CSP, on the other hand, are expected to make a significant contribution to meeting global electricity demands if advanced technical and cost-cutting advances are combined with sufficient funding [11, 13]. According to Solar Power and Chemical Energy Systems [19], this technology is widely used in projects around the world that are either operating, under construction, or in progress, with a combined capacity of 6 128 MW, 1 547 MW and 1 592 MW. Concentrated solar energy technologies are distributed in many countries of the world [11], including: Spain and USA which are leading countries in this technology [2], Middle East, South end North Africa, Chile, Australia, India and south western of China [11, 14]. Figure 1.3 highlights the countries with the highest production of energy using CSP plants between (1984 and 2022).

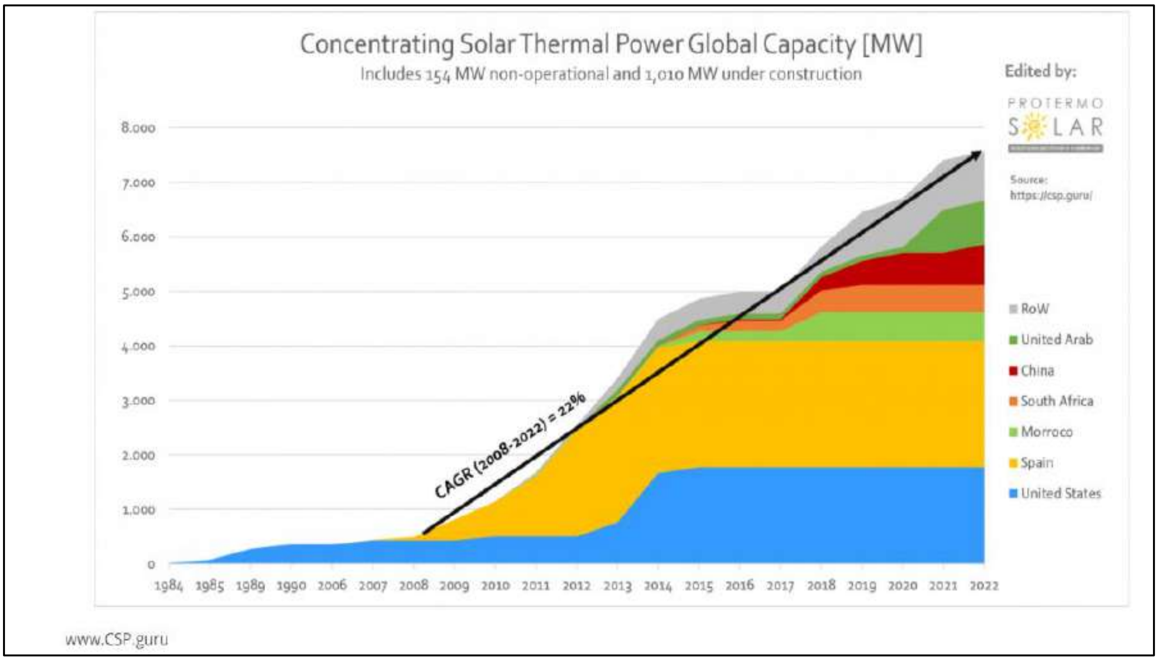


Figure 1.3: Global capacity of installed CSP plants in different countries [17, 19].

figure 1.4, highlights the principles with the installed capacity using CSP plants around the world. The project is presented as: operational, under construction and Development. Were the MENA region reached 1 280 MW, in which morocco has an important installed capacity of more than 500 MW especially in ourzazet region.

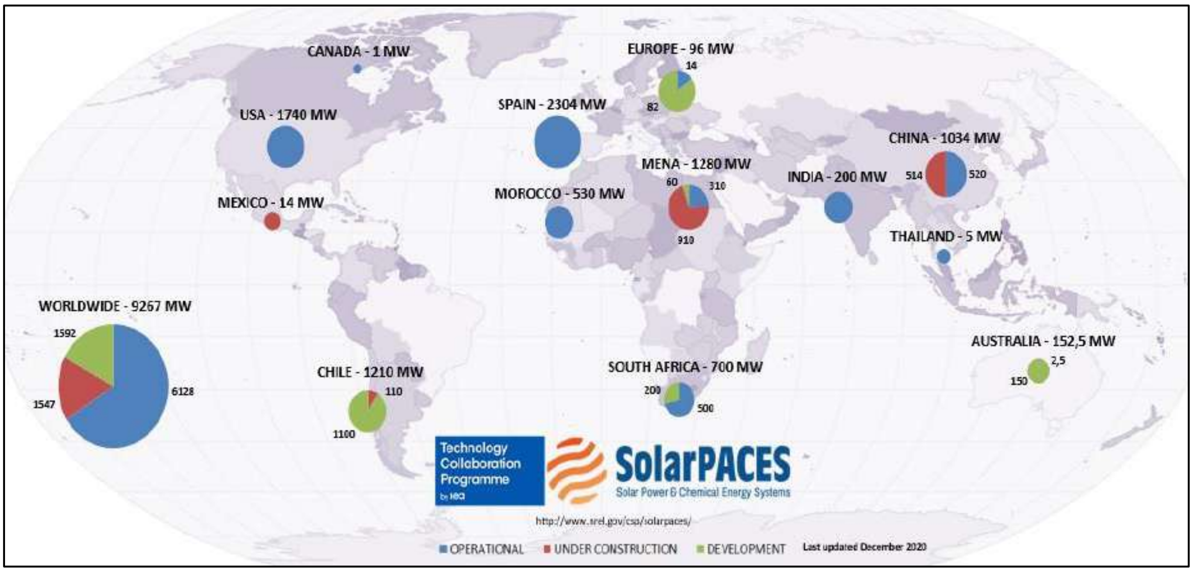


Figure 1.4: CSP Projects Around the World.

A peculiar feature of this technology, which distinguishes it and makes it advantageous compared to other production systems from renewable sources [20], is the ability to modulate the supply of electricity (dispatching) according to user needs. In fact, to allow a continuous or on-demand distribution of energy, with this technology it is possible to accumulate the thermal energy produced in storage tanks [11, 14, 15], the power plant is so capable to work even in the absence of direct light, with cloudy skies and at night. The collected thermal energy is transformed into electricity by Rankine cycle turbogenerators [5]. Therefore, unlike solar photovoltaics, as well as wind energy, thermodynamic solar can produce electricity in a continuous [13], and programmable way using thermal storage [20]. The parabolic trough technology is the most popular and mature CSP design among [5]. the four previously mentioned technologies in section 1.4. The figure 1.5 presents the share of technology from the operational CSP on the word.

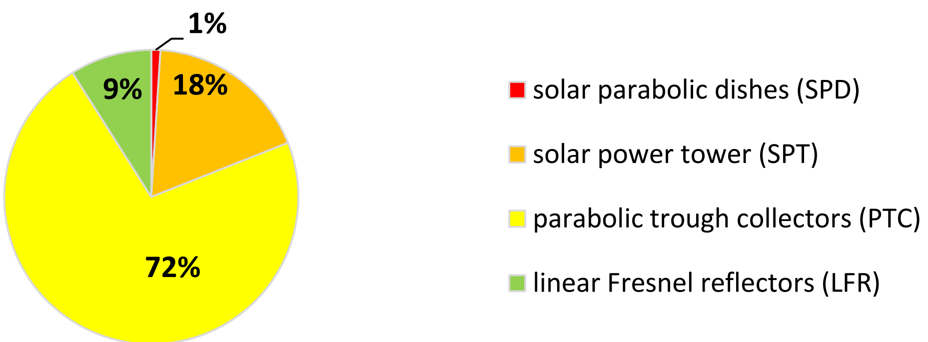


Figure 1.5: Operational CSP share in the world by technology.

1.6 PTC-CSP Working principle and the thermal energy storage option:

Parabolic trough collector consists of a group of parabolic reflectors [11], which are assembled in parallel to form a solar field [2]. As long troughs [11]. This curved mirrors arranged in a line, concentrate solar radiation on pipes surface located at the mirrors' focal centre [21]. And contain HTF, Reflectors are usually coated with silvered acrylic [11]. In the PTC, sunlight is concentrated by about (70 – 80) times on receiver pipes achieving operating temperatures of 350 °C to 550 °C [21]. The energy received by the heat transfer fluid (HTF) is conveyed to the water to produce steam, that driving a conventional steam turbine for electricity generation [11, 21].

After nightfall or on overcast days, the integration of a storage system will help to ensure that the plant continues to generate electricity. The use of thermal energy storage would also improve the plant's overall performance [15]. Notice the shape below figure 1.6:

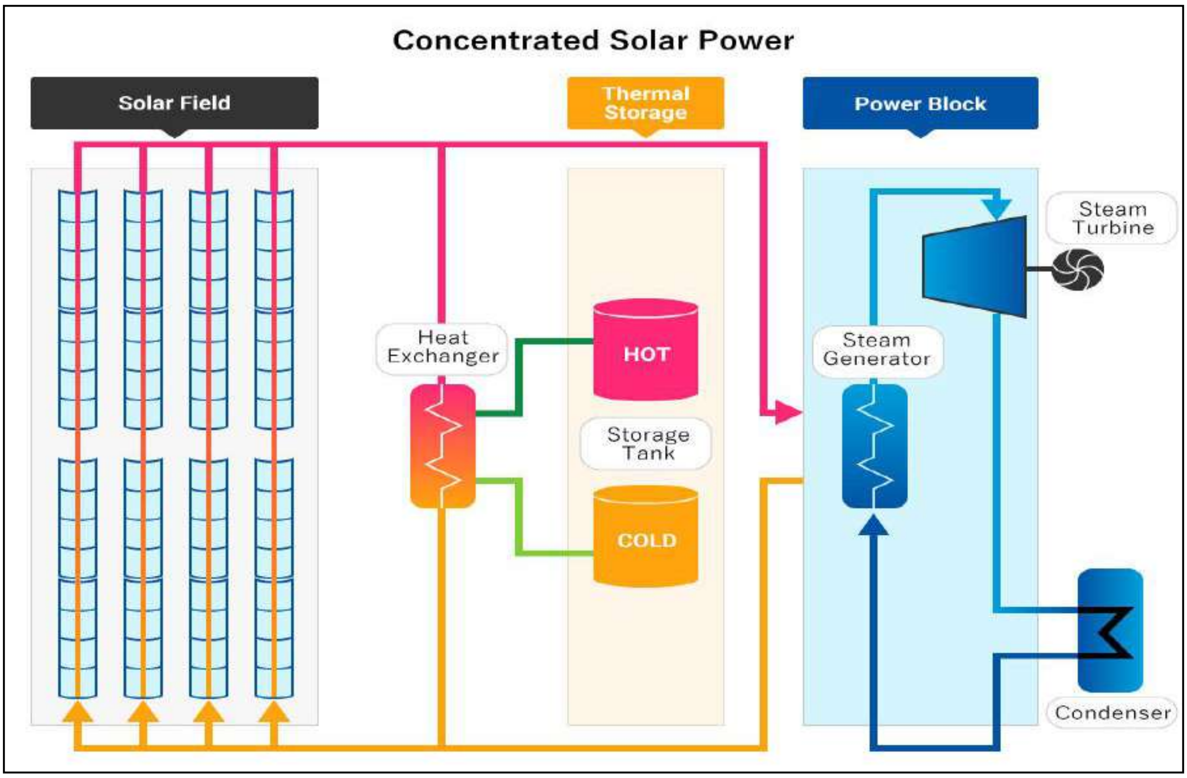


Figure 1.6: Parabolic trough system schematic [22].

1.6.1 Components of CSP:

CSP is one of the most attractive solar technology options for collecting solar radiation and transferring it into solar thermal energy that can be used for electricity generation through a power cycle [11, 21]. A typical CSP plant can be divided into three main subsystems: " Solar Field, Thermal Storage and Power Block [2]. Table 1.1 summarize the role and the principle of competes of each sub systems.

Table 1.1: Main subsystems to solar power (CSP) plant [2, 11].

	Parabolic Trough Power Plant
Solar Field	Converts solar energy into thermal energy. In this unit, its most important components are: (the parabolic-type solar collectors and the system for transporting the heat transfer fluids).
Thermal Storage	Stores thermal energy using molten salt (the heat transfer fluid) as a heat-storage medium. In this unit, its most important components are: (Hot tank, Cold tank).
Power Block	Generates electricity through a steam turbine with steam produced by solar energy. In this unit, its most important components are: (Turbine, Generator end Condenser).

1.6.2 Heat Transfer Fluid " HTF":

Heat transfer fluid plays an important role in solar power plants. HTF is up of the essential components that make up a thermal energy storage device, such as the storage material, the type of contact and heat transfer between the storage material and the HTF, and any heat transfer improvements [1, 23]. Heat transfer fluids must be compatible with the containment materials, storage media and be able to operate in the required temperature range [13, 23, 24].

The most widely used HTF for CSP power plants are synthetic oils and molten salts. Due to their higher specific heats, strong heat carrying power, and high density, they are suitable choices [13, 24]. Note the table 1.2 below showing some types of HTF:

Table 1.3: Thermophysical properties of heat transfer fluids [13, 24].

Name	Type	Min Optimal Operating Temperature (°C)	Max Optimal Operating Temperature (°C)
Hitec	Nitrate Salt	142	538
Hitec XL	Nitrate Salt	120	500
Caloria HT 43	Mineral Hydrocarbon	-12	315
Hitec Solar Salt	Nitrate Salt	238	593
Therminol VP-1	Mixture of Biphenyl and Diphenyl Oxide	12	400
Therminol 59	Synthetic HTF	-45	315
Dowtherm Q	Synthetic Oil	-35	330

1.7 Solar Power in the Word:

Solar thermal power use only the direct sunlight, called Direct Normal Irradiation (DNI) [1]. Hence, it must be sited in regions with high direct solar radiation. Steppes, savannahs, semi-deserts, and true deserts are examples of typical site regions where the climate and vegetation do not contain high levels of atmospheric humidity [16]. Therefore, the most promising areas of the world include the South-Western United States, Central and South America, North and Southern Africa, the Mediterranean countries of Europe, the Near and Middle East, Iran, India, Pakistan, China and Australia. In these regions Solar thermal technology can produce approximately up to (100 -130) GWh of solar electricity per year on a square kilometre of land see figure 1.7 [11, 14, 16].

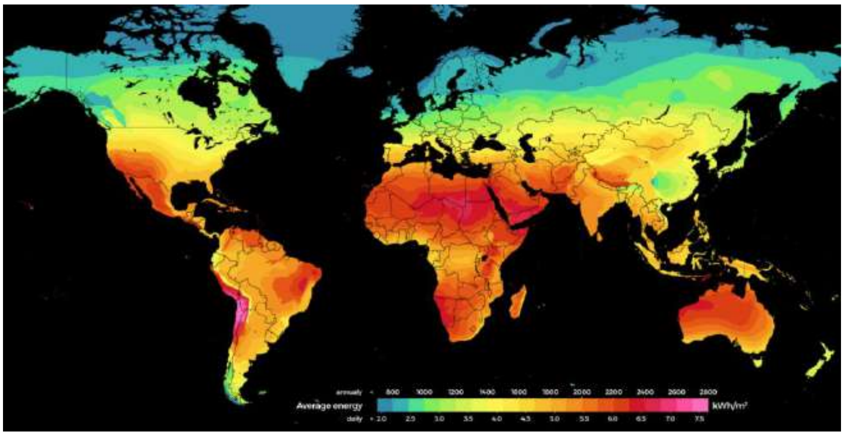


Figure 1.7: DNI in the world.

The power plant performance can be evaluated by the maximal power production and total annual energy output. The feasibility of the CSP plants depends directly on the available levels of DNI at the selected site [2].

Algeria is a large country with a fairly large differences in climate and topography in which the solar resources are also abundant with an average amount of sunshine more than 3 154 h annually and the average annual direct natural irradiance rate is greater than 2 000 KWh/m^2.year [2, 3].

1.8 The national renewable energy program in Algeria (PNER):

Algeria is entering a new era of sustainable energy for the period 2015-2030. Algeria has started its green energy dynamic with the launch of an ambitious program for the development of renewable energies (RE) and energy efficiency. This vision of the Algerian government is based on a strategy that emphasizes the development of inexhaustible resources such as solar energy, their use to diversify energy sources and the preparation of Algeria for tomorrow [25-27]. The country aims to install large capacities (including photovoltaic, wind power and concentrated solar power technology), notice the shape below figure 1.8 under the renewable energy program to reach a total capacity of 22 000 MW by the end of 2030, divided by technology and period of implementation, the program also aims to achieve energy efficiency as it will reduce carbon dioxide emissions in Algeria.

The updated energy efficiency will also lead to energy savings for all sectors (construction, public lighting, transport and industry) [25-29], broken down by sector in the table 1.4 and (table Annex A.1). Where Algeria aspires to be a major player in the generation of electricity from CSP, which will be key drivers of long-term sustainability [28, 30].

Table 1.5: Program of Renewable Energy created by Sonelgaz 2015-2030 [28].

	First phase 2015-2020 (MW)	Second phase 2021- 2030 (MW)	Total (MW)
Photovoltaic	3 000	10 575	13 575
Wind	1 010	4 000	5 010
CSP	_	2 000	2 000
Cogeneration	150	250	400
Geothermal	05	10	15
Biomass	360	640	1 000
Total	4 525	17 475	22 000

The National Renewable Energy Programme (PNER), for the advancement of concentrated solar thermal power technology is divided into three stages [27]:

1) During 2011–2013: 300 MW of CSP.
2) From 2016 to 2020: 1 200 MW of CSP will be installed.
3) From 2021 to 2030: a capacity of about 600 MW per year will be installed.

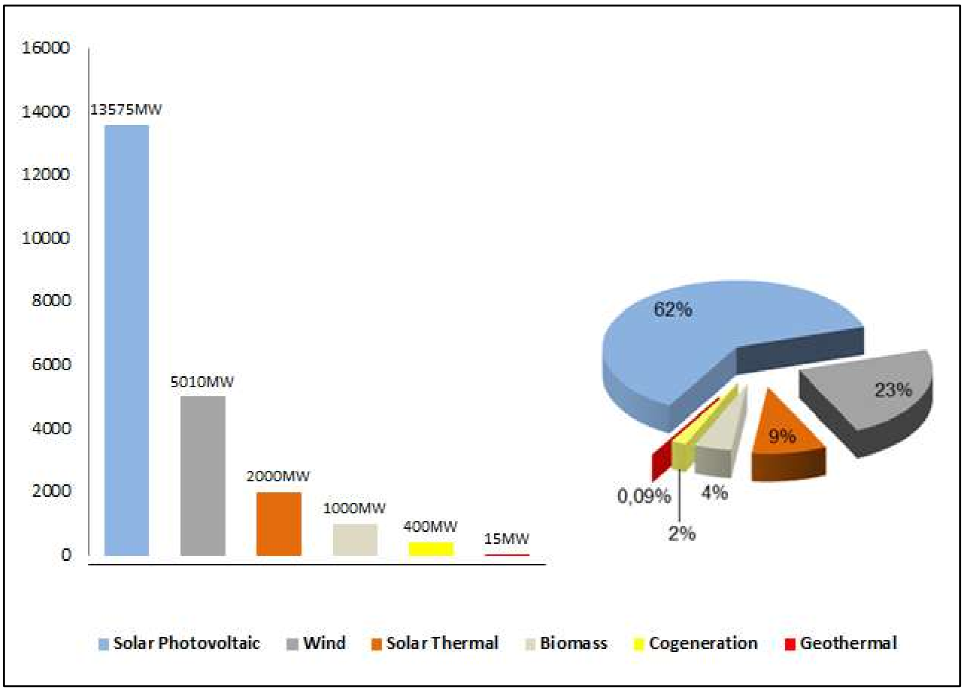
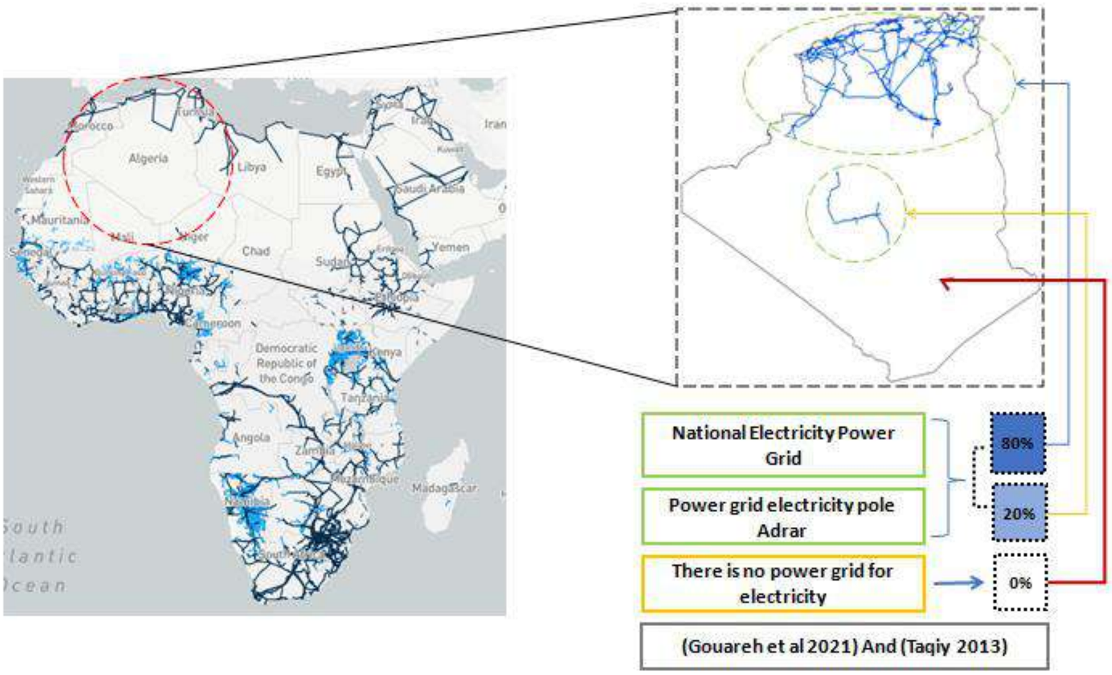


Figure 1.8: Division of program by technology sector PNER in Algeria.

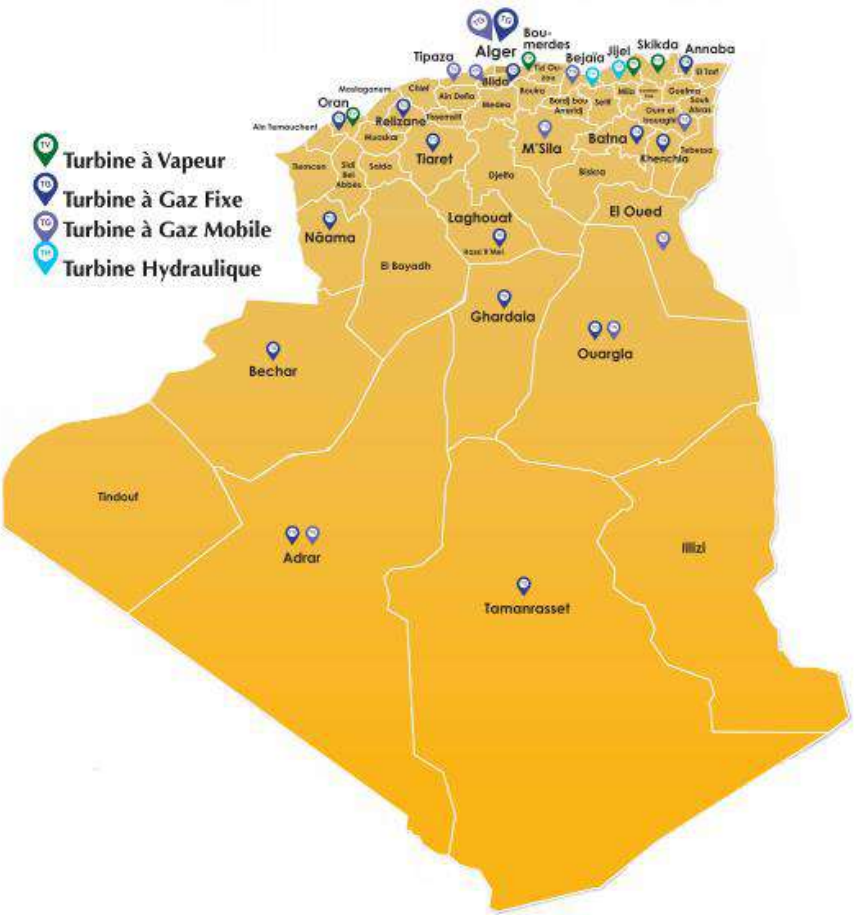
1.9 Power grid in Algeria:

Algeria has an extensive power grid more than 329 782 Km of power grid lines, and it serves almost the entire population. Recently the coverage capacity of the electrical installations network is 98 % and more than 80 % in the north of the country [27]. In 2017, the Installed Capacity reached 19 471 MW, and an Electricity Transmission Network 29 379 Km where the moment national electric power company Sonelgaz still the monopolist of this sector in Algeria [31]. The electricity grid in Algeria is sub-divided into transmission grids (High voltage) and distribution grids (Medium and low voltage).

National Interconnected Network (NIR): Covers the north of the country and the north-eastern regions, as it is connected by a 220 KV and 400 KV transmission network. The pole in Salah - Adrar - Timimoun, which operates in two gas power plants in Adrar and Salah, through an interconnected grid of 220 KV extending from Ain Salah to Timimoun via Olive and Adrar. In the south, the local grid is isolated from the national grid. figure 1.9 shows a map of the Algerian electrical grid and the park exploited in 2017 (see Annexe A.1).



(a)



(b)

Figure 1.9: (a) The Algerian electrical power grid, (b) The electric exploited park in 2017 [27, 32].

1.10 Conclusion:

We discussed the importance of energy in the world in this chapter, as well as the different types of renewable energies and their capabilities, especially solar thermal energy, which has the potential to replace a portion of conventional energy production. They also focused on the different forms and applications of solar energy technology, deepening our understanding of the technology and its potential as a renewable energy source.

In the next chapter, we'll look at a virtual model of a 100 MW concentrated solar power plant (PTC) and look at its potential and effectiveness in the area.

Chapter 2: PTC power plant simulation using (SAM).

2.1 Introduction:

Based on the overview of solar energy around the world, as one of the important resource in the future and the different technology used to convert the solar energy into electricity, parabolic trough system was suggested as one of the best technology owing to its industrial maturity and advantages. It can contribute on the energy production for renewable energy strategy which are the vision of several countries. The suitable design for concentrated solar thermal based power CSP and the evaluation of energy generation in the most favourable site constitute a huge challenge.

In this second chapter, we will address the presentation of the working methodology for simulations of a 100 MW PTC station in different site of Algeria territory. The SAM simulation system will be defined for modeling simulations as the best program among others by describing the system and identifying its potential and areas of use. Also, it will present how to identify the data sources and required input parameters for the program for simulation.

In this study, four regions will be identified based on precedent study on the literature that illustrated the most important elements of the PTC and the criteria to be defined for modeling in the SAM program. Schemes describing the station and the mode of operation will be identified with an electrical assessment methodology.

2.2 Methodology:

2.2.1 Software selection:

In this work a PTC type CSP of 100 MW will be simulated under different climatic conditions (different sites across Algeria territory). The use of computing tools in the modelling and simulation of PTC systems has been utilized extensively and also made analysis of these systems possible. This study is carried out using a System Advisor Model (SAM), The program is a performance model developed by the (NREL) [18] [14].

Unlike other simulation programs, the SAM simulation software of PTC plant, which is based on Transient System Simulation (TRNSYS), was selected for PTC-CSP modelling for several reasons summarized as below: (detailed performance analysis from a complete system-level simulation perspective, availability of input datasets for plant component design parameters, and ability to run a large number of simulations using scripts and codes written in multiple programming languages to conduct parametric and sensitivity analyses) [33], unlike experimental studies, simulation does not include uncertainty but necessarily has assumptions and simplifications provides enormous information for the vised objective [14, 34 -35] .So the simulation process give us the possibility of testing the influence of several variables on system performance with minimum effort and less cost.

Modelling and simulation of a PTC involve the generated electricity, electrical power output and capacity factor analyses…etc. Where the results can be gathered and/or decoupled, analysed and presented separately. This technique, which is completely reasonable for a PTC, gives considerable convenience in results analyses and decision making [14, 36].

2.2.2 Description of the System Advisor Model:

The SAM is a performance and financial model designed to facilitate decision making for people involved in the renewable energy industry: (Project managers and engineers, Incentive program designers, Technology developers, Researchers.) developed by National Renewable Energy Laboratory [18, 37]. SAM makes performance predictions and cost-of-energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that you specify as inputs to the model. Projects can be either on the customer side of the utility meter, buying and selling electricity at retail rates, or on the utility side of the meter, selling electricity at a price negotiated through a power purchase agreement (PPA), or on no financial model [35].

The first step in creating a SAM file is to choose a technology and financing option for your project (PV, Wind, CSP...etc). SAM automatically populates input variables with a set of default values for the type of project. Next, it is important to provide information about a project's location and the type of equipment in the system. SAM includes several databases of performance data and coefficients for system components such as photovoltaic modules and inverters, parabolic trough receivers and collectors or biopower combustion systems [34, 35]. For those components, we can simply choose an option from a list. For the remaining input variables, we can change either use the default value to awns based on the literature. Some examples of input variables are: (operational parameters numbers of modules, tracking type, collector and receiver type, solar multiple, storage capacity and power block capacity for parabolic trough systems), see figure 2.1.

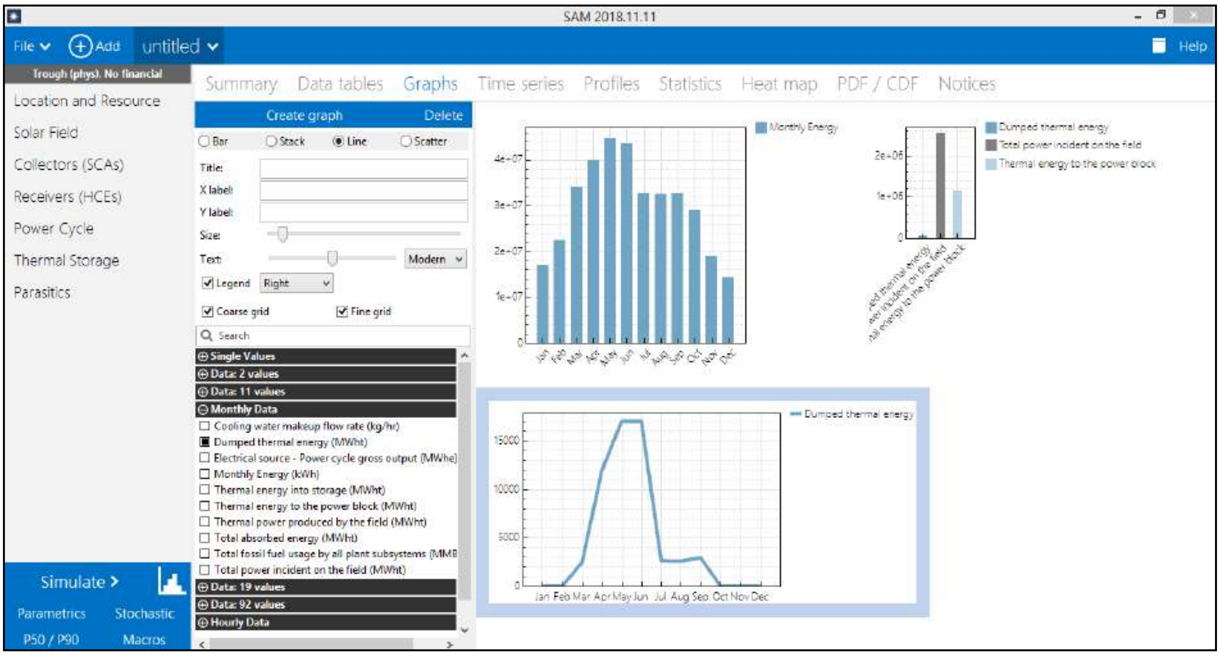


Figure 2.1 : The SAM main window showing the results summary for a wind power system.

The performance model of SAM is discussed in detail in the rest of this section. The figure 2.2 presents the flow chart of a SAM simulation. Where the presented model includes sections permitting to estimate the electricity production. see Annexe (A.2).

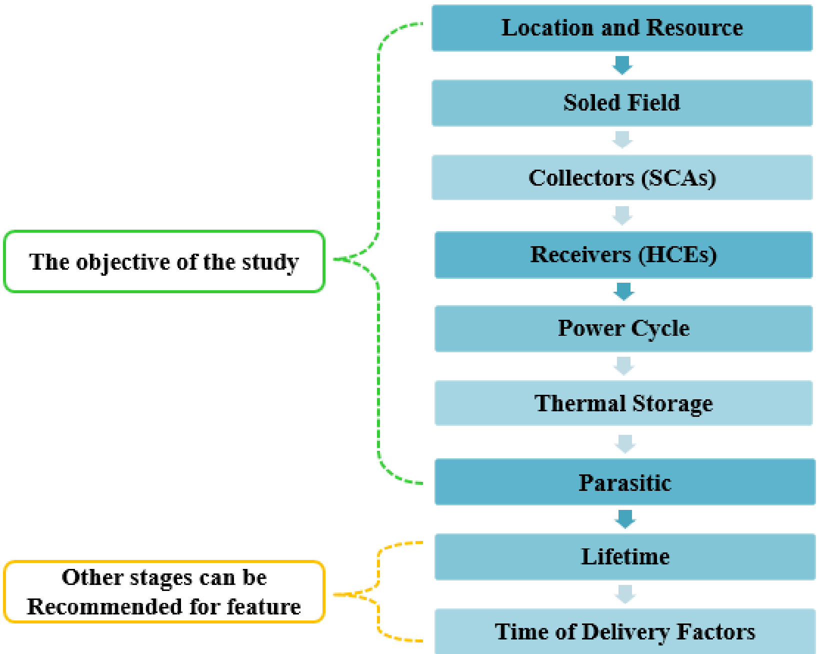


Figure 2.2: Flow chart of a SAM simulation, includes sections permitting to evaluate the electricity production [38].

Running the model also requires a weather file for your project's location in one of three formats: (TMY2, TMY3, or EPW). Files for many locations in the United States and around the world are available in those formats for free on different websites [13]. SAM includes the complete set of TMY2 files for U.S. locations, a tool for automatically downloading weather files from the (NREL) weather file databases using a project site's address or geographic coordinates, and a tool for creating weather files with your own weather data. Once you are satisfied with the input variable values, you run simulations, and then examine results. A typical analysis involves running simulations, examining results, revising inputs, and run the process until you have a confidence result.

SAM displays modelling results in tables and graphs, ranging from the metrics table displaying, first year annual production, and other single-value metrics, to the detailed annual cash flow and hourly performance data that can be viewed in tabular or graphical form. A built-in graphing tool displays a set of default graphs and allows for creation of custom graphs. Graph sliders make it easy to visually examine the effect of changing input values in graphs and tables without changing values on the input pages. All graphs and tables can be exported in various formats for inclusion in reports and presentations, and also for further analysis with spreadsheet or other software [34 -39]. SAM comes with a full-featured scripting language called LK, which automates batch processing simulations and allows for more complex analyses as well as reading and writing data from files [35].

SAM includes a suite of applications for users to access the model in the way that works for them. The desktop application for SAM (Windows, macOS or Linux) has a user-friendly interface, extensive documentation, and advanced analysis features [34]. A PDF output function can also create a report of varying detail with technology and financial assumptions to share with project collaborators [37] and the source code for SAM is available on (GitHub) for those who want to contribute their own models, explore the model algorithms, or help fix bugs [34].

SAM used simulation modules in their applications written in (SSC, C/C++, C#, Java, Windows, Python, LK, MATLAB, and other languages) [35]. Notice to figure 2.3.

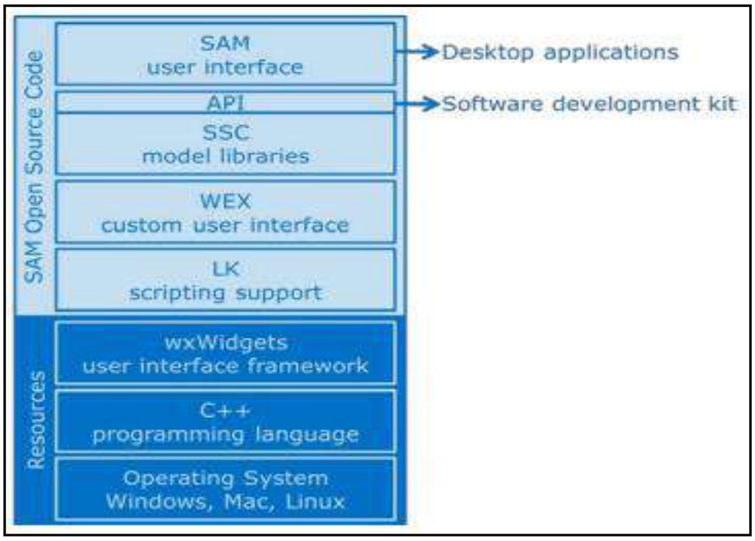


Figure 2.3: Diagram of SAM structure (NREL) [35].

2.2.3 Site selection for CSP simulation:

Climatic conditions are critical for maximizing the overall CSP-PTC plant efficiency [40]. Algeria's geographical location in the Sun Belt region, as well as climatic conditions such as abundant sunshine throughout the year, low humidity and precipitation, and plenty of unused flat land near road networks and transmission grids, provide many advantages for the widespread use of solar energy, including an enormous potential for power generation compared to global energy demands [27] For all solar energy systems, the single greatest uncertainty in predicting the performance of a solar power plant is the solar radiation variation. The solar resource assessment plays an essential role in: the site selection of a solar project, the estimation of its annual power generation, and the evaluation of its temporal performance. Understanding the spatial and temporal variability of solar resources is very essential for the proper assessment of solar energy [7, 11].

Selecting the best sites for CSP installation in a country involves numerous factors, yet the availability of good solar resources (DNI) is the utmost importance factor [41, 42]. In addition, many other factors can be considered for selecting a suitable location of PTC-CSP such as proximity to road and power grid also the availability of land area and sunshine duration... etc [2, 43]. Based on the literature, gouareh et al conducted adetailed study on the solar Technology (CSP) in Algeria the study developed a suitability map for CSP installations in Algeria using a GIS Multicriteria Decision Making Analysis. Under three scenarios; the first one is EQual Weighted (EQW scenario) where an equal-weighted is assigned to each criterion to ignore the relative importance of each one, the two others scenario are conducted using two differences

MCDM techniques; Analytic Hierarchy Process for AHP scenario and Best Worst Method for BWM scenario. As results of their study, the BWM scenario is presented as the best scenario, comparing to tow others scenarios as shown in the figure 2.4.

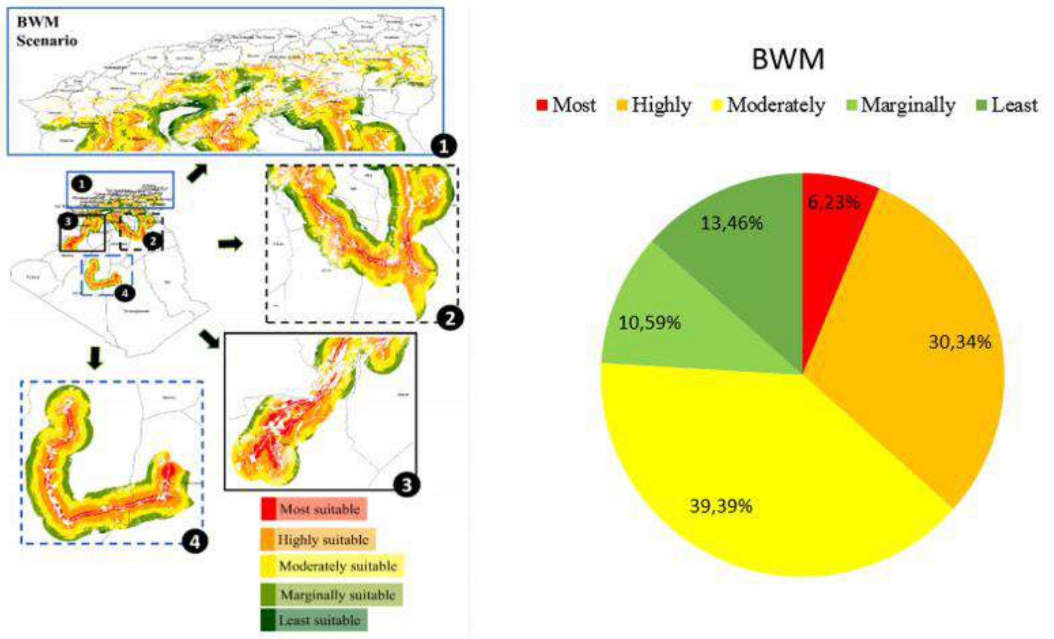


Figure 2.4: Final suitability map for CSP plants (BWM scenarios) [2].

The figure 2.5 shows that more than 256 808.49 Km² (equivalent to 11 % from the total land of Algeria), is considered as suitable site for installing CSP plants, with five levels of suitability (most, highly, moderately marginally and least suitable). The Least and Marginally suitable presented in green colour and the Moderately suitable in yellow occupied 24.05 %, 39.39 % from the total suitable land respectively. The most and the highly suitable zones are given in the red and orange colour and present land of 93 896.6 Km² which is largely sufficient for installing many CSP projects in the region [2].

The study concluded that, according to the DNI map figure 2.5, more than seventeen provinces, including Tindouf, Bechar, Naama, Sidi Bel Abess, M'Sila, Tebessa, Elbayadh, Laghouat, Djelfa, Gherdaia, Ouargla, Tamanghasset, North-East of Adrar, Illizi,...etc, have the highest irradiation zones (with more than 2 077 kWh/m^2.year).But applying the decision criteria (all evaluation criteria) presented in the study of gouareh et al, some provinces are degraded to low suitable class and some others are excluded due to the no access to the power grid (more than 50 000 Km) to the nearest power line. For this reason, the number is reduced and occupied only the provinces of Bechar, Naama, Elbayadh, Laghouat, Gherdaia, and Ouargla which present the large lands of most suitable class and Adrar region in which the major land is classified in the highly suitable zones.

Based on these results four sites are selected for CSP plants to be simulated separately. Ouargla and Bechar for the national interconnected power grid, Adrar region due to the existing of the Pole-Adrar- Power-Grid (PAPG). In the south, the weak infrastructures make these regions as no possible lands for CSP on-grid project for the nearest future but Tamanghasset region is selected to give idea about the region production due to its high DNI potential in the region, which can be proposed as long-term objective to be installed in the far future.

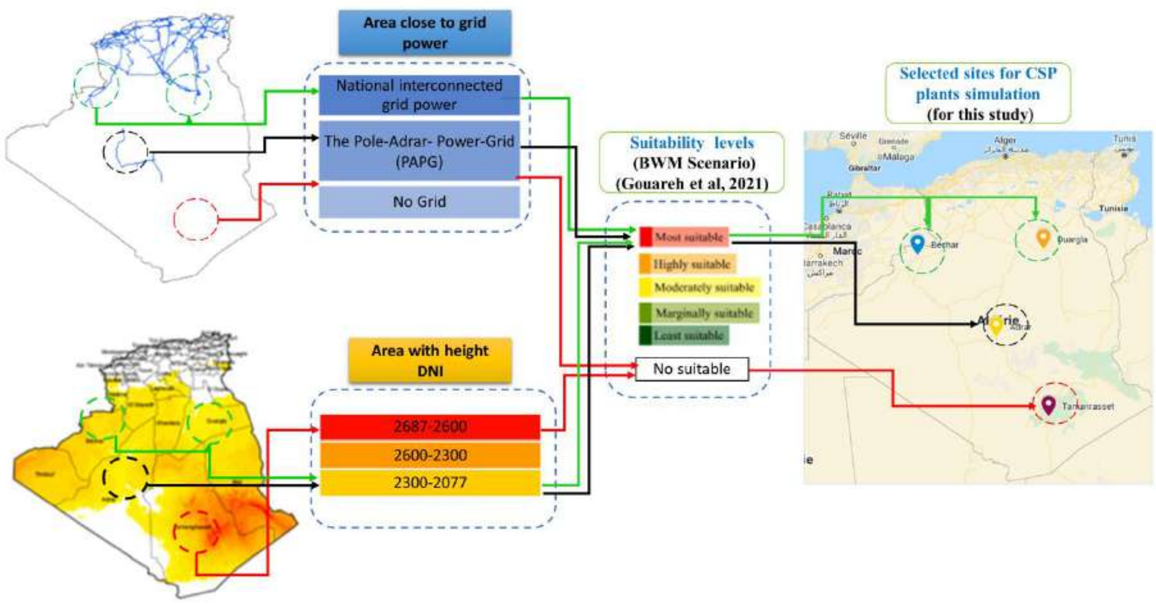


Figure 2.5: The four selected regions in Algeria for PTC-CSP simulation.

a Solar radiation (DNI):

The solar radiation characteristics decide the potential for CSP implementation in any given geographic area. Irradiance is defined as the total specific radiant power per unit area, or radiant flux, that reaches a receiver surface and is measured in W/m^2 [44]. As the irradiance is integrated over a period of time, it becomes solar irradiation, which is calculated in Wh/m^2 [44, 45]. When this irradiation is considered over the course of a given day it is referred to as solar insolation, which has units of KWh/m^2. Day [6, 46]. However, by assigning a number of useful solar hours in a given day then the units simplify to W/m^2. As such, the terms irradiance and insolation are typically used interchangeably. Solar radiation consists primarily of direct beam and diffuse, or scattered, components. The term "global" solar radiation simply refers to the sum of these two components. The daily variation of the different components depends upon meteorological and environmental factors: cloud cover, air pollution and humidity and the relative earth-sun geometry.

The direct normal irradiance (DNI) is synonymous with the direct beam radiation and it is measured by tracking the sun throughout the sky. In CSP applications, the DNI is important in determining the available solar energy. It is also for this reason that the collectors are designed to track the sun throughout the day. The annual DNI value will also greatly influence the Levelized Electricity Cost (LEC). Typical values of DNI at different latitudes and selected locations around the country are presnted in figure 2.5. Based on the information presented here it can be seen that desert regions appear to provide the best resources for CSP implementation [2].

2.2.4 Systems design and operation parameters:

This study is carried out using a System Advisor Model (SAM). In this study, potential sites for installing solar thermal power plants are selected on the basis of solar resource assessment, land availability, and feasible infrastructure. A case study of a 100 MW parabolic trough collector solar thermal power plant is simulated for these potential sites. The parabolic trough CSP plant uses synthetic oil as heat transfer fluid and molten salt for the thermal energy storage system.CSP plants have been designed for the nameplate capacity of 100 MW and it occupies an area of (963 174 m^2 with a solar multiple equal to 2), And HTFs fluid is Hitec Solar Salt, field HTFc fluid is therminol VP-1, Receiver (Solel UVAC 3), Cooling condenser type (Air cooled) end Collector type (SkyFuel SkyTrough (with 80-mm OD receiver)). See Annexe (A.2): This PTC plant consists of three main parts, namely the solar field, thermal storage system and power block. A layout model of the PTC-CSP plant is shown in figure 2.6:

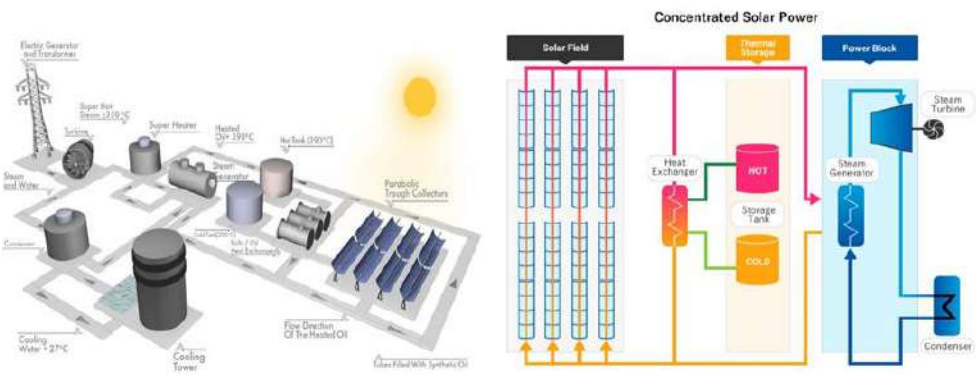


Figure 2.6: 3D vision of Parabolic Trough Solar Collector plants and A schematic model of the PTC-CSP plant [22].

The Parabolic Trough model simulates a solar field with a parabolic trough that transfers thermal energy to a power block where electricity is produced, with the option of a Thermal Energy Storage (TES) device. Many of the system's components are defined using first-principles thermodynamics. Mathematical models that reflect component geometry and energy transfer properties are used, allowing for the specification of system components' characteristics for example (collector geometry and optical parameters, absorber geometry, absorptivity, and emissivity). It is worth mentioning that the development of the Parabolic Trough model makes use of the following models: collector model adapted from NREL (SAM model 2018), receiver heat loss, field piping pressure, and power cycle performance, show figure 2.7 and see Annexe (A.2).

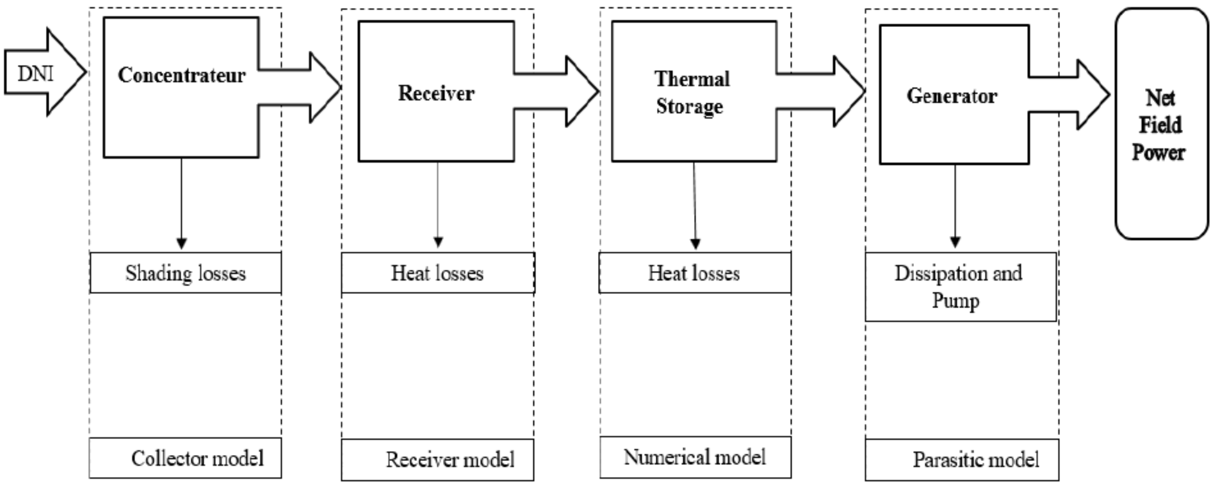


Figure 2.7: Model methodology , with own processing [40].

The technical input parameters used to model the PTC-CSP plants presented in this paper are summarized in Appendix [13]. Solar Multiple (SM) is a parameter that represents the solar field aperture area as a multiple of the power block rated capacity. For instance, a solar multiple of one (SM 1) represents the solar field size that, under reference solar conditions, generates thermal energy enough to drive the power block at its design gross output, accounting for thermal and optical losses. A solar multiple greater one indicates that the solar field size, under reference solar conditions, is capable of generating more thermal energy than the energy required to drive the power block at its rated capacity. The surplus thermal energy must be stored (or dumped for systems without storage).

For the solar resource data CSP plant use only the direct sunlight, called Direct Normal Irradiance (DNI), Hence, it must be sited in regions with high direct solar radiation. An appropriate selection of the site for installing CSP plants is of prime importance for harvesting maximal output from the plants. The feasibility of the CSP plants depends on the available levels of DNI at the selected site. Four representative sites (Ouargla, Bechar, Adrar and Tamanghasset) are selected in this research work for the performance investigation of CSP plants, all of these four sites offer high DNI, it was selected based on previous studies [2] as shown in figure 2.8.

In this study, a Typical Meteorological Year (TMY) data set of sites considered has been used. The TMY data file contains hourly values for DNI, ambient temperature, wind speed, sun angle, atmospheric pressure and solar azimuth angle for one complete year [40].

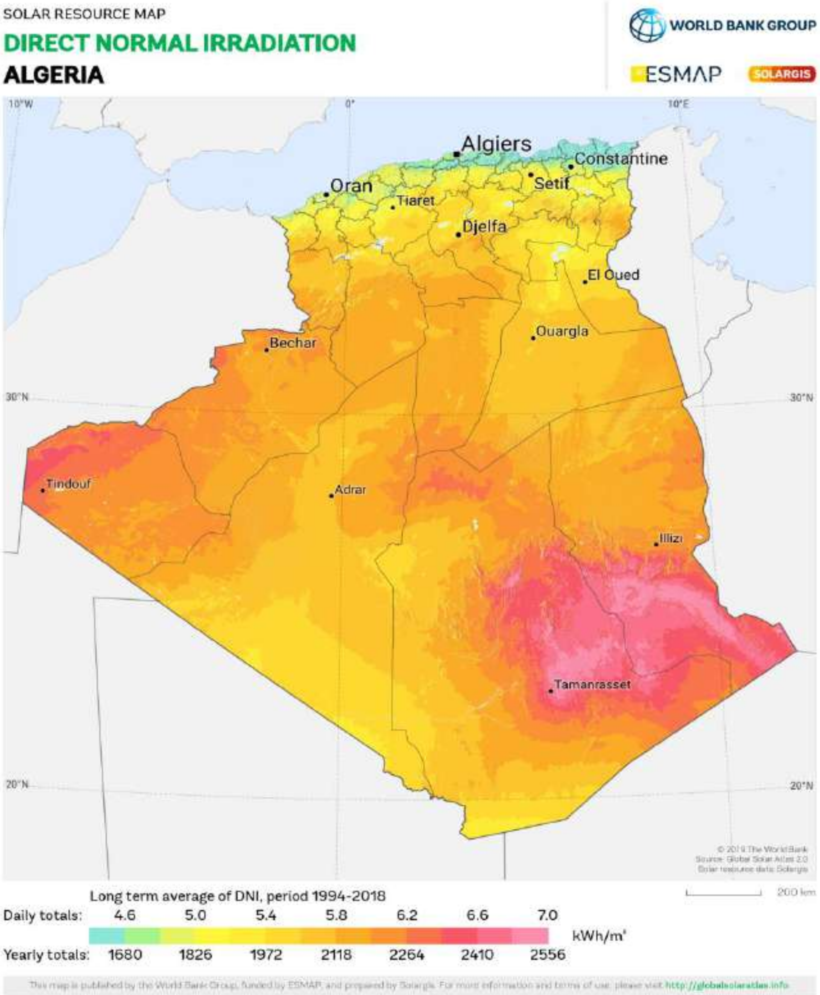


Figure 2.8: DNI map of Algeria from PVGIS and the selected sites location for PTC-CSP plants [47].

SAM combines time series weather data and system specs to calculate the electricity production, SAM comes with built-inradiation data (weather data) for many locations including

America, Spain, China and India. Unfortunately, it doesn't include weather data for Algeria. So in this work, the hourly radiation data of a year of the hypothetical plant location has been obtained from Photovoltaic Geographical Information System (PVGIS) then it is integrated to SAM. The simulation of the plant is carried out for one year (8 760 hours). The plant starts to generate electricity around (1h - 24h). Plant specifications, configurations and the input parameters used in SAM simulation of the plant are selected based on previous studies [41, 48], in which SAM was used for CSP modelling. The design is used to evaluate different numerical states such as annual energy production, capacity for each month in the four sites.

The framework diagram figure 2.9 and table 2.1 (present geo-spatial Longitude and latitude and meteorological parameters of the selected sites).

Table 2.2: Spatial (Longitude and latitude) and meteorological parameters of the selected sites [49].

Parameters	Units	Ouargla	Bechar	Adrar	Tamenghest
Latitude	(DD)	31,949	1,617	27,874	22,785
Longitude	(DD)	5,325	-2,217	-0,294	5,523
Direct Normal Irradiance	($KWh/m^2.day$)	6,65	6,94	6,89	7,29
Diffuse Horizontal	($KWh/m^2.day$)	1,77	1,73	1,82	1,83
Global Horizontal	($KWh/m^2.day$)	5,99	6,04	6,23	6,65
Elévation	(m)	135	781	256	1371

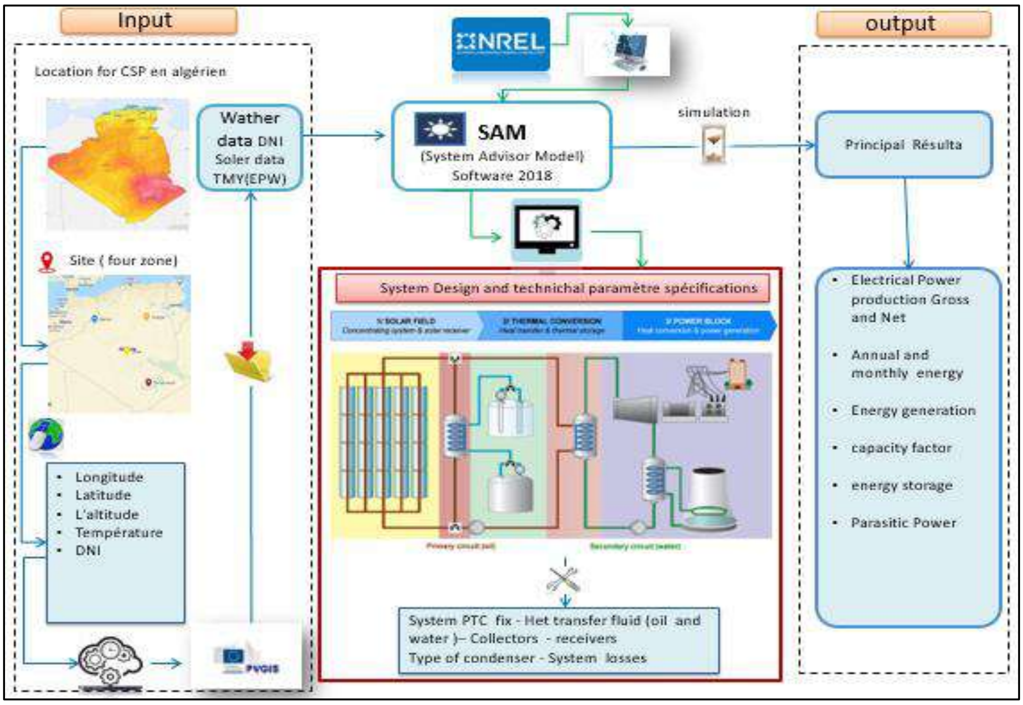


Figure 2.9: Conceptual study plan of system design and technical parameter specification, see Annexe (A.2).

The simulation of the energy output of the PTC plant at four sites suggested is performed using the SAM software and the calculation conducts in the following manner:

a) Calculation of the total power collected and delivered by the collector (Collector Power in, Collector Power Out), each of following parameters must be used: (Hourly DNI) of the four sites, Ambient temperature, atmospheric pressure and wind speed, Sun angle and solar azimuth degree, Concentrator size (area, focal length) and its intercepted factor, number of dishes, dishes separation North-South and east-west, collector array shading).

b) Calculation of the power delivered by the receiver (Receiver power out) using the following parameters: (Receiver dimensions such as the aperture diameter, absorber surface area, cavity wall surface area, absorptance and insulation thickness and conductivity, temperature of heater head).

c) Calculation of the net electric power output (Net Output) after subtraction of parasitic electric power via the use of pump and fun parameters [40]. Each stage of the plant performances calculation requires some parameters. The details of these calculations as various mathematical equations can be found in Ref [13, 41, 50].

2.3 SAM simulation framework for CSP Parabolic Trough:

This section presents the details of the method employed in developing the SAM model for the 100 MW Concentrated Solar Power (CSP) plant. The approach generally follows the guidelines as suggested. Because there are various fields that need to be specified, the following approach is recommend [51]:

This manual defines and documents the conventions, methodology, and information flow associated with the System Advisor Model physical trough model in the SAM [34]. A detailed overview of each subsystem is provided, with the engineering. To model a parabolic trough system, choose the physical trough model. The physical trough model is suitable for most systems model that use the same set of inputs for location and resource and system costs [34].

2.3.1 Background and Modeling Approach:

The physical trough model characterizes a parabolic trough CSP plant by deriving performance equations from first principles of heat transfer and thermodynamics where possible. In practice, this means that empirical "curve-fit" relationships are eliminated to the degree that is practical for the type of modeling analysis done in SAM [34]. The primary benefit of this approach is the added flexibility in changing system parameters and component properties at a fundamental level (absorber emissivity, glass thickness, ... etc.) and simulating their impact on overall system performance.

The physical modelling approach achieves many other goals in addition to deriving system performance from first principles: the model includes transient effects related to the HTF thermal capacity in the field piping, headers, and the balance of the plant, it allows for more flexible field component specification, including several receiver and collector types within [14, 34, 35, 51]. Location and Resource:

The Location and Resource page provides access to the solar resource library, which is a collection of weather files stored on the computer. SAM solar resource library displays information from weather files in the solar resource data folders. The default solar resource library that comes with SAM contains weather files for a few locations around the United States for the default configurations [34, 38]. You should add files to build your own library of PVGIS. Once files are in your library, you can use them for different projects.

2.3.2 Solar Field:

The Solar Field displays variables and options that describe the size and properties of the solar field, and properties of the heat transfer fluid. It also displays reference design specifications of the solar field [34].

The solar field is the heat-collecting portion of the plant. It consists of one or more loops of solar collector assemblies (SCA), with each loop laid out in parallel. A common header pipe provides each loop with an equal flow rate of heat transfer fluid (HTF), and a second header collects the hot HTF to return it either directly to the power cycle for power generation or to the thermal energy storage system for use at a later time [34]. To minimize pumping pressure losses, the field is typically divided into multiple sections, each section with its own header set, and the power cycle is situated near the middle of the field. The figure 2.12 shows one possible plant layout where two header sections are used for 20 total loops. Each loop in this illustration contains 8 individual SCA, and each portion of the header is connected to two loops - one on the top and one on the bottom of the figure 2.10.

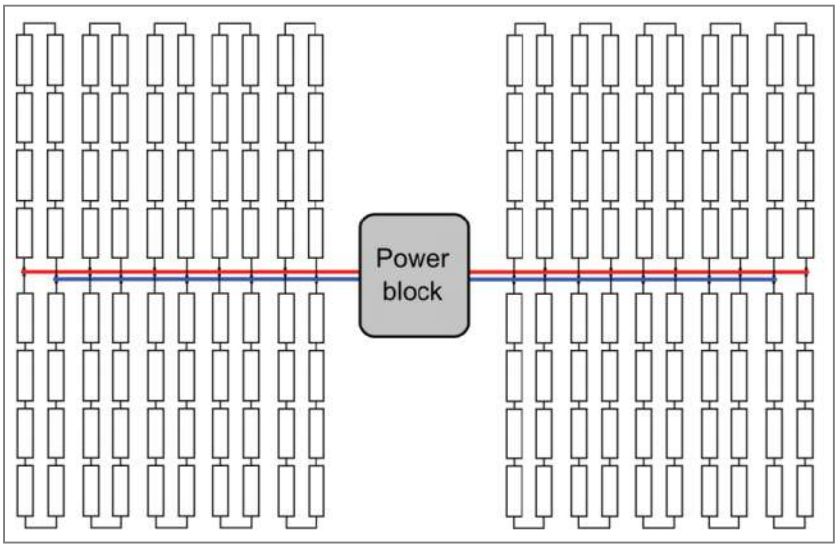


Figure 2.10: One possible field arrangement, where the field is broken up into two header sections.

Number of field subsections: SAM assumes that the solar field is divided into between " 2, 4, 6, 8 and 12 " subsections. See show figure 2.11.

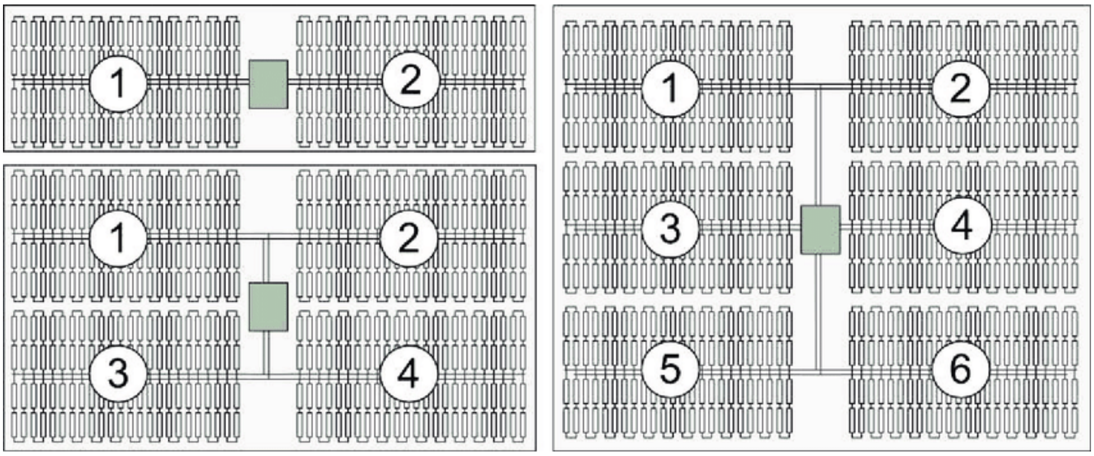


Figure 2.11: He number of field subsections determine the location and shape of header piping that delivers heat transfer fluid to the power block.

Actual number of loops in the field, equal to the solar multiple times the required number of loops at a solar multiple of 1.0 [34]. The required number of loops is rounded to the nearest integer to represent a realistic field layout. The solar field controls concentrated solar power plants, which convert the direct natural radiation of the sun (DNI) into thermal energy, which is then converted into electricity. DNI can change dramatically in a short period of time, and the solar field at a trough plant must be designed to accommodate these changes. The Solar Field Control (SAM) algorithm uses user defined inputs to make operational decisions based on the level of DNI resources, ambient temperature, presence of thermal storage .... etc [38].

And we can notice some of the values of the solar field entered into the system, which are shown as follows: Total solar field area 963 174 m^2, Solar Multiple 2, Solar field volume containing 256 loops, number of complexes (8), figure 2.12 inlet and outlet temperatures of heat transfer fluid HTF (293 °C - 525 °C)......etc. The solar field takes up most of the area 98 %, the remaining accommodates the power block and the thermal storage facility [2, 3, 41].

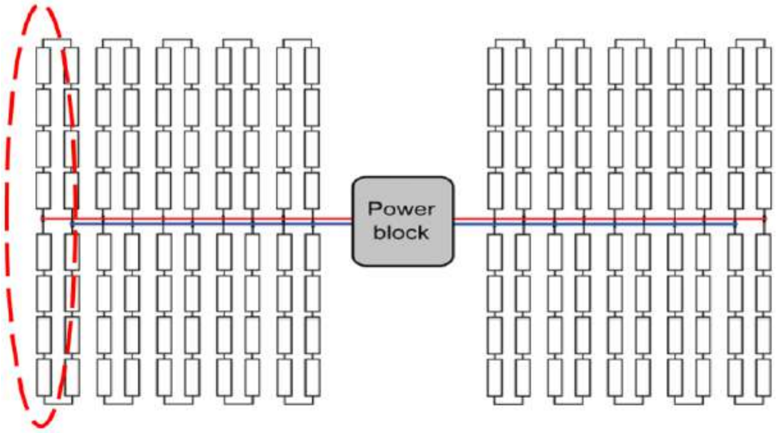


Figure 2.12: Solar Field alignment.

2.3.3 Collector Assembly and Field Optics:

The collector model and optical calculations used in the physical trough model are based on the collector model in SAM empirical trough model. System Advisor defines the collector as the portion of the solar field that reflects irradiation to the receiver [21, 34, 51]. This equipment is distinct from the receiver component that consists of an evacuated glass envelope and tube receiver, as shown in figure 2.13.

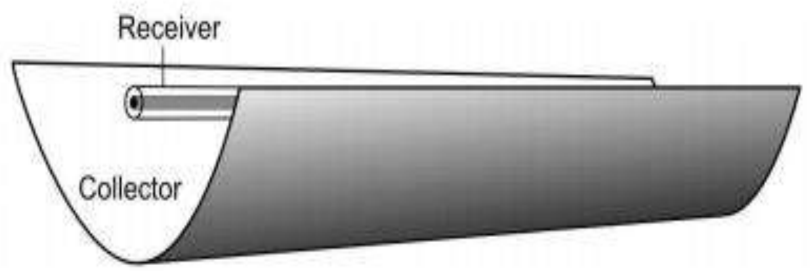


Figure 2.13: The trough includes both a collector to reflect light and a receiver to absorb and transport heat.

The optical calculations for the collector model extend to the point of determining the magnitude of solar flux that is incident on the receiver. To determine the flux incident on the receiver, we must consider both constant optical losses and variable optical losses that change with solar position show figure 2.14. The aperture area value does not include area lost due to gaps between mirror modules or non-reflective structural components. After accounting for spaces, holes, and structural area, the total reflective aperture area may be less than (100*5 = 500 m^2) [34] after the collector structure occupies 100 m lengthwise and 5 m across the aperture.

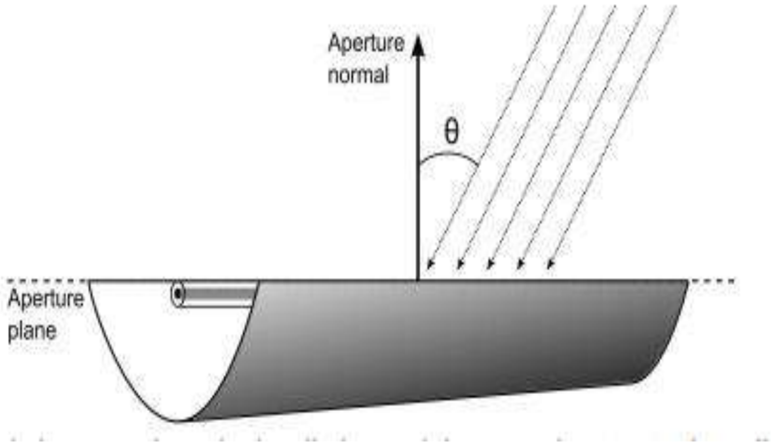


Figure 2.14: The angle between the solar irradiation and the normal vector to the collector aperture plane.

When the solar irradiation does not fall parallel to the plane of the collector aperture, losses occur that increase in proportion to the acuteness of the incidence angle [21]. The difference in angles between the natural to the aperture plane and the solar irradiation is proportional to the incidence angle. The figure 2.15 illustrates this.

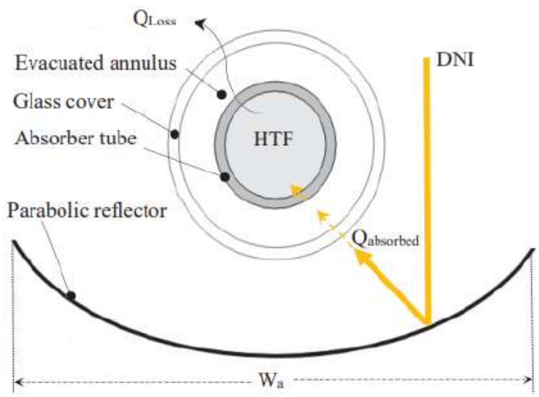


Figure 2.15: Schematic representation of HCE.

2.3.4 Thermal storage:

Thermal energy storage systems are key components of concentrating solar power plants in order to offer energy [20]. Utility-scale electric plants (such as centralised PV and wind turbine farms) that experience intermittent outages during weather transients can pose operational challenges for grids with high renewable energy penetration. CSP is the only green technology that can store energy in a thermal energy storage (TES) device at a reasonable cost. Storage allows for power generation during temporary weather fluctuations, changing operating hours to meet peak demand, raising the plant's capacity factor, or providing low-level heat to plant processes that need it (like maintaining the power cycle in a standby mode) [34, 52], see figure 2.16.

SAM thermal storage for a two-tank system; that is, two tanks each are capable of holding the entire HTF volume for thermal storage. One tank is dedicated to storing the hot fluid while the other holds the exhausted cold fluid [34, 53].

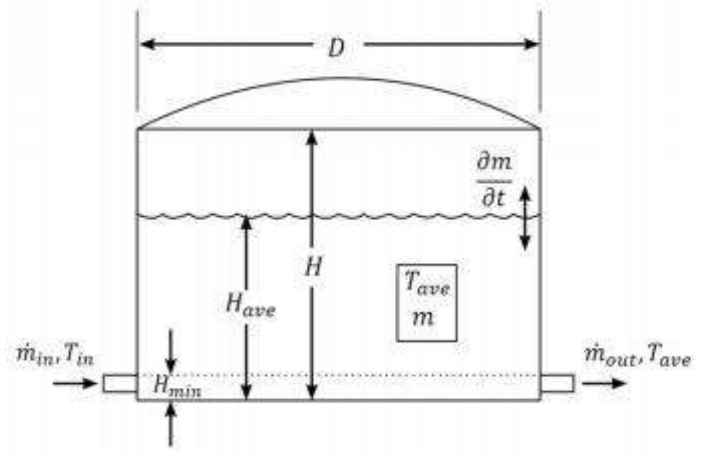


Figure 2.16: A schematic of the variable-volume tank model. Fluid level varies with differences in the inlet and outlet mass flow rate.

The values used to set the thermal storage are shown as follows: Full Load Hours of TES (6 hours) or the physical capacity, which is the number of hours of storage multiplied by the power cycle design thermal input and it is used to calculate the system's maximum storage capacity. Storage volume 10 482.8 m^3 the total heat transfer fluid volume is divided among the total number of tanks so that all hot tanks contain the same volume of fluid, and all cold tanks contain the same volume of fluid. TES Thermal capacity 1 870.79 MWht, Tank height 12 m, the volume of fluid 873.569 m^3 in a tank that corresponds to the tank's minimum fluid height specified. Storage HTF "min and max" operating temperatures (238 °C - 593 °C) and "Hitec Solar Salt" is the storage fluid used in the thermal energy storage system [13, 50, 52].

2.4 Conversion chain:

The biggest challenge in prediction of the CSP performance coming from a projected solar thermal plant is the unsteady nature of the solar resource. Models involve weather and insolation data which bring in uncertainties in the final power output. It is not sufficient to calculate the annual energy yield simply by expected load hours, as it is usually done for conventional fossil fuel power stations and the energy flow in a parabolic trough power plant has the following structure: Direct solar radiation is concentrated and converted into thermal energy. The thermal energy is converted into pressure energy of vapor, which is converted into kinetic energy [41].

The kinetic energy is finally transformed into electrical energy, the final product of the power plant. These energy conversion steps are realized in the respective power plant components: The parabolic trough collector and the tracking system are essential for the concentration process. The receiver converts the radiation energy into thermal energy. Heat transfer medium and thermal storage are carriers of the thermal energy. The steam generator has the function to convert the thermal energy into pressure energy of a gaseous medium. This is done by the evaporation of water. The cooling system has the aim to complete the liquid/gaseous-cycle converting the steam back to water. The steam turbine converts the pressure energy in the steam into rotational energy. The electric generator, finally, converts the rotational energy into electric energy, which can be supplied to the electric grid, figure 2.17 [54 -55].

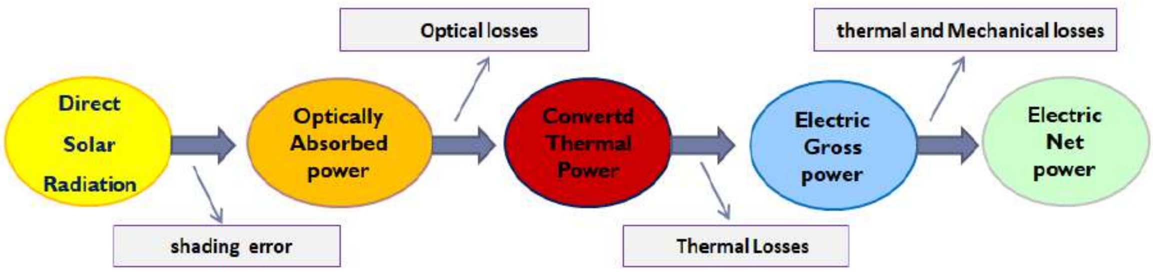


Figure 2.17: Successive transformation of natural power to electric power in the CSP system.

2.5 Modeling and Simulation of Parabolic Trough Power Plant:

Absorbed Power: The equation for the absorbed solar radiation is given by [44, 56], see show figure 2.18.

$$\mathbf{p_{abs}} = \boldsymbol{DNI} \times \mathbf{cos(\theta)} \times \boldsymbol{IAM} \times \boldsymbol{E_l} \times \mathbf{SF_{Avail}} \times \mathbf{R_s} \times \boldsymbol{\eta}_{\mathbf{opt}} \qquad (2.1)$$

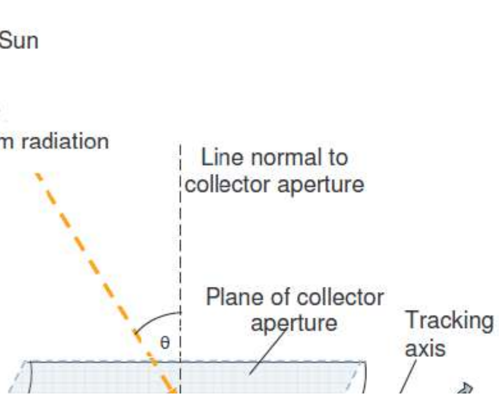


Figure 2.18: Angle of incidence on a parabolic trough collector.

One of them is the declination angle. This angle is the angular position of the sun at solar noon, with respect to the plane of the equator. As the Earth rotates around the Sun through the course of a year, the declination angle will change, within a range of ($-23.45^{\circ} \leq \theta \leq 23.45^{\circ}$). The figure 2.19. Declination angle due to Earth's tilt.

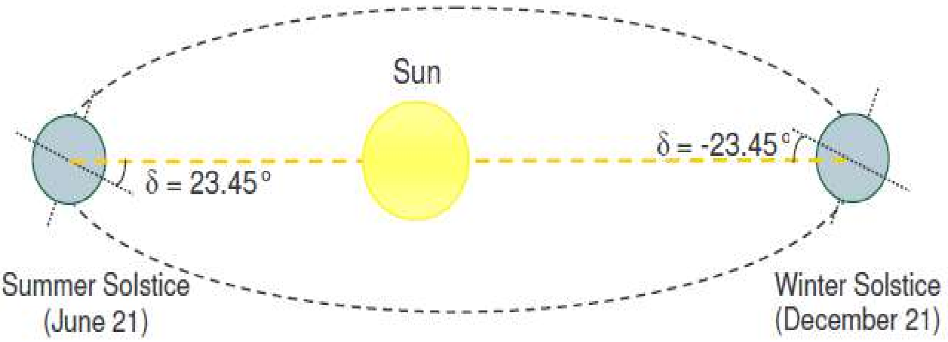


Figure 2.19: Declination angle due to Earth's tilt

$$\delta = 23.45 \sin *\left(360 * \frac{284+N}{365}\right) \qquad (2.2)$$

Where:

N: The day number of the year, from 1 (corresponding to January 1) to 365 (corresponding to December 31).

The position of the sun depends on the hour angle, or the angular displacement of the sun east or west of the local meridian. The hour angle is negative when the sun is east of the local meridian (in the morning), positive when the sun is west of the local meridian (afternoon), and zero when the sun is in line with the local meridian (noon). The hour angle comes as a result of the rotation on the earth, which spins on its axis at a rate of 15° per hour:

$$\omega = (SolarTime - 12) * 15 \quad (2.3)$$

Where:

w is the hour angle [deg] and SolarTime is the solar time h.

In solar time, the sun:

aligns with the local meridian (w = 0) at exactly 12:00 h, or "solar noon." However, standard time is based not on the local meridian, but on a standard meridian for the local time zone.

$$SolarTime = Standard\ Time - DST + \frac{(Lst - Lloc)}{15} + E * \frac{1h}{60\ min} \quad (2.4)$$

Where:

DST = Daylight Savings Time adjustment (1 h during Daylight Savings Time, 0 h during standard time).

Lst =standard meridian for the local time zone [deg].

Lloc =the local meridian of the collector site [deg].

E = equation of time [min]. E, the equation of time, accounts for the small irregularities in day length that occur due to the Earth's elliptical path around the sun.

$$E = 229.18\ (0.000075 + 0.001868\cos(B) - 0.032077\sin(B) - 0.014615\cos(2B) - 0.04089\sin(2B)). \quad (2.5)$$

$$B = \frac{360}{365}(n-1) \quad (2.6)$$

Where:
n = day number of the year (1 for January 1, 365 for December 31).

$$\cos\theta_z = \cos(\delta)\cos(\varnothing)\cos(\omega)\sin(\delta)\sin(\varnothing) \quad (2.7)$$

Where:

δ = declination angle.

ω = hour angle.

Ø = latitude location of the plant.

$$\mathbf{Cos\ \theta = \sqrt{Cos^2(\theta z) + Cos^2(\delta)\ sin^2(w)}} \quad (2.8)$$

$$\mathbf{IAM = \frac{K}{cos(\theta)}} \quad (2.9)$$

Where:

Incidence Angle Modifier (IAM) the optical parameters are factors that are reduced when the angle of incidence increases.

$$\boldsymbol{K}\mathbf{=cos(\theta)+0.000884(\theta)-0.00005369(\theta)} \quad (2.10)$$

$$\boldsymbol{\eta_{opt} = \rho * \gamma * \tau * \alpha} \quad (2.11)$$

Where:

(ρ) is the mirror reflectivity, (γ) is the interception factor, $(\tau)$is the transmissivity of the glass envelope and (α) is the absorbtivity of the absorber tube.

$$\mathbf{R_s = \frac{Wef}{W}} \quad (2.12)$$

$$\boldsymbol{E_l = 1 - f * \frac{tan\theta}{Lcol}} \quad (2.13)$$

Where:

f and $Lcol$ are in meters.

This factor is the fraction of the solar field that is operable and tracking the Sun.

The thermal power delivered by the oil (in W) is given by:

$$\mathbf{P_{oil} = m_{oil} * C_p (T_{inlet} - T_{outlet})} \quad (2.14)$$

Where:

m_{oil} is the oil mass flow rate sent to power block (kg/s), and T_{inlet} and T_{outlet}. are the inlet and outlet temperatures of the power block.

For the Therminol VP-1, the specific heat is given by:

$$\mathbf{C_p = 1509 + 2.496 * T_{oil} + 7.87 * 10^{-4}\, T^2_{oil}} \quad (2.15)$$

The oil mass flow (in kg/s) available from the solar field is:

$$m_{oil} = \frac{Pcollected * Aaperture}{Cp\,(T\ field\ oulet - T\ field\ inlet)} \quad (2.16)$$

where:

Aaperture represent the total area of mirror surface of the solar field (m^2) and (J/kg. ºC) the specific heat of the oil.

The collected power, per unit of aperture area, is the difference between the absorbed power and thermal losses and is given by:

$$P_{collected} = P_{abs} - P_{loss\ col} - P_{loss\ pip} \quad (2.17)$$

An expression to quantify these losses (in W/m) is:

$$P_{loss\ col} = L_{c1} + L_{c2} \quad (2.18)$$

$$L_{c1} = a_2\,\Delta T_1^2 + a_1\,\Delta T_1 - a_0$$

$$L_{c2} = (b_2\,\Delta T_1^2 + b_2\,\Delta T_1 - b_0)*\left(\frac{DNI}{900}\right)*\cos\theta$$

Where:

Ai and bi are characteristic coefficients of each type of absorber tubes and ΔT1 represents the difference between the oil temperature (T_{oil}) and the ambient temperature (T_{amb}).

Thermal losses from the piping leading to and from the loops in the solar field are accounted (in W/m^2) by following equation:

$$P_{loss\ pip} = Lp_1\,\Delta T_1 - Lp_2\,\Delta T_1^2 + Lp_3\,\Delta T_1^3 \quad (219)$$

$Lp_1 = 0.01693$

$Lp_2 = 0.0001683$

$Lp_3 = 6.78*10^{-7}$

This factor is the fraction of the solar field that is operable and tracking the Sun. In this context the mechanical power available from the turbine is:

$$P_{mec} = P_{therm} \times \eta_{therm} \quad (2.20)$$

The total thermal power delivered to the cycle is given by:

$$P_{therm} = P_{oil} \times \eta_{stem.gen} \quad (2.21)$$

. Where:

$\eta_{steam.gen}$ *is* the efficiency of the steam generator and the reheater.

Finally, the electric power that can be delivered to the net is given by:

$$P_{net} = P_{mec} - P_{loss.el} - P_{aux} \tag{2.22}$$

Where:

$P_{loss.el}$ are the electrical losses on the generator and on the transformer and P_{aux} are the losses associated with the auxiliary services of the power plant.

2.6 Conclusion:

In this chapter, a 100 MW parabolic trough-based solar thermal power plant is designed and simulated using SAM software. The simulation has been applied in four locations. The following were covered: Systems design and operation parameters and How to choose of the site for CSP simulation as well Methodology and Description of the System Advisor Model and SAM simulation framework for CSP.

Based on the criteria of CSP power plant a location within Algeria is selected and simulation of plant using Parabolic Trough Collectors is performed. The results obtained provide the necessary data for designing a CSP power plant in Algeria. And the study of design and simulate parabolic trough-based CSP plant with the assistance of NREL weather database and SAM (System Advisor Model) software. To analyse the thermodynamic aspect and annual performance of the hypothetical parabolic trough CSP technology.

The last chapter Analyses the necessary data to compare the many aspects of concentrated solar energy technology and present the most important results.

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Chapter 3: Results & Performance Assessment.

3.1 Introduction:

As the national renewable energy potential is strongly dominated by solar energy, Algeria considers this energy as an opportunity and a lever for economic and social development, in particular through the establishment of industries that create wealth and jobs. This strategic choice is motivated by the immense potential in solar energy. This energy constitutes the major axis of the program which devotes an essential part to solar thermal (CSP). Solar is expected to reach by 2030 more than 37 % of national electricity production Despite a fairly low potential [57].

After identifying the selected regions of CSP power plants and elaborating the SAM for a name plant capacity of 100 MW with a thermal storage of 6 hours. This chapter, present a general potential assessment and offers a feasibility analyses of deployment and promotion of CSP in Algeria. Furthermore, the performance comparison between CSP plants will be carried out for four sites (Bechar, Ouargla, Adrar and Tamanghasset) across Algeria. The study also discusses the possibility of application of CSP plants on the proposed region based on the analysis on different parameters such as the: (Electrical power generation (or electrical source - Power cycle) gross, net and losses at the first level, the capacity utilization factor, Annual water usage in the second level.

In the last part this study gives a detailed result concerning thermal energy from the field to the power block for each month in the year and hourly thermal energy behaviour in the storage system focused on four typical days of the years especially at Ouargla region.

3.2 Results and discussions:

3.2.1 Analysing and evaluating weather resources:

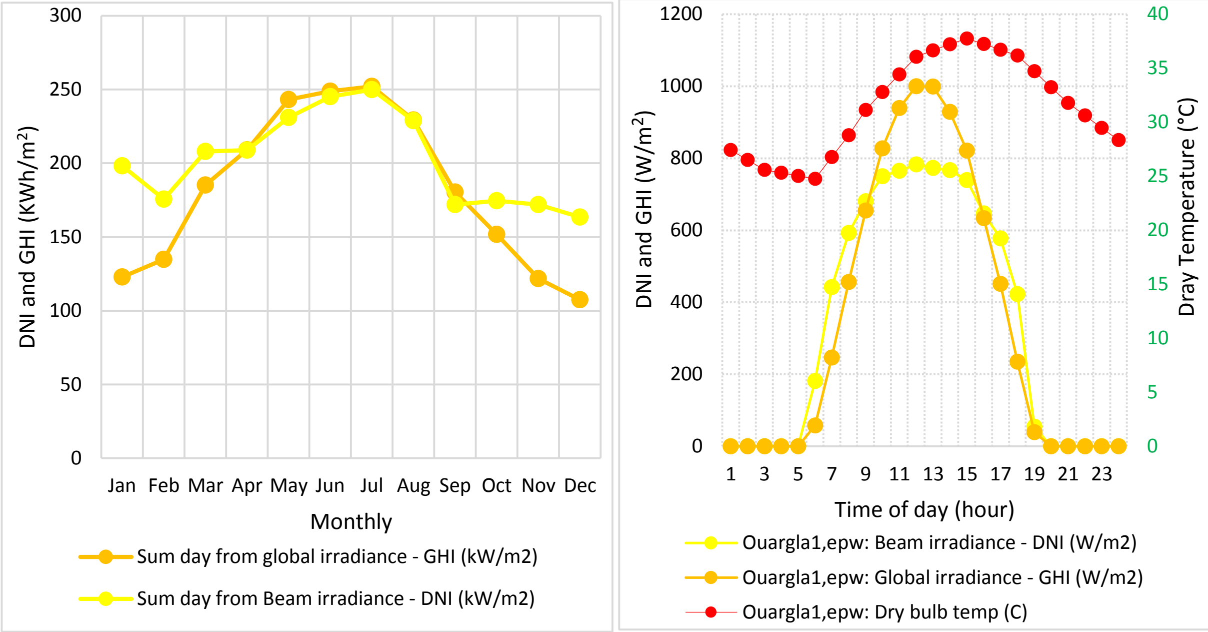
CSP technologies absorb and concentrate DNI incident on the earth's surface to heat a working fluid and then generate energy through a thermodynamic cycle. Solar radiation variability is the single greatest uncertainty in predicting the efficiency of a solar power plant for all solar energy systems. The solar resource assessment plays an essential role in: the site selection of a solar project, the prediction of its annual power generation and the prediction of its temporal performance. Hence, understanding the spatial and temporal variability of solar resources is essential for the proper assessment of solar energy.

Selecting the best sites for CSP installation in a country involves numerous factors, yet the availability of good solar resources (DNI) is of the utmost importance. Accurate hourly DNI estimations are required for simulated CSP plants in the specified locations four generate accurate and representative DNI hourly time series for the four specified sites, the comprehensive solar resource simulated study conducted by gouareh et al 2021, has been used as the starting point. The study used a combination of satellite-based solar irradiance simulated and the (PVGIS).

The final results of the study, represented in the form of specific sites according to important criteria and values, among which provide a high value for the DNI, have been used to validate the DNI hourly time series of the Typical Metrological Year (TMY) used in our analysis.

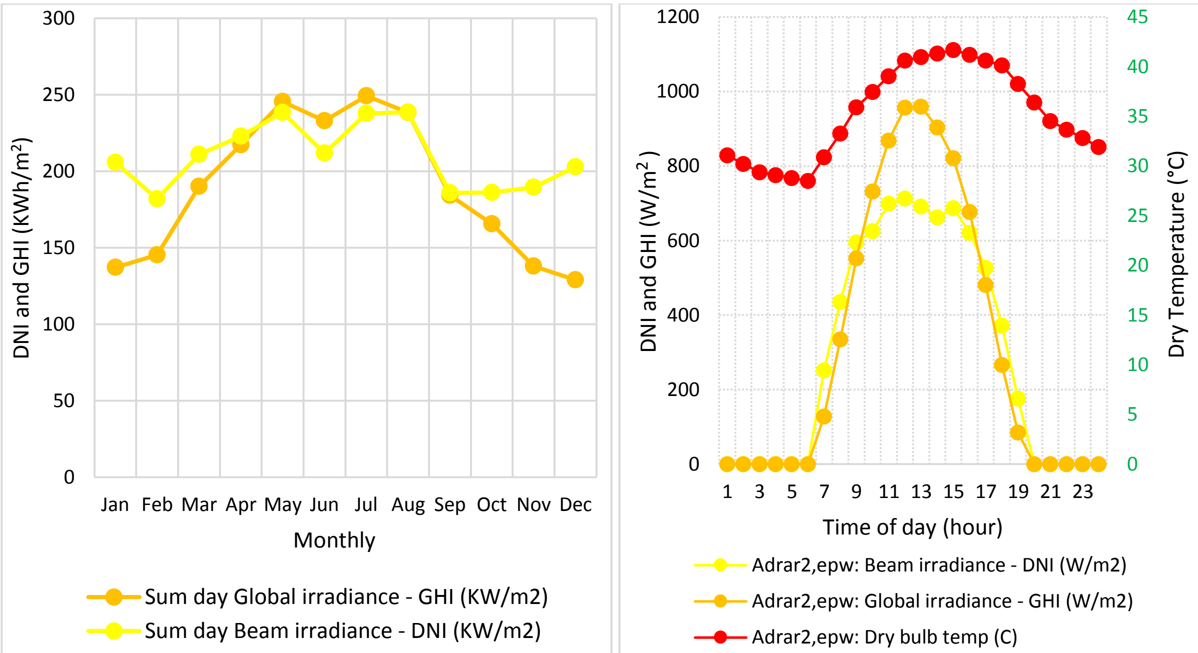
Proper selection of installation site for CSP and Solar PV plants is of utmost importance in harvesting maximum yield from plants. The active viability of PV and solar power plants depends on the available levels of DNI or GHI and the temperature at the specific location. The four representative sites (Bechar, Ouargla, Adrar and Tamanghasset) were selected in this research work to examine the performance of the CSP plants. All of these four sites offer high levels of DNI and GHI. Hourly DNI and GHI climate data are shown for one whole year in 8760 hours. (figure 3.1 (a), figure 3.2 (a), figure 3.3 (a) and figure 3.4 (a)) for each region shows the monthly changes in DNI and GHI at the four representative sites.

Adrar is located in the central region of Algeria. Tamanghasset is in the southern part of Algeria, Bechar is in the southwestern part while Ouargla is in the southeast part of Algeria. (figure 3.1 (b), figure 3.2 (b), figure 3.3 (b) and figure 3.4 (b)) shows for each region a DNI and GHI profile, a typical summer day temperature from June and a July day for the four locations.



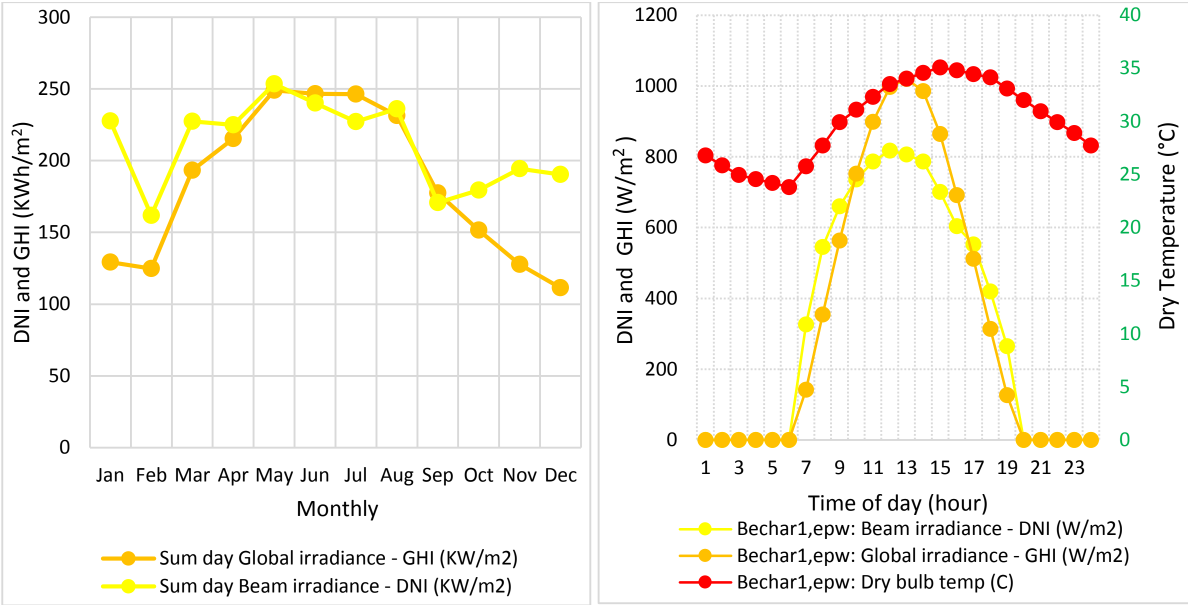
(a) (b)

Figure 3.1: (a) Monthly sum values of global and direct irradiation for Adrar. (b) The global horizontal irradiation, direct normal irradiation, and temperature profile for a typical day of June in Ouargla.



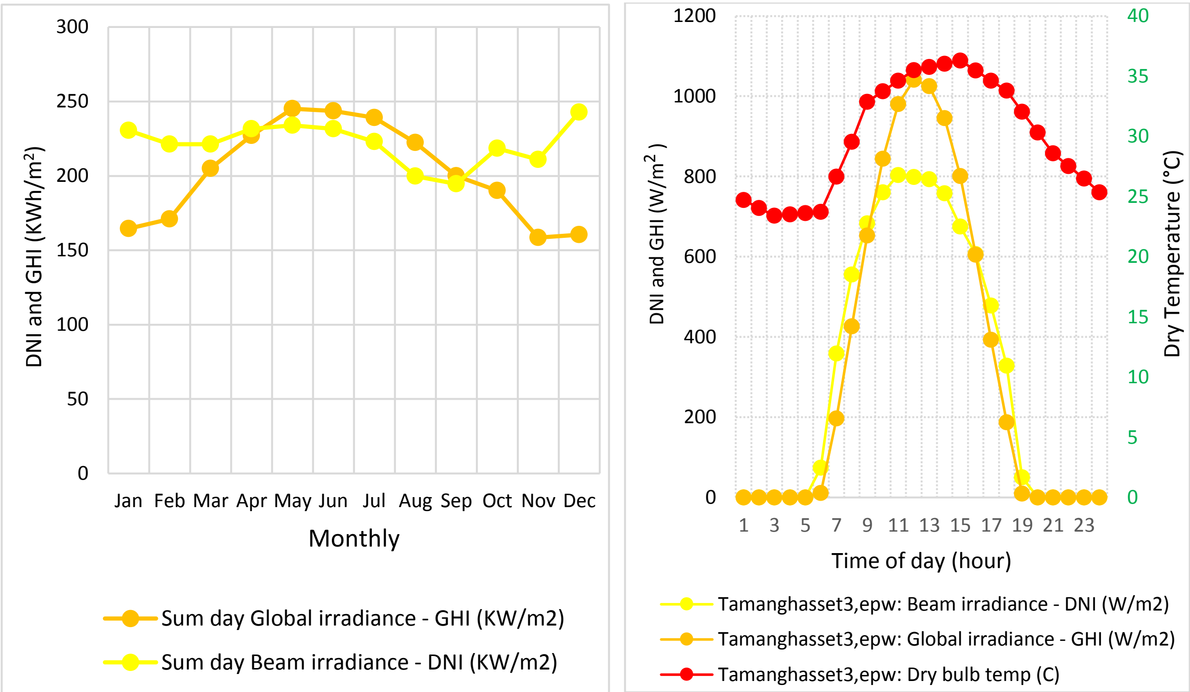
(a) (b)

Figure 3.2: (a) Monthly sum values of global and direct irradiation for Adrar. (b) The global horizontal irradiation, direct normal irradiation, and temperature profile for a typical day of June in Adrar.



(a) (b)

Figure 3.3:(a) Monthly sum values of global and direct irradiation for Adrar. (b) The global horizontal irradiation, direct normal irradiation, and temperature profile for a typical day of June in Bechar.



(a) (b)

Figure 3.4:(a) Monthly sum values of global and direct irradiation for Adrar. (b) The global horizontal irradiation, direct normal irradiation, and temperature profile for a typical day of June in Tamanghasset.

Algeria has an important potential of direct and global solar radiation of about 2 500 KWh/m^2.year and 2 200 KWh/m^2.year, respectively. In the summer months (May, June, July and August) DNI and GHI reached its maximum values for the four selected regions. We also note that the value of DNI present a low value from October to February in (Bechar, Ouargla and Adrar), unlike the Tamanghasset region where the DNI reached approximately more than 200 Wh/m^2 across the year. For the GHI is a low value compared to DNI are indicated in the period from October to February in the four regions.

DNI and GHI values were recorded during a typical day in June in the regions proposed in this study, where we observed that the DNI values reach the maximum during the afternoon and it was null in the morning and evening periods. Where the maximum value recorded in each region for DNI and GHI respectively are as follows: (Ouargla 782.3 W/m^2, Bechar 817 W/m^2, Adrar 713.06 W/m^2, Tamanghasset 803.13 W/m^2), and (Ouargla 1 000.13 W/m^2, Bechar 985 W/m^2, Adrar 959.47 W/m^2, Tamanghasset 1 041.4 W/m^2). The availability of solar irradiation (DNI and GHI) is in the period from (05:00 h (sunrise) to 19:00 h (sunset)) with a difference of 1 to 2 hours from region to another.

The maximum temperature recorded in these regions for the typical day of June (figure 3.1 (b), figure 3.2 (b), figure 3.3 (b) and figure 3.4 (b)) reached 41.68 °C which correspondent to Adrar. The others region recorded temperature values less than 40 °C, as 37.77 °C in Ouargla, 35.07 °C in Bechar and 36.29 °C Tamanghasset. This maximum temperature correspondent to the day time of 15:00 h.

3.2.2 Electrical power generation:

The performance of PTC-CSP power plants with a capacity of 100 MW is analysed in this study, which was conducted in the four regions (Bechar, Ouargla, Tamanghasset and Adrar). figures (3.5 and 3.6) shows the gross, net and losses (Parasitic) electrical output by GWh for each region.

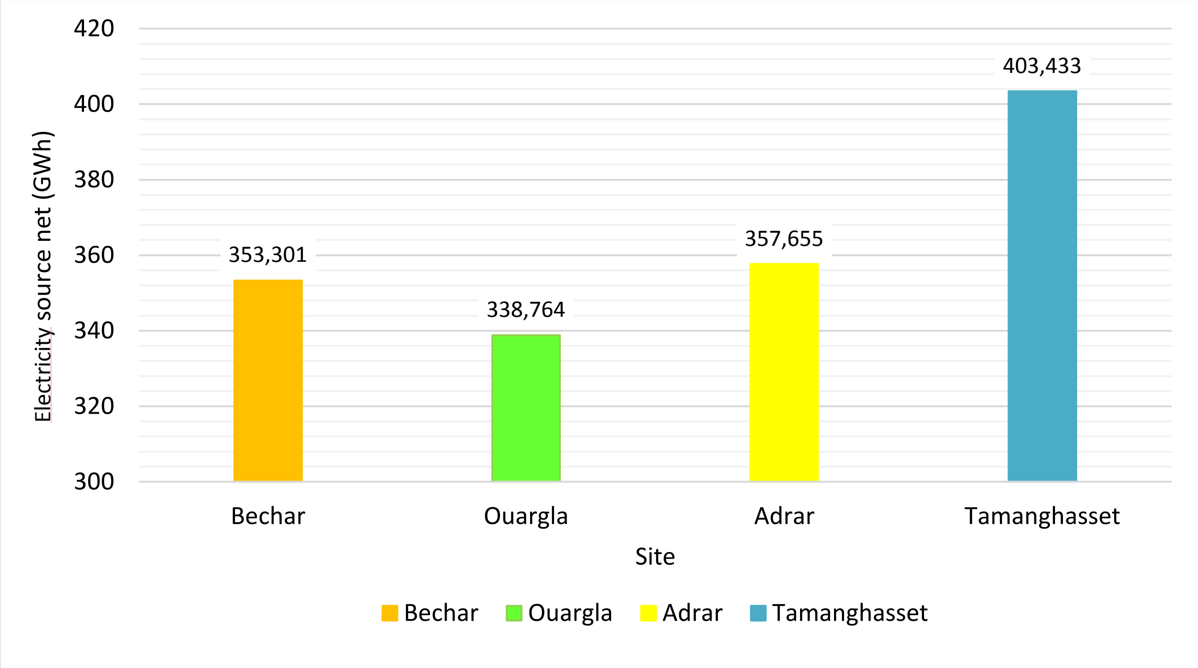


Figure 3.5: Annual electricity source net (GWh) for the selected site.

Based on the figure 3.5, the results show that the annual electrical output of the CSP plants reached approximately 403.433 GWh at Tamanghasset region. It is important to indicate that this station have the maximum electrical output compared to the other regions, where its value was 357.655 GWh in the Adrar pole as well as its value reached 353.302 GWh in Bechar, and less than in Ouargla with 338.764 GWh.

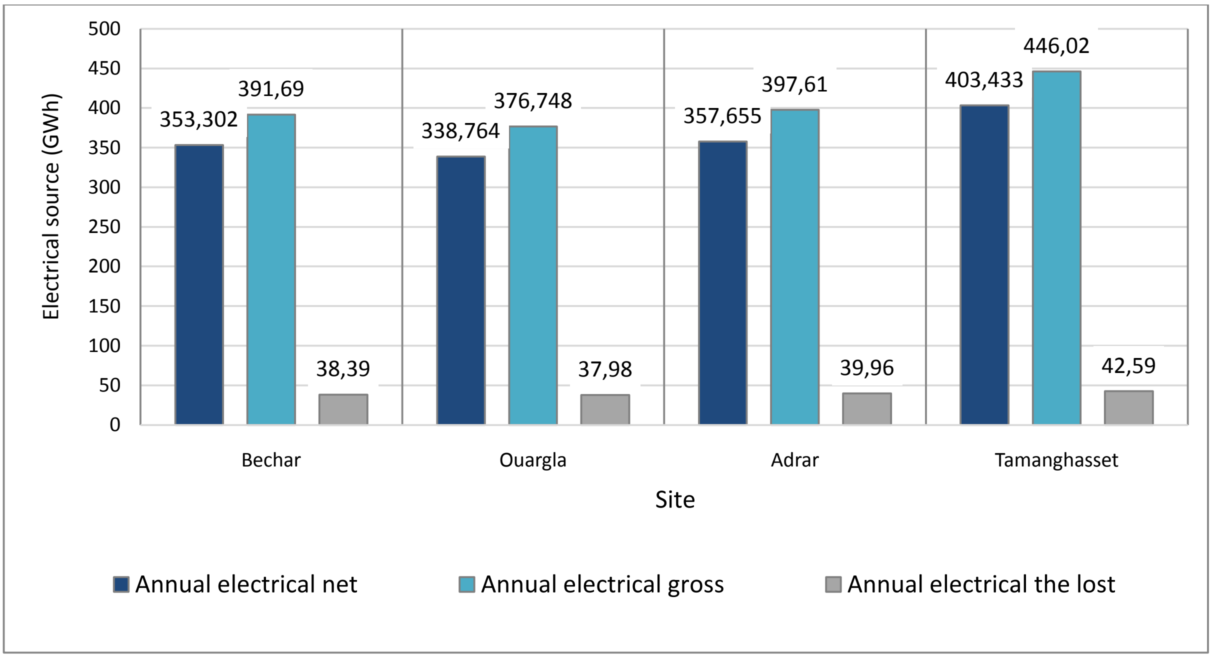


Figure 3.6: Electrical source - Power cycle (gross, net and the lost (Parasitic)) output (GWh).

According to the results presented in the figure 3.6, it is clearly appeared that the values of gross or total electrical output is more important compared to the net electrical output, and that is due the consideration of energy losses in the first (gross) to supply auxiliary equipment's of the PTC CSP. In the other hand it is remarkable that in Tamanghasset region the losses reached a maximum value of 42.59 GWh comparing to the other regions, where this value is relatively related to the total electrical energy production in this region (Tamanghasset 446.02 GWh).

The energy losses and power cycle gross output for the three other regions from the max to the min are respectively (Adrar 39.96 GWh, 397.61 GWh), (Bechar 38.39 GWh, 391.69 GWh) and (Ouargla 37.98 GWh, 376.748 GWh). With a difference of 69.3 GWh between the highest Tamanghasset and the lowest Ouargla. The energy losses represent approximately (10.08 %, 10.05 %, 9.80 % and 9.54 % from the total in Ouargla, Adrar, Bechar and Tamanghasset. Through the results, we notice that the energy lost by the station PTC-CSP system is almost constant around 10 % but its absolute value increases with the increase in the production of electrical energy from region to another, as shown in figures (3.5 and 3.6).

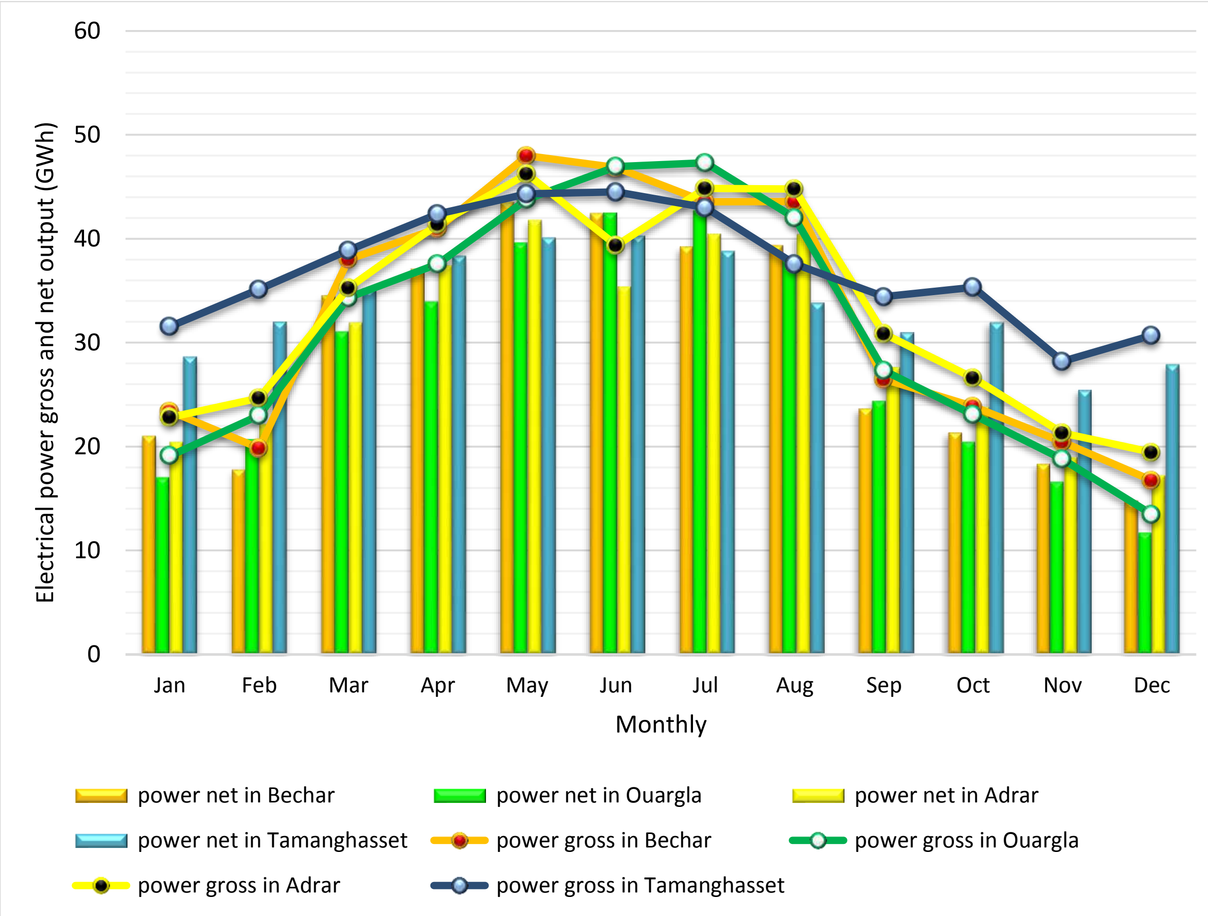


Figure 3.7: Electrical power gross and net in (GWh) by month for the selected site.

Overall more energy is available in summer solstice thanks to better DNI and high temperature (figure 3.1, 3.2, 3.3 and 3.4). Through the results, figures 3.7, we note that total annual energy output of the CSP plants four site is very high in summer months, which is very useful to supply the high electrical load in the summer season. And we also note that it is low during the winter solstice.

It was found that the net and total energy value decreases during the winter solstice and increases during the summer solstice in the four, noting that a decrease in the net and total energy value occurred during the month of June in the Adrar region due to a decrease in the DNI value, as is evident from figure (3.2 and 3.7).

3.2.3 Parasitic power present in the CSP-PTC plant system:

Simulated (CSP) plant using the SAM has a capacity of 100 MW, to support the electrical grid in the aforementioned regions. By analyzing the results, a group of parasitic forces were found represented by (TES and HTF cycle pump, auxiliary heater operation, condenser operation, field collector drives, fixed load, generation-dependent load and HTF solar field pump), and there are two types of this parasitic force (thermal and electrical). While the results of parasite strength will be presented below for one day for the months of June and December in four regions (Ouargla, Bechar, Adrar and Tamanghasset).

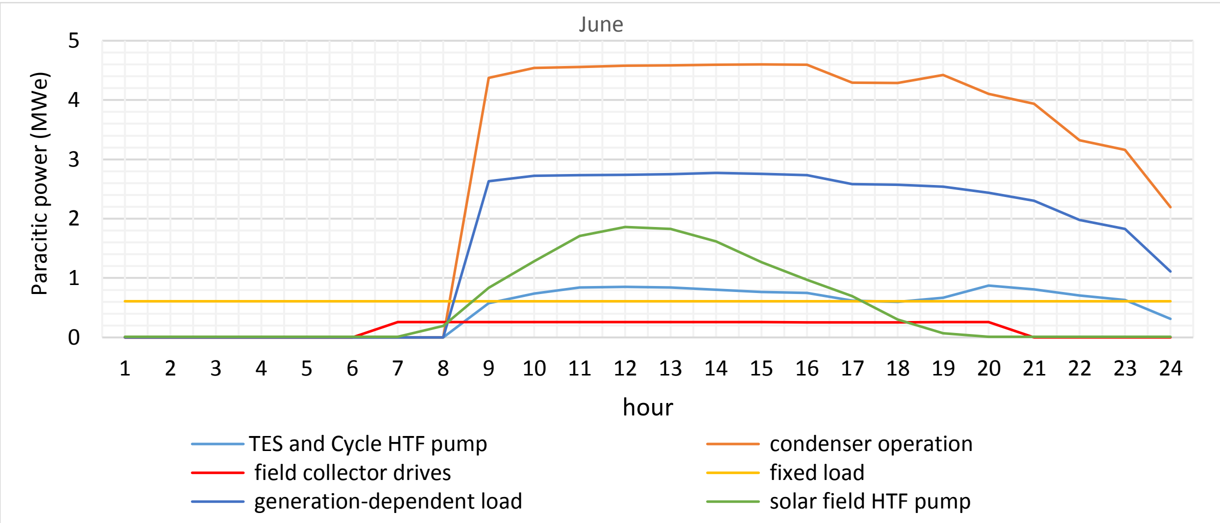


Figure 3.8: Hourly parasitic Power (MWe) of typical day in June, Bechar.

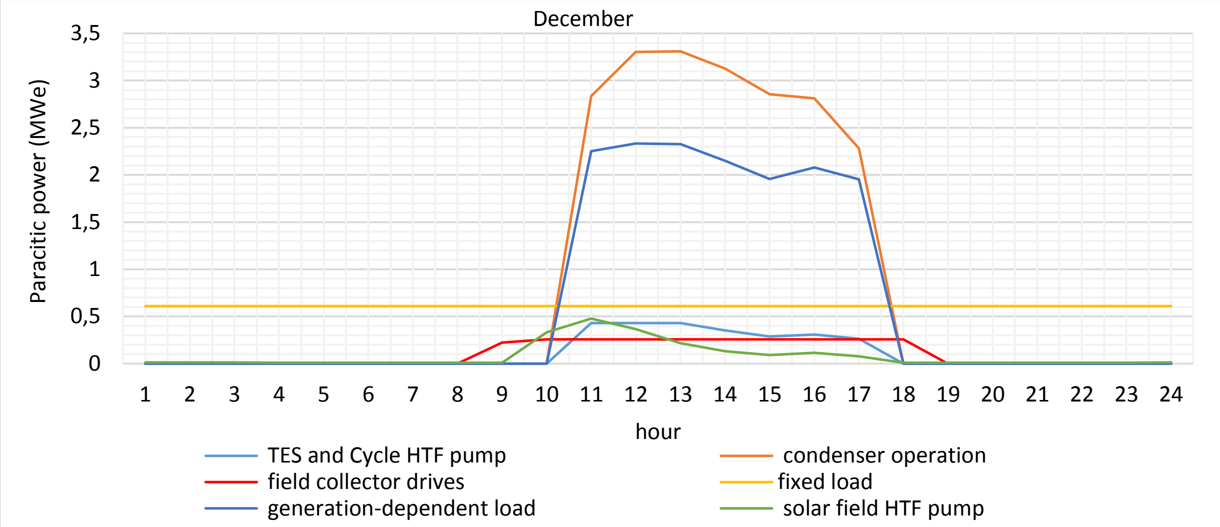


Figure 3.9: Hourly parasitic Power (MWe) of typical day in December, Bechar.

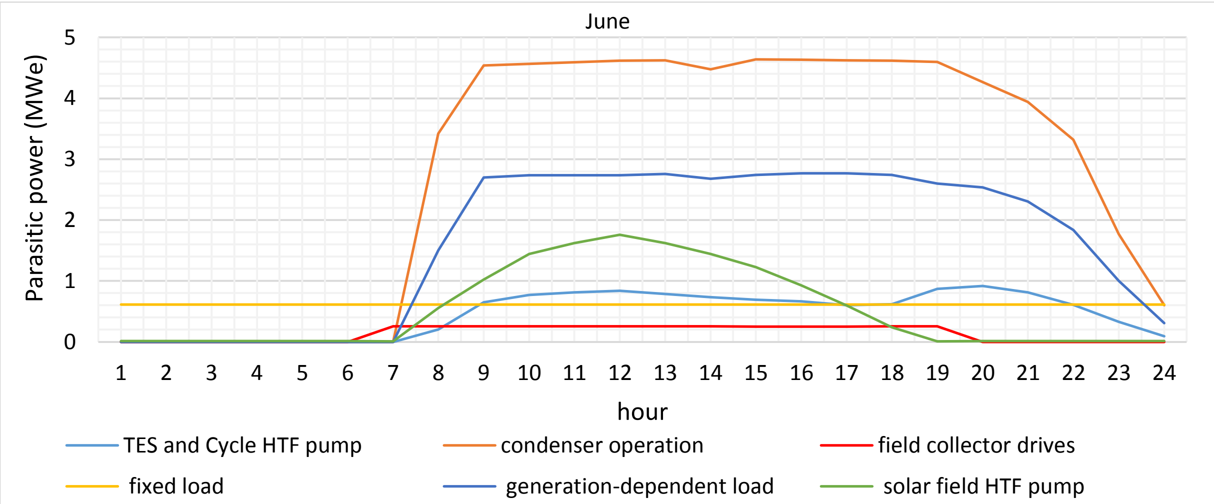


Figure 3.10: Hourly parasitic Power (MWe) of typical day in June, Ouargla.

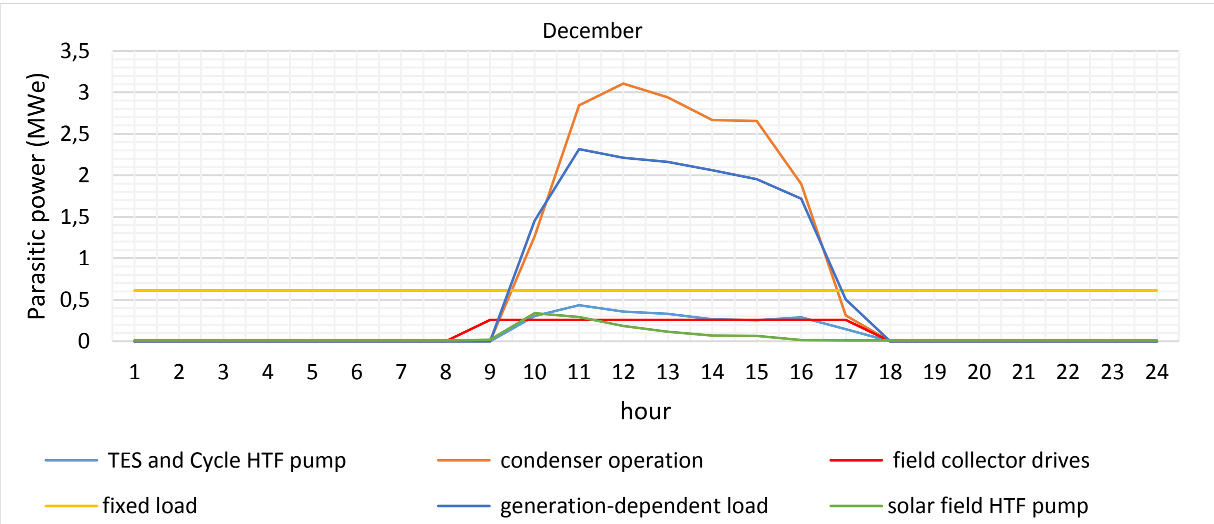


Figure 3.11 : Hourly parasitic Power (MWe) of typical day in December, Ouargla.

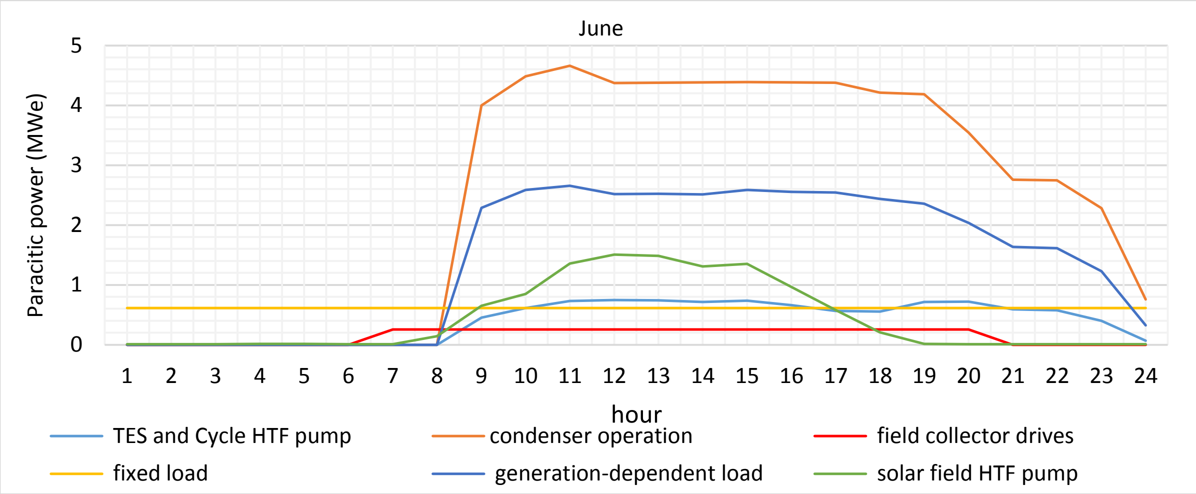


Figure 3.12: Hourly parasitic Power (MWe) of typical day in June, Adrar.

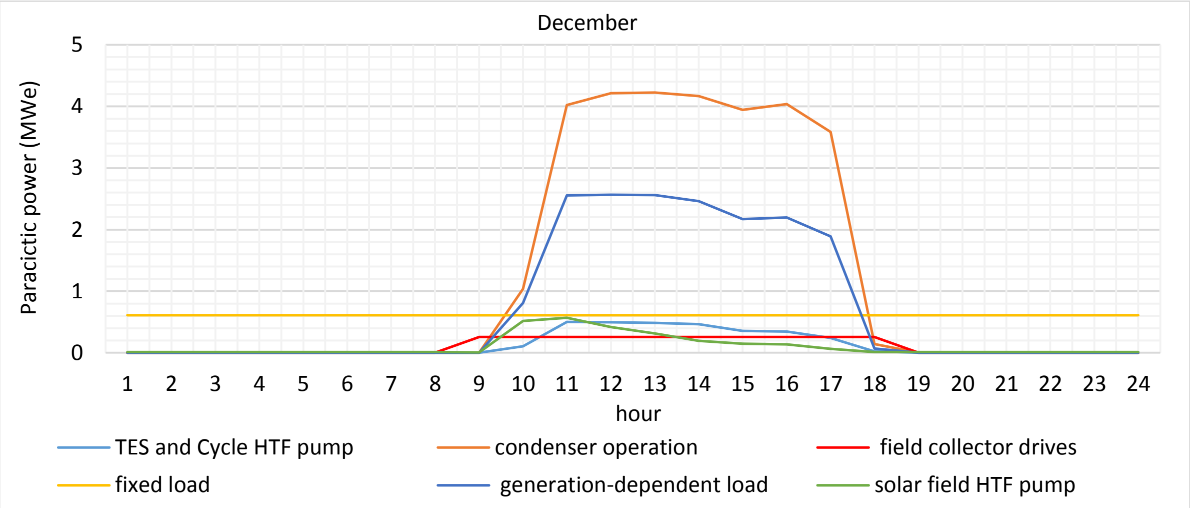


Figure 3.13: Hourly parasitic Power (MWe) of typical day in December, Adrar.

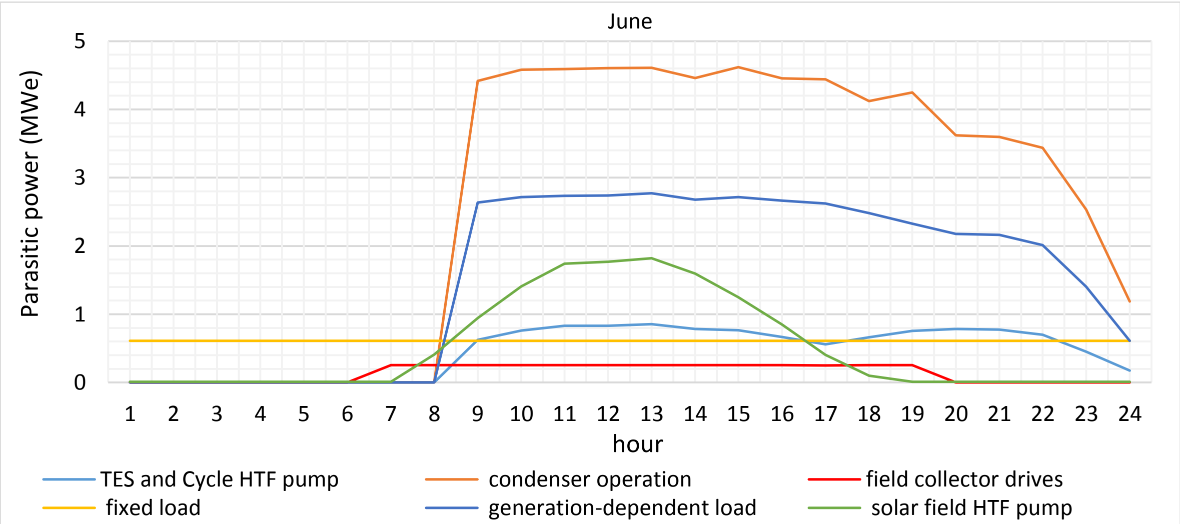


Figure 3.14: Hourly parasitic Power (MWe) of typical day in June, Tamanghasset.

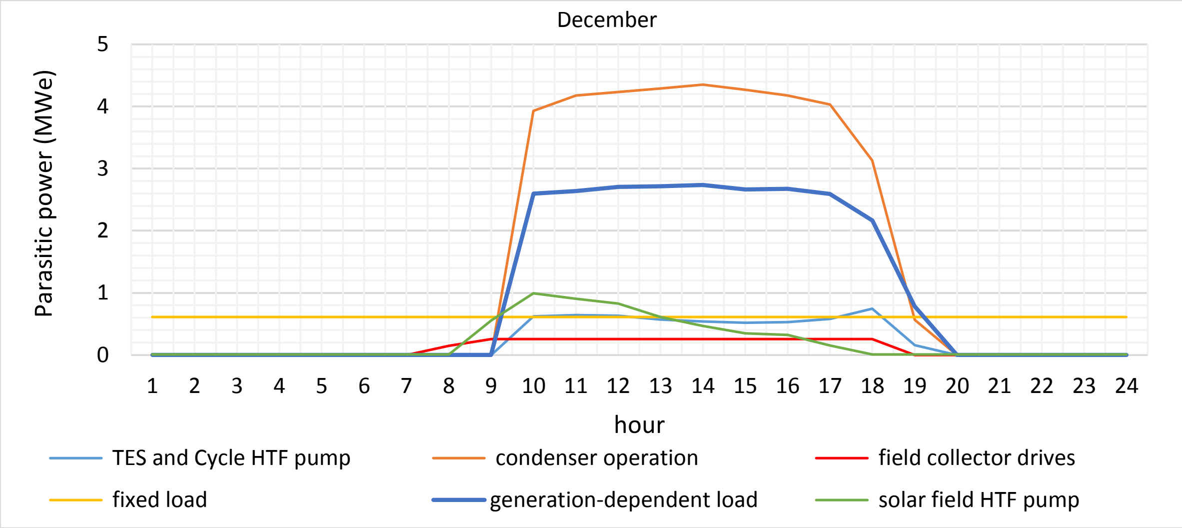


Figure 3.15: Hourly parasitic Power (MWe) of typical day in December, Tamanghasset.

Through the results shown in two figures (10 to 16) for a typical day of two months, June and December, in the four locations, we note that the energy lost by the station system varies from month to month and varies from day to day. It was found that the lost energy value is greater during the summer months and less during the winter months. It is also observed that the energy consumption of subsystems increases with the increase in electrical energy production.

The largest energy consumption value was recorded by the condenser running, where the increase in the parasitic power peak starts from (6 h - 24 h), as the operating value of the capacitor increases between (0 - 4.8) MWe, which starts when the decrease during the last hours of the day during Summer days. During winter days, the largest value of energy consumption was recorded by the condenser running, as the increase in the parasitic capacity starts from (9 h - 19 h), as the operating value of the capacitor increases between (0 - 4.5) MWe, which is null at 19 hours.

Regarding the HTF rotary pump, its value was between (0 - 2.9) MWe during the previous timing, and for the TES rotary pump, the energy value ranged between (0 - 1.8) MWe from an hour (7-24) and in December of an hour (9 and 10 - 18), given that there is a constant value of the constant load, its value is 0.611 MWe throughout the day and in the two months of June and December, and that there is a constant value for the field complex motors as well, knowing that they only operate during daylight periods only at a value of 0.256 MWe. Load dependent generation, where the increase in the parasite's peak energy starts from (8h - 24 h), while the load dependent generation value increases between (0 - 1.8) MWe, which begins when the decrease in the last hours of the day during summer days, within days. Winter The increase in parasitic energy value starts from (9 h - 18h).

3.2.4 Water use at the CSP-PTC plant:

This work emphasizes the sustainable realization of the PTC-CSP technology for electricity generation under the arid climatic conditions with scarce water resources, the technical evaluation took into account the different design configurations using the dry cooling option of the plant due to the lack of water resources on the one hand and on the other hand its impact on the energy produced by the PTC-CSP plant and the Capacity Factor system, in addition to the fact that it has a level on DNI, see show table 3.1.

Table 3.2: Categories value output of PTC-CSP plant.

	Ouargla	Bechar	Adrar	Tamanghasset
Annual Electricity source net (GWh/Year)	338.764	353.301	357.655	403.433
Capacity factor (%)	37.2	38.7	39.2	44.3
Gross to Net conversion (%)	89.9	90.1	90	90.5
Total annual water usage (m^3): Cycle + Mirror washing	73 417.1	74 541	75 508.9	78 664.9

In general, the water usage in the PTC-CSP power plant is divided into three main parts; parabolic trough washing, steam generation, and the cooling system. A large difference exists between the two cooling systems, the power plant with the evaporative cooling system consumes about 14 times more water than the one with the air-cooled system. This is because the power plant with the dry air cooling system only uses water for steam generation and the washing of the mirrors.

For the Bechar site, the 100 MW CSP plant achieves a total net conversion of 90.1 % and the overall plant efficiency is close to 38.7 %. 74 541 m^3 of water is required annually to wash the parabola and Annual electricity source net 353.301 GWh/Year. For the Ouargla site, the 100 MW CSP plant achieves a total net-to-net conversion of 89.9 % and the plant's overall efficiency is close to 37.2 %. 73 417.1 m^3 of water is required annually to wash the parabola and Annual electricity source net 338.764 GWh/Year. For the Adrar site, the 100 MW CSP plant achieves a total net-to-net conversion of 90 % and the overall plant efficiency is close to 39.2 %. 75 508.9 m^3 of water is required annually to wash the parabola and Annual electricity source net 357.655 GWh/Year. For the Tamanghasset site, the 100 MW CSP plant achieves a total net-to-net conversion of 90.5 % and the overall plant efficiency is close to 44.3 %. 78 664.9 m^3 of water is required annually to wash the parabola and Annual electricity source net 403.433 GWh/Year.

The results obtained for the concentrated solar power plant are compared with similar works available in the literature and the comparison is given in the table 3.1. It was found that the increase in water consumption is linked to the energy production, as it was noticed by comparing the results obtained for the four sites that the higher the site's energy production, the higher the water consumption with it.

3.3 Performance analysis of the PTC-CSP plant design in Ouargla region:

Data of figure 3.16 show the thermal power produced by the field, thermal energy to the power block, DNI-cosine and DNI for the proposed CSP plants in Ouargla.

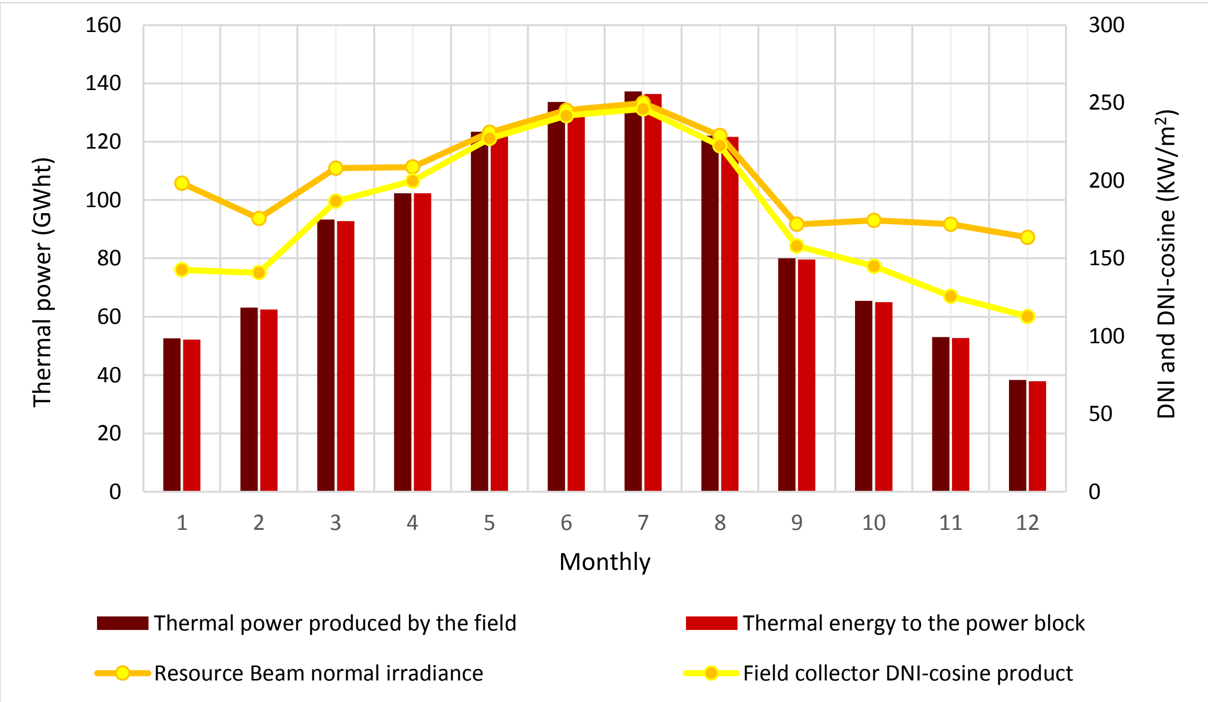


Figure 3.16: Thermal power changes for the of the station PTC-CSP in the Ouargla region within a year.

The gross (total) electrical energy output of the plant depends on the incident radiation and the heat energy input cycle to the turbine contained in the power block. Monthly data show that the CSP system during operation has some loss during the conversion process from radiation in the single solar field to the destination of thermal energy that is transferred to the power block although it is relatively small compared to what is produced by the plant system, as shown in figure 3.16.

3.3.1 Results Thermal Energy Storages (TES):

We all agree that the power plant is capable of generating enough electricity to supply the excess electricity needs to feed the main grid during the day in addition to the excess thermal energy to feed the storage tank. We know that the power plant consumes part of the electricity from the grid during the night, so the energy storage system has been integrated with a maximum storage capacity of 6 hours at night depending on the electricity demand (peak load design). So we present the results of the changes in storage systems at the PTC-CSP station in Ouargla region for a perfect day in January, July, August and December:

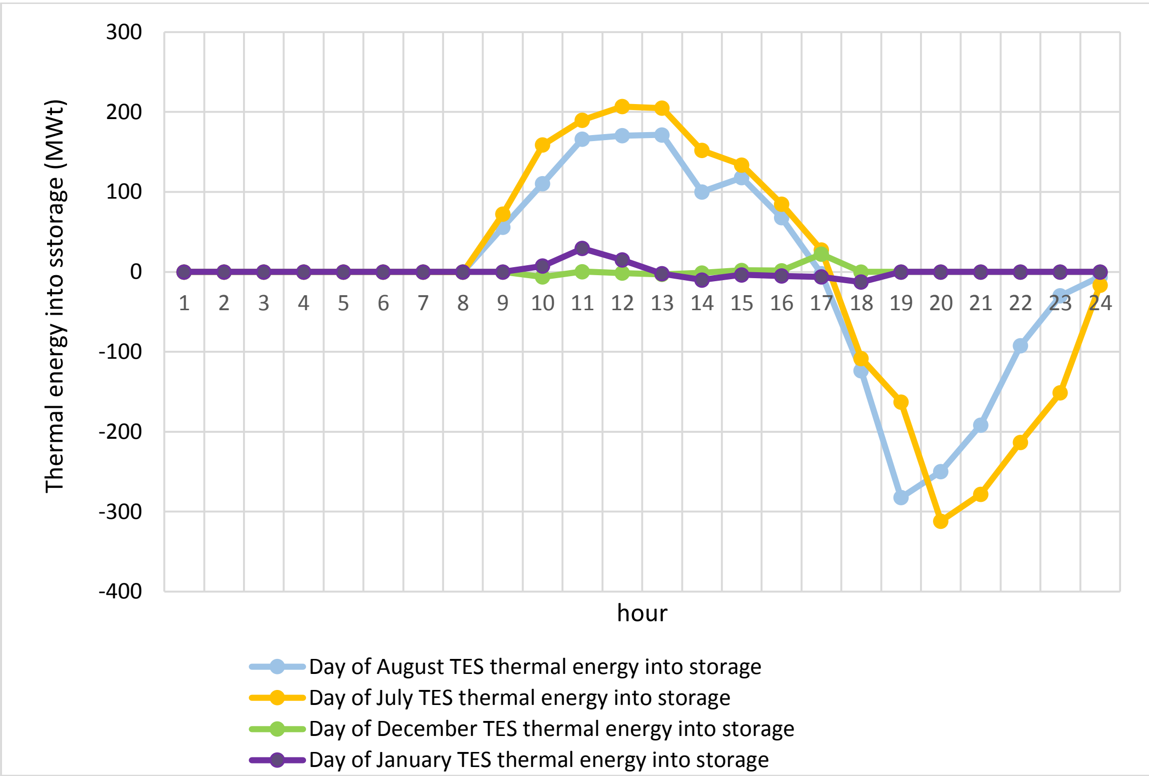


Figure 3.17: Charging and discharging of thermal energy storage during (January, July, August and December) for Ouargla region.

The plant is capable of saving up to 338.764 GWh/Year of annual electricity source net table 3.1, and it reached 37.20 % in the Ouargla region. We notice during the twenty-four hours for each of the following months: (January, July, August and December) that they differ in terms of the amount of heat energy stored, as we found that the winter months (December and January) are almost non-existent, and the largest value reached the amount of thermal energy storage, respectively, (22.0846 - 29.2989) MWt, this indicates that the plant cannot be stored in thermal storage. As well as the largest value reached by the amount of thermal energy storage for two months (June, August), respectively (195.956 - 171.254) MWt, and this indicates that the plant cannot be stored in thermal storage.

With reference to the average daily charge and discharge periods of thermal energy storage for the month (January, July, August and December for the Ouargla region) shown in figure 3.17, and given that the energy storage tank is designed with a capacity of 1 870.79 MWt. We notice through the results presented within two months (December and January), where we notice from one in the morning until eight in the morning the absence of charging and discharging to store energy for a station, so that the charging process starts from eight in the evening. In the morning until seventeen hours. In the morning, but it is almost non-existent. It peaks at 11 am in January and 17 am in December. This is due to the weak potential of solar radiation within a month.

We also notice through the results presented within two months (July, August), where we notice from one in the morning until eight in the morning the absence of charging and discharging to store energy for a station, so that the charging process starts from eight in the morning until five in the evening due to the potential of solar radiation Available during the day, the unloading process is from 17 am to 24 pm. See figure 3.17.

3.3.2 Hourly electrical power of (PTC-CSP) output and the contribution on the National Electrical Power Grid (NEPG):

In order to present the contribution of PTC-CSP plant un the NEPG, Ouargla project is considered as an example in wish total electrical output is reached (GWh).

The SAM is an impotent software wish vive us the possibility to present the electrical on put profile in different time resolution, (hourly, daily, monthly and yearly). In the other hand the hourly NEPG conception or power lead is not easily available literature Oslo in unofficial site of National power organises (Ministry of energy, Sonelgaz, ... etc)

The figure 3.18 present the hourly electrical profile of 100 MW PTC-CSP installed in ouargla region. Due to Density of information figure 3.19 with more than 8760 h. Different levels (zoom-in) are used, from (figure) to another.

Where the first present the: And the second present hourly (Electrical power in GW) for the four months (Dec, Jan, Jul, Aut). Where the four the summer period is more important compared to the winter.

In order to present the hourly contribution of PTC-CSP 100 MW, Ouargla it is sufficient to compare only the form of the profile and not the values. The figure present clearly this idea. In which the NEPG consumption of one day is presnted as percentage share % from, the total Energy consumption around The steadied day.

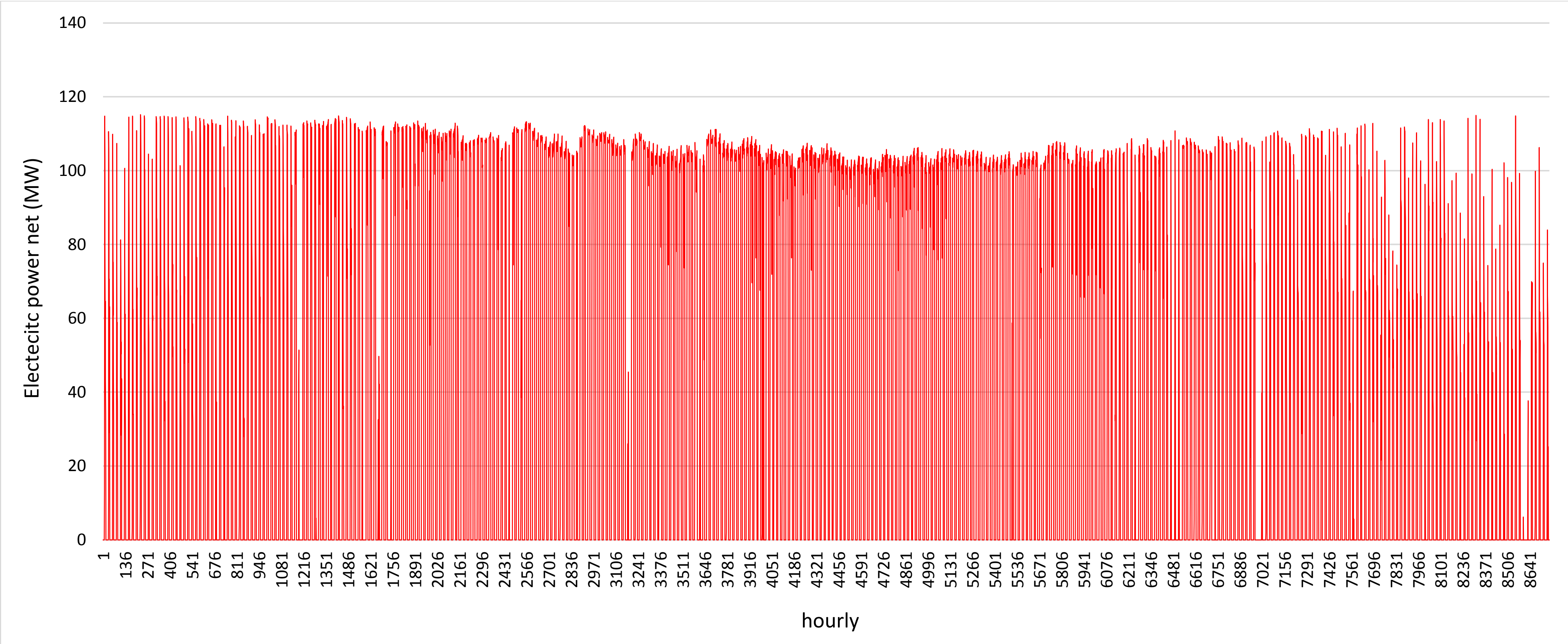


Figure 3.18: Electricity power net for 8760 hours, in Ouargla region.

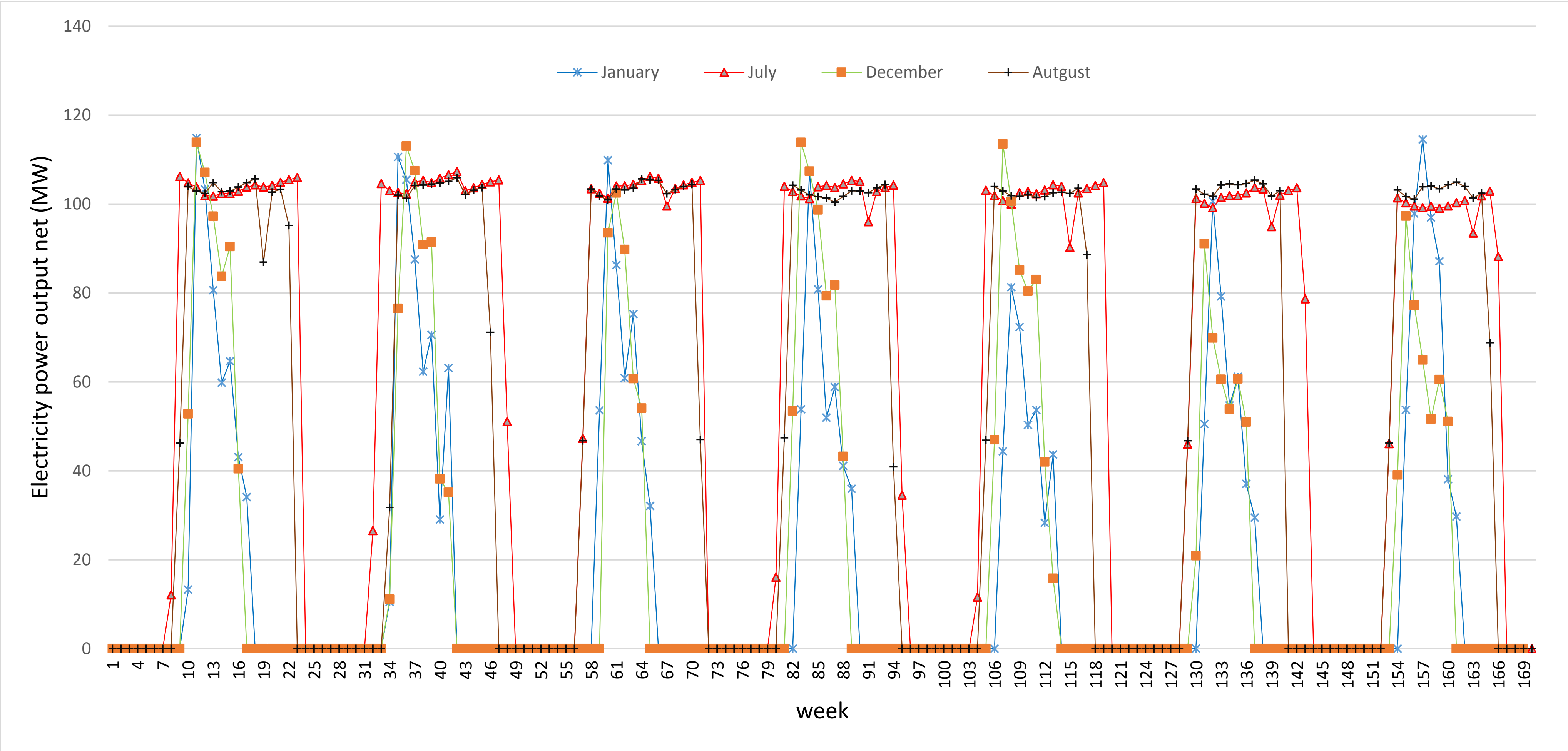


Figure 3.19: Electricity power output net in the week of monthly (January, July, August and December) in Ouargla region.

The figure 3.19 displays the net electrical energy output for one week of the months (January, July, August and December) for Ouargla region. Based on the results, we can notice that during the winter months (January and December) the value of the net electrical power gives a highest value and reached 113 MW in some days on the week. Unlike the summer months (July and August), this value did not exceed 106 MW. However, we note that the hours of electrical energy output with a production capacity more than 100 MW in the summer months (July and August) are more than in the winter months, as it reached 16 hours of production per day with a production capacity between 110 and 106 MW. This indicates that the net electrical energy output in the summer months is better than the winter months, as it reached 11 hours of production without stability at the same production level, where when the highest value is given, it can be marked only for a few time and then the electrical production decreases significantly.

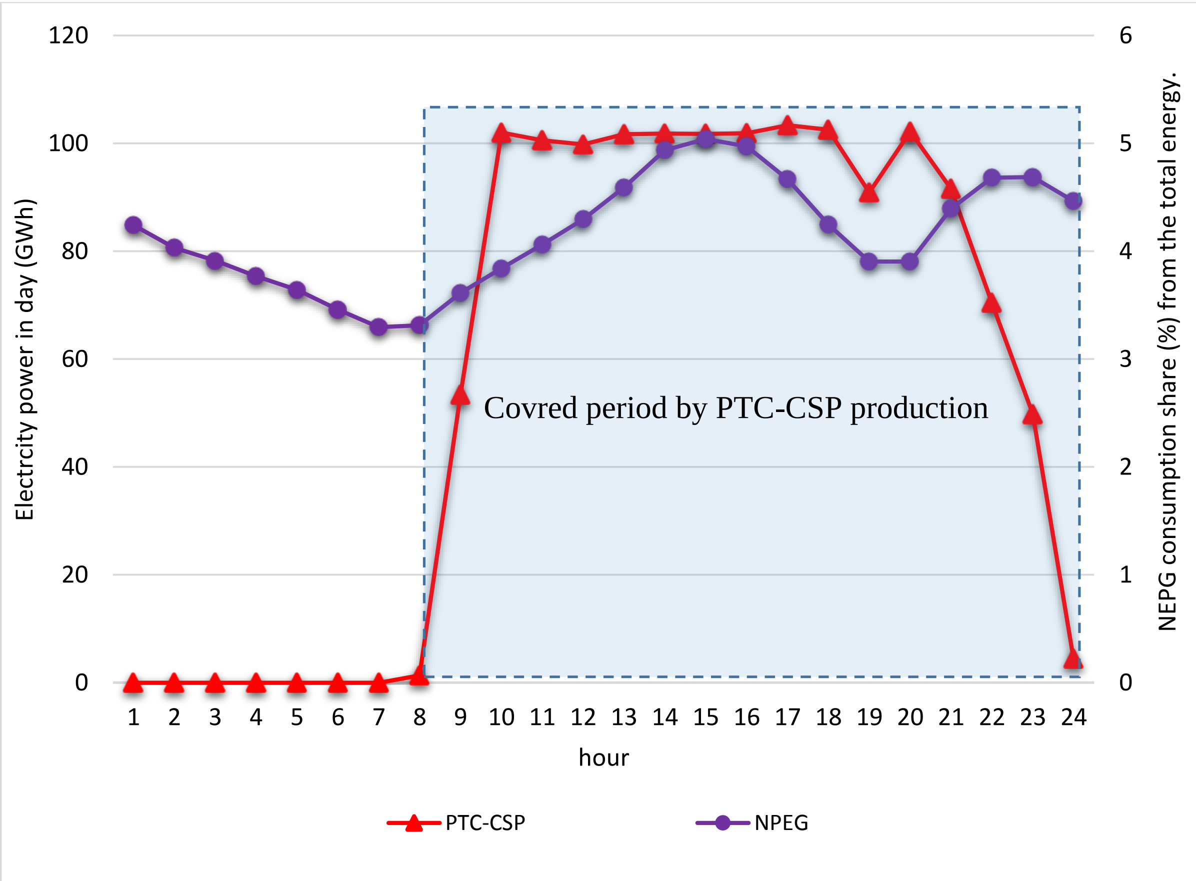


Figure 3.20: PTC-CSP plant contribution on the NEPG monthly (Jun), in Ouargla region.

Based on the results, we can note that a PTC-CSP can be considered as one of the most solution, where the majority of production hours of the plant. Correspondent to the masc. hourly consumption from the NEPG.as presented in figure 3.20.

3.4 Conclusion:

The design, performance analysis and optimization of a 100 MWe parabolic trough collector Solar Power Plant with thermal energy storage has been carried out for four locations in the Algeria region. The SAM software has been used to assess the performance of the designed CSP plant in four locations of whose annual average DNI is greater than 5.5 KWh/m^2.day. The initial analysis of the proposed design revealed that the CSP plant in Bechar has an annual energy yield of 338.897 GWh whereas that in Ouargla recorded 325.213 GWh, whereas that in Adrar recorded 343.349 GWh and that in Tamanghasset recorded 387.295 GWh.

The capacity factor as an indicator of the plant performance is around 38% in the studied regions, where Tamanghasset present a capacity factor of 43%. The particular analysis of PTC CSP in ouargla region in the last part of the chapter give us an important results about the contribution of CSP plant on the National Electrical Power Grid, where the plant (with thermal energy storage system of 6 hours) can covering approximately 16 hours of energy production in which 10 hours are in the maximum power defined as 100 MW in our case. , the proposed 100 MW parabolic trough-based CSP plant with TES system is found to be very important suggestion for the (Ouargla, Bechar, Adrar and Tamanghasset) regions and can contribute to the sustainable energy planning in the future where the capacity can be raised by considering more than one plants in the same region where the lands are largely available across the Algerian territory.

General conclusion

General Conclusion:

The world agrees that renewable energy is the best option for generating electricity and also to reduce environmental risks as a result of fossil energy. Therefore, the biggest part of the world's thinking is to go for renewable energy as the ideal solution.

While Algeria has adopted this option and supported it by establishing solar power stations to contain the huge amount of solar energy, and the most important of these stations is the PTC-CSP station to support the electrical grid in remote areas, which was the subject of our study in this through the application and simulation of this station in four selected regions according to the classifications It was selected according to the classifications according to the DNI ratio in the area and some conditions such as proximity to the electrical grid......etc. to simulate this station in the four regions with the help of SAM program, which provided us with some results from the amount of electricity produced for the station, the carrying capacity, capacity and storage time.

In the first chapter, we discussed the importance of energy in the world, as well as the different types of renewable energies and their potential, especially solar thermal energy, which can replace a part of traditional energy production. They also focused on the different forms and applications of solar energy technology, deepening our understanding of the technology and its potential as a renewable energy source and to reduce the risks to our planet from fossil energy. In the second chapter, we present an explanation of the SAM system as well as a study and parameter positioning of the design and simulation of the design of a parabolic trough-based PTC CSP with the help of the NREL weather database and SAM software. To analyse the thermodynamic aspect and annual performance of CSP virtualization through a parabolic.

we touched in the last chapter The result of parameter and performance of a CSP plant designed in four locations (Ouargla, Bechar, Adrar and Tamanghasset) with an average annual DNI greater than 5.5 kWh/m2/day. The preliminary analysis of the proposed design showed that the CSP plant in Bechar produces electricity power net 338,897 GWh, while in Ouargla it recorded 325,213 GWh, while in Adrar it recorded 343,349 GW / Tamanghasset 387,295 GWh.

As a result of this study, which we conducted by simulating the CSP-PTC station, we concluded that the best production of the station is in the summer, as well as among the best regions was Tamanghasset, and the lowest production was in Ouargla, and the production was weak in the winter months with the rest of the remaining regions.

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Annexes

Annexes :

Table A.1: SPE production location in opération.

Région	Localité	Type	Puissance installée (MW)
Alger	ALGER PORT	TG Fixe	2 x 36 MW
	HAMMA 2	TG Fixe	2 x 209 MW
	BAB EZZOUAR	TG Fixe	4 x 27 MW
	HAMMA	TG Mobile	2 x 24MW
	SABLETTE	TG Mobile	2 x 25 MW
	BARAKI	TG Mobile	3 x 24MW
Blida	LARBAA	TG Fixe	4 x 140 MW
	BOUFARIK 1	TG Fixe	4 x 24 MW
	BOUFARIK 2	TG Fixe	3 x 235 MW
	BOUFARIK 3	TG Mobile	2 x 24 MW
	BENI MERED	TG Mobile	2 x 24 MW
Tipaza	AHMER EL AIN	TG Mobile	3 x 24 MW
Boumerdes	RAS DJINET	TV	4 x 168 MW
Bejaia	AMIZOUR	TG Mobile	8 x 23 MW
	IGHIL EMDA	TH	2 x 12 MW
	DARGUINAH	TH	2 x 32,5 + 5,2 MW
Oran	MARSAT TV	TV	5 x 168 MW
	RAVIN BLANC	TV	1 x 73 MW
	ORAN EST	TG Fixe	2 x 40 MW
	MARSAT	TG Fixe	8 x 23 MW
Relizane	RELIZANE	TG Fixe	3 x 155 MW
Tiaret	TIARET 1	TG Fixe	4 x 30 MW
	TIARET 2	TG Fixe	3 x 100 MW
Nâama	NAÄMA	TG Fixe	8 x 23 MW
JIJEL	JIJEL	TV	3 x 196 MW
	ERRAGUENE	TH	1 x 14,4 MW
	MANSOURIAH	TH	2 x 50 MW
Annaba	ANNABA	TG Fixe	2 x 36 MW
Skikda	SKIKDA	TV	2 x 131 MW
Oum El Bouagui	F'KIRINA 1	TG Mobile	4 x 25 MW
	F'KIRINA 2	TG Fixe	2 x 146 MW
Batna	AIN DJASSER 1	TG Fixe	2 x 126 MW
	AIN DJASSER 2	TG Fixe	2 x 132 MW
	AIN DJASSER 3	TG Fixe	277,5MW
Khenchela	LABREG	TG Fixe	3x140 MW
M'Sila	M'SILA 1	TG Fixe	2 x 23 MW
	M'SILA 2	TG Fixe	3 x 100 MW
	M'SILA 3	TG Fixe	2 x 215 MW
	M'SILA 4	TG Mobile	12 x 24 MW

Annexes:

El Oued	EL OUED	TG Mobile	8 x 23 MW
Laghouat	TILGHEMT 1	TG Fixe	2 x 100MW
	TILGHEMT 3	TG Fixe	3 x 197 MW
Hass R'Mel	H.R.NORD	TG Fixe	4 x 22 MW
Ghardaïa	GHARDAÏA	TG Fixe	2 x 8,5 MW
Béchar	BÉCHAR	TG Fixe	4 x 6 MW
Adrar	ADRAR	TG Fixe	3 x 15 MW + 2 x 20 MW + 4 x 25 MW
	ADRAR	TG Mobile	2 x 23 MW
	KABERTENE	TG Mobile	2 x 23 MW
	Z. KOUNTA	TG Mobile	4 x 23 MW + 4 x 25 MW
	TIMIMOUN	TG Mobile	2 x 23 MW + 2 x 25 MW
Ouargla	H.M.NORD 1	TG Fixe	5 x 24MW
	H.M.NORD 2	TG Fixe	2 x 100MW
	H.M.NORD 3	TG Fixe	3 x 220MW
	H.M.S	TG Fixe	2 x 16 + 2 x 20 MW
	H.M. Ouest	TG Fixe	4 x 123MW
	H.M.Ouest	TG Mobile	4 x23 MW
	OUARGLA	TG Mobile	4 x 24 MW
Tamanrasset	IN SALAH ANCIENNE CENTRALE	TG Fixe	2 x 3,5 MW
	IN SALAH NOUVELLE CENTRALE	TG Fixe	4 x 23 MW
Biskra	OUMACHE 2	TG Fixe	457 MW
Total	**12 019 MW**		

Table A.2: Plant Specifications and Configurations.

Catégories	Values	Référencé ou assumption
Location and Resources:		
- Location.	Bechar, Ouargla, Adrar and Tamanghasset	Gouareh,2021
- Latitude and Longitude.	According to the location	From NREL (wader data)
Solar Field:		
(Solar Field Parameters)		
- Solar Multiple.	2	Assume
- Irradiation at design.	887 W/m^2	From NREL
- Design-Point ambient temp.	150 C°	Liaqat,2018
- Design-point wind Velocity.	5 m/s	NREL, SAM
- No. of Field Sub Sections.	2	NREL, SAM
- Row spacing.	15 m	NREL, SAM
- Deploy angle - Stow angle.	10° - 170°	NREL, SAM
- HTF Pump Efficiency.	0.85	NREL, SAM
(Heat Transfer Fluid)		
- Field HTF fluid.	Therminol VP-1	Liaqat,2018 - Assume
- Design loop inlet temp.	293 °C	Liaqat,2018
- Design loop outlet temp.	525 °C	Liaqat,2018
- Min field velocity.	0.153546 m/s	Liaqat,2018
- Max Field Velocity.	1.99737 m/s	Liaqat,2018
- Min single loop flow rate.	1 kg/sec	Liaqat,2018
- Max single loop flow rate.	12 kg/sec	Liaqat,2018
- Header design min flow Velocity.	2 m/s	Liaqat,2018
-Header design max flow Velocity.	3 m/s	Liaqat,2018
(Design Point)		
-Actual No. of loops.	189	NREL, SAM, Assume
-Single loop aperture.	5248 m^2	Liaqat,2018, SAM, Assume
-Total aperture reflective area.	991872 m^2	Liaqat,2018

Annexes:

-Field thermal output.	623.596 MWt	Liaqat,2018
(Mirror Washing)		
-Water usage per wash.	0.7 l/m^2, aper	NREL, SAM, Assume
-Washes per year.	63	NREL, SAM, Assume
(Single Loop Configuration)		
-Number of SC/HCE assemblies per loop.	8	Liaqat,2018, SAM, Assume
Receiver:		
-Receiver.	Solel UVAC 3	Liaqat,2018, SAM, Assume
-Absorber tube inner diameter.	0.066 m	Liaqat,2018
-Absorber tube outer diameter.	0.07 m	Liaqat,2018
Power Cycle:		
-Design Grosse output.	111 MWe	Liaqat,2018, Assume
-Estimated gross to net - conversion factor.	0.9	Liaqat,2018, SAM
-Estimated net output design (nameplate).	100 MWe	Liaqat,2018, SAM, Assume
-Rated cycle conversion efficiency.	0.356	Liaqat,2018, SAM
-Design inlet temperature.	391 °C	Liaqat,2018, SAM, Assume
-Design outlet temperature.	293 °C	Liaqat,2018, SAM
-Boiler operating pressure.	100 Bar	Liaqat,2018, SAM
-Cooling condenser type.	Air cooled	SAM , Assume
Thermal Storage:		
-Field HTF fluid.	Hitec Solar Salt	Liaqat,2018, SAM, Assume
-Full load hour of TES.	6 hr	Liaqat,2018, SAM, Assume
-Storage Volume.	10482.8 m^3	Liaqat,2018, SAM , Assume
Parasitic:		
-Balance of plant parasitic.	0.02467 MWe/Mwcap	Liaqat,2018
-Auxiliary heater, boiler parasitic.	0.02273 MWe/Mwcap	SAM, Liaqat,2018

-Piping Thermal loss coefficient.	0.45 $W/m^2.K$	Liaqat,2018

Abstract:

Solar energy is considered as one of the most resources that can be exploited to produce electrical energy, by using a thermodynamic cycle with the use concentrated solar power (CSP) system to convert the thermal energy from the sun into electricity.

The objective of this research is to design and evaluate the electrical energy generation and the performance of large-scale parabolic trough concentrating solar power on-grid plants as an essential future solar power in Algeria. The calculation process is given for Four favourites sites (Bechar, Ouargla, Adrar and Tamanghasset) in Algeria. The parabolic trough CSP plant for nameplate capacity of 100 MW will be simulated using a free software of System Advisor Model (SAM). The electrical output will be calculated based on solar to electrical efficiency, capacity utilization factor, and land use factor and other technical factors of the plant integrated as input data in the System Advisor Model.

The results show that the annual electrical output of the CSP plants reached approximately 403.433 GWh at Tamanghasset region. It is important to indicate that this station have the maximum electrical output compared to the other regions, where its value was 357.655 GWh in the Adrar pole as well as its value reached 353.302 GWh in Bechar, and less than in Ouargla with 338.764 GWh. In addition, the PTC-CSP of Ouargla region presents an important future electrical energy generation system which can covering a large period on the energy consumption from the National Electrical Power Grid
Key words: CSP, Technical parameters, Electrical Power, SAM.

Résumé :

L'énergie solaire est considérée comme l'une des ressources les plus exploitables pour produire de l'énergie électrique, en utilisant un cycle thermodynamique avec le système d'utilisation de l'énergie solaire concentrée (CSP) pour convertir l'énergie thermique du soleil en électricité.

L'objectif de cette recherche est de concevoir et d'évaluer la production d'énergie électrique et les performances de centrales solaires à concentration parabolique à grande échelle sur le réseau en tant que future énergie solaire essentielle en Algérie. Le processus de calcul est donné pour quatre sites favoris (Bechar, Ouargla, Adrar et Tamanghasset) en Algérie. La centrale CSP à auge parabolique d'une capacité nominale de 100 MW sera simulée à l'aide d'un logiciel gratuit de System Advisor Model (SAM). La production électrique sera calculée en fonction de l'efficacité solaire/électrique, du facteur d'utilisation de la capacité, du facteur d'utilisation des terres et d'autres facteurs techniques de la centrale intégrés en tant que données d'entrée dans le modèle System Advisor.

Les résultats montrent que la production électrique annuelle des centrales CSP a atteint environ 403,433 GWh dans la région de Tamanghasset. Il est important d'indiquer que cette station a la production électrique maximale par rapport aux autres régions, où sa valeur était de 357,655 GWh dans le pôle Adrar ainsi que sa valeur a atteint 353,302 GWh à Bechar, et moins qu'à Ouargla avec 338,764 GWh. De plus, le PTC-CSP de la région de Ouargla présente un important futur système de génération d'énergie électrique qui peut couvrir une grande période sur la consommation d'énergie du Réseau Electrique National.

Mots clés : CSP, Paramètres techniques, Puissance électrique, SAM.

الملخص:

تعتبر الطاقة الشمسية من أكثر الموارد التي يمكن استغلالها لإنتاج الطاقة الكهربائية، وذلك باستخدام الدورة الديناميكية الحرارية مع استخدام نظام الطاقة الشمسية المركزة (CSP) لتحويل الطاقة الحرارية من الشمس إلى كهرباء.

الهدف من هذا البحث هو تصميم وتقييم توليد الطاقة الكهربائية وأداء حوض القطع المكافئ واسع النطاق الذي يركز على محطات الطاقة الشمسية على الشبكة كطاقة شمسية مستقبلية أساسية في الجزائر. يتم إجراء عملية الحساب لأربعة مواقع مفضلة (بشار، ورقلة، أدرار و تمنراست) في الجزائر. سيتم محاكاة محطة CSP ذات الحوض الصغير المكافئ بسعة 100 ميجاوات باستخدام برنامج مجاني من .System Advisor Model (SAM) سيتم حساب المخرجات الكهربائية بناءً على الكفاءة من الطاقة الشمسية إلى الكهرباء، وعامل استخدام السعة، وعامل استخدام الأراضي والعوامل الفنية الأخرى للمصنع المدمجة كبيانات إدخال في نموذج مستشار النظام.

أظهرت النتائج أن الإنتاج الكهربائي السنوي لمحطات الطاقة الشمسية المركزة بلغ 403.433 جيجاوات ساعة في منطقة تمنراست. ومن المهم الإشارة إلى أن هذه المحطة تتمتع بأقصى إنتاج كهربائي مقارنة بالمناطق الأخرى حيث بلغت قيمتها 357.655 جيجاواط ساعة في قطب أدرار وقيمتها 353.302 جيجاواط ساعة في بشار وأقل من ولاية ورقلة ب 338.764 جيجاواط ساعة. بالإضافة إلى ذلك، يقدم PTC-CSP لمنطقة ورقلة نظامًا مهمًا لتوليد الطاقة الكهربائية في المستقبل يمكن أن يغطي فترة كبيرة من استهلاك الطاقة من شبكة الطاقة الكهربائية الوطنية.

الكلمات المفتاحية: CSP ، المعايير الفنية ، الطاقة الكهربائية